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ALASKA DEPARTMENT OF FISH AND GAME
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MOOSE RESEARCH CENTER REPORT

By

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Paul D. Arneson

Volume XVI
Project Progress Report
Federal Aid in Wildlife Restoration
Project W-17-7, Jobs 1.1R, 1.7R, 1.12R, 1.13R, 1.14R and 19.15R

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J. Oldemeyer was involved in every project in one way or another in addition to his own studies here at the MRC and his help was most appreciated.

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JOB PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: Albert W. Franzmann and Paul D. Arneson

Project No.: W-17-7 Project Title: Big Game Investigations

Job No.: 1.1R Job Title: Moose Productivity and Physiology

Period Covered: July 1, 1974 to June 30, 1975

SUMMARY

Calf mortality at the Kenai Moose Research Center (MRC) during winter 1974-75 was 100 percent. Poor calf survival was also experienced throughout Game Management Unit 15. Snow depths were greater than 50cm from January through early April 1975. The Willow Lake Rehabilitation Area supported greater numbers of moose than similar control areas and calf survival appeared better. Adult moose mortality attributable to "winter kill" was experienced at the MRC as well as in Game Management Unit 15C. Marrow fat of two adult moose which were winter-killed at the MRC was 7.4 and 8.6 percent, which was similar to marrow fat values in winter-killed calves. Three of the last four winters on the Kenai Peninsula were severe enough to result in poor calf survival, and recruitment into the population has been negligible.

Of six, adult, female penned moose examined from January through March, 67 percent were pregnant. Six moose examined outside the enclosures had a pregnancy rate of 83 percent. During tagging operations in Game Management Unit 13 in March 1975, 86 percent of 59 moose examined were pregnant and 83 percent of 29 moose examined in Game Management Unit 15C in April 1975 were pregnant.

Whole body weights were obtained from 67 moose during this report period. Serial weights from adult male moose indicated tremendous weight gain through the summer months (up to 28 percent body weight) with weight losses up to 10 percent during the rut. Adult female moose (except a female with calf) gained weight through the summer and continued to gain through the rut.

Blood samples were collected from 409 moose during this report period, making a total of 1,488 samples collected and analyzed to date at the MRC. No more samples will be added to computer storage and analyses and interpretation of computer output has begun.

Six-hundred and ten hair samples were collected and analyzed for 18 mineral elements during this report period making a total of 1,266 samples analyzed since May 1972. Seven manuscripts relative to moose hair element analyses were prepared for publication during this report period. References to three, abstracts of two and the text of two papers are included in this report.

Eight moose milk samples were analyzed for 18 mineral elements and gross composition studies of 20 moose milk samples were completed. A manuscript is in preparation regarding comparative value of milk composites of North American wild ruminants. A manuscript comparing hair and milk values is included in this report.

Mineral metabolism and cycling studies were initiated and analyses of browse, soil and water were completed. No interpretation was made of these preliminary data, however.

Serum corticoid levels proved useful as an adjunct to excitability evaluation in moose and a manuscript regarding these data was prepared and is incorporated into this report.

Browse production and utilization studies at the MRC by John Oldemeyer, U. S. Fish and Wildlife Service, are continuing. The procedure has been described in a paper and the abstract is in this report. Abstracts of two other papers by John Oldemeyer which relate to his moose browse studies are included in this report.

Browse quality and the Kenai moose population was the subject of a multiauthored paper which considered the digestibility, fiber, protein and mineral aspects of browse quality. The text is incorporated into this report.

CONTENTS

BACKGROUND

The basis for investigations of moose (*Alces alces*) productivity and physiology initiated at the Kenai Moose Research Center (MRC) was outlined in preceding progress reports (LeResche 1970, LeResche and Davis 1971, LeResche et al. 1973, and Franzmann and Arneson 1973). These studies were continued during this reporting period. This report will update data collected but will not involve detailed interpretation since papers are in various stages of preparation regarding these studies. Papers completed and published or accepted for publication were incorporated into this report when appropriate.

Utilizing hair sampling and analysis to monitor moose mineral metabolism (Franzmann et al. 1974 and Franzmann et al. 1975) has resulted in an expansion of our efforts to assess the quality factors in the mooses' environment. We have initiated plant, soil and water mineral element analyses along with continuing moose hair and tissue analyses. John L. Oldemeyer has reported on his browse quality studies at the MRC (Oldemeyer 1974) and has prepared additional papers presently in review (abstacts and paper in this report).

OBJECTIVES

To measure natality, mortality and general condition of moose at the Kenai Moose Research Center.

To establish baselines by sex, age, season, reproductive status, area, drug used, excitability and condition for the following physiologic parameters in moose, and to evaluate their usefulness as indicators of nutritional and general status in moose:

A. Blood Values for:
   1. Calcium
   2. Inorganic phosphorus
   3. Calcium/phosphorus ratio
   4. Glucose
   5. Blood urea nitrogen (BUN)
   6. Uric acid
   7. Cholesterol
   8. Total protein
   9. Albumin
   10. Globulin
   11. Albumin/globulin ratio
   12. Alpha-1, alpha-2, beta and gamma globulins
   13. Bilirubin
   14. Alkaline phosphotase
   15. 11-hydroxycorticosteroids
   16. Serum glutamic oxalacetic transaminase(SGOT)
   17. Hemoglobin
   18. Hematocrit (PCV)
   19. White blood cells
   20. Differential cell count

B. Hair element values for:
   1. Zinc (Zn)
   2. Copper (Cu)
   3. Magnesium (Mg)
   4. Manganese(Mn)
   5. Calcium (Ca)
   6. Sodium (Na)
   7. Potassium (K)
   8. Cadium (Cd)
   9. Iron (Fe)
   10. Lead (Pb)
   11. Cobalt (Co)
   12. Chromium (Cr)
   13. Nickel (Ni)
   14. Arsenic (As)
   15. Selenium (Se)
   16. Mercury (Hg)
   17. Aluminum (Al)
   18. Molybdenum (Mo)

C. Heart and respiratory rate
D. Body temperature

To establish excitability stress classifications for moose based upon appropriate and selected physiologic parameters mentioned above.

To estimate browse production and utilization and to quantitatively and qualitatively estimate consumption of all plant materials by moose.

To determine nutritional values and digestibilities of the more common moose forage species.

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

PROCEDURES

Kenai Moose Research Center Facilities

LeResche and Davis (1971) provided a thorough description of the facilities. An update of facility additions was reported by Franzmann and Arneson (1974b). No additions or alterations of facilities were done during this report period.

Productivity and Mortality

Mortality and natality within the pens were assessed by ground observation, periodic aerial observations and trapping. Rectal examination of females after January 1 was utilized for pregnancy determination.

Weights and Measurements

Weights were obtained utilizing a weighing device consisting of a winch mounted on the front of a pickup truck with a bracket holding two legs of the tripod (Franzmann and Arneson 1974b). This winch/tripod device allowed us to weigh a moose in 4 minutes or less and thereby weigh a greater proportion of moose immobilized.

Physiology - Blood, Hair and Milk

Blood and hair samples were obtained from moose trapped within the MRC enclosures, trapped outside the MRC enclosures, immobilized by John Coady for Interior moose studies (Job 1.11R), immobilized for marking on the Kenai Peninsula (Job 1.4R), immobilized for marking in Game Management Units 13 and 14 and harvested by hunters in Game Management Unit 22.

Blood was collected from live animals by jugular vein puncture utilizing sterile evacuated containers. One vial contained heparin to provide a whole blood sample for hemoglobin determination at the MRC utilizing a Hb-Meter (American Optical Corp., Buffalo, N.Y.) and packed cell volume (PCV) values utilizing a micro-hematocrit centrifuge (Readacrit-Clay-Adams Co., Parsippany, N.J.). Three other 15-ml vials were filled with blood and centrifuged at the MRC to separate serum and blood cells. Sera were frozen and one sample was sent to Alaska Medical laboratories, Anchorage, Alaska for blood chemistry analysis (Technicon Autoanalyzer SMA-12) and protein electrophoresis. One of the remaining frozen serum samples was sent to U.S. Seal, Veterans Administration Hospital, Minneapolis, Minnesota for endocrine analysis. The remaining sample was retained for potential future analysis.

Hair samples were obtained by plucking hair from the point of the shoulder (hump) on these moose. These samples were sent to Dr. Arthur Flynn at Case Western Reserve University, School of Medicine, Cleveland, Ohio, for analysis of 18 mineral elements utilizing an atomic absorption spectrometer.

Milk samples collected by "milking" immobilized moose were frozen and 1cc of frozen milk was sent to Dr. Arthur Flynn for mineral element analysis and a minimum of 5cc of frozen milk was sent to Dr. D.E. Ullrey, Department of Animal Husbandry, Michigan State University, East Lansing, Michigan for standard milk analysis.

Mineral Metabolism and Cycling

Plant and soil samples were collected from diverse areas in and around the MRC from various habitat types by John L. Oldemeyer, U.S. Fish and Wildlife Service. Water samples were collected from lakes in each of the MRC enclosures, Coyote Lake and the MRC well. Plant, soil and water samples were sent to Dr. Flynn at Case Western Reserve University, School of Medicine, Cleveland, Ohio for atomic absorption spectrometer analysis of 18 mineral elements.

Excitability Evaluation

The initial approach to this problem was to subjectively classify captured moose on the basis of activity prior to and during handling. State of excitement was evaluated on a 1 to 5 scale (1 - none, 2 - slight, 3 - moderate, 4 - excited, and 5 - highly excited). Serum samples were selected from each month sampled during 1973 to compare samples through all seasons and determine the usefulness of serum corticoid levels in assessing handling stress in moose. An attempt was made to obtain samples from each of the five excitability classes. No samples were available for May, but 11 were selected from the January sample and 10 were selected from each of the remaining months of the year for a total sample of 111. No selection was made based upon sex or age, however, a representative sample of the sex and age structure of the population was obtained.

Serum samples were sent to the Department of Surgery, Cleveland Metropolitan General Hospital, Case Western Reserve University School of Medicine, Cleveland, Ohio to be fluorometrically analyzed for plasma 11-hydroxycorticosteroids by the rapid procedure for clinical screening as outlined by Mejer and Blanchard (1973).

Condition Evaluation

Each moose processed at the MRC, as well as other areas of collection, was given a subjective condition evaluation and graded from 1 to 10 based on the criteria as outlined by Franzmann and Arneson (1973).

FINDINGS

Productivity and Mortality

Table 1 presents raw tagging, breeding and mortality data for all moose within the enclosures for the period May 1, 1974 through April 30, 1975. Total number of observations and times trapped are also included.

Two yearlings were recruited into the population within the MRC enclosures following the winter of 1973-74 (Table 2). Eleven calves were born within the pens in spring 1974 raising the population to 53 moose (5.1 moose per square kilometer). Female yearling moose #109 in Pen 1 was found dead on Aug. 9, 1974. Death resulted from foreign body pneumonia initiated by immobilization on August 7, 1974 and subsequent entanglement in underbrush. Male yearling moose #98 in Pen 3 experienced immobilization difficulties on August 7, 1974 and was released from the trap slightly ataxic. The moose has not been found and is assumed dead. Two Pen 4 calves died during summer 1974 from unknown causes and three adult females died prior to December 3, 1974 from causes outlined in Table 3. A moose census at the MRC on December 3, 1974 (Table 4) reflected

Table 1. Histories of individual moose in Kenai Moose Research Center enclosures, May 1, 1974-April 30, 1975.

PEN I

			Significant Observations				
Moose No.	Sex	Age (years)	Date	Event	Circumstances	No. Times Observed	No. Times Captured
10	F	7	July 16, 1974	With calf Weight: 322kg	Trapped	14	3
			Aug 6, 1974	With calf Weight: 336kg	Trapped		
			Sept 18, 1974	Died: overdose	Trapped		
35	M	6	May 29, 1974	Weight: 347kg Antlers: 71cm	Trapped	28	10
			Aug 7, 1974	Weight: 481kg Anglers: 111cm	Trapped		
			Oct 1, 1974	Weight: 434kg Antlers: 108cm	Trapped		
43	M	7	Aug. 7, 1974	Weight: 526kg Antlers: 126cm	Trapped	38	5
			Sept. 4, 1974	Weight: 549kg	Trapped		
			Oct. 11, 1974	Weight: 484kg	Trapped		
58	M	4	June 13, 1974	Weight: 354kg Antlers: 71cm	Trapped	22	3
			Aug. 7, 1974	Weight: 418kg Antlers: 101cm	Trapped		
			Oct. 1, 1974	Weight: 386kg Antlers: 102cm	Trapped		
R70-8	F	6	June 4, 1974	Weight: 309kg Not pregnant	Trapped	22	2
			Dec. 13, 1974	Radio collar put on	Trapped		
69	F	5	June 17, 1974	With no calf	Observed-helicopter	11	4
			July 16, 1974	Weight: 336kg Condition 6	Trapped		
			Aug. 6, 1974	Weight: 370kg Condition 7			
			Sept. 12, 1974	Weight: 393kg Condition 7			
109	F	1	June 13, 1974	Weight: 161kg Condition 6	Trapped	6	2
			Aug. 9, 1974	Found dead	Observed		
116	M	Calf	Sept. 5, 1974	First tagged: (#10's calf)	Trapped	4	3
			Sept 18, 1974	Orphaned	Trapped		
			Dec. 10, 1974	Radio collared	Trapped		
			April 10,1974	Found dead	Observed		
125	F	8 1/2	Feb. 20, 1974	Broke into Pen 1 from Trap 10E	Trapped	0	3
			Feb. 21, 1975	First collared Condition 5 Pregnant	Trapped		

Table 1. Histories of individual moose in Kenai Moose Research Center enclosures, May 1, 1974-April 30, 1975.

PEN II

Moose No.	Sex	Age (years)	Date	Event	Circumstances	No. Times Observed	No. Times Captured
			Significant Observations				
1	F	10	June 11, 1974	Not lactating, with no calf	Trapped	14	2
3	F	12	June 4, 1974	Not lactating or pregnant, no calf this year Weight: 309kg	Trapped	11	7
			Aug. 13, 1974	Weight: 370kg Condition 6	Trapped		
			Sept. 4, 1974	Weight: 373kg	Trapped		
			Nov. 19, 1974	Weight: 382kg Condition 5	Trapped		
R70-4	F	7	July 17, 1974	Femur broken with dart-overdosed Weight: 270kg With calf	Trapped	4	1
670	F	4	May 29, 1974	With calf	Trapped	27	5
			July 26,1974	Weight: 338kg With calf	Trapped		
			Jan. 25,1975	Last seen with calf	Observed		
36	M	7	May 30, 1974	Weight: 423kg Antlers: 78cm	Trapped	18	3
			July 24,1974	Weight: 594kg Antlers: 107cm	Trapped		
40	F	6	May 29, 1974	With calf Weight: 298kg	Trapped	51	5
			Dec 17, 1974	Radio collar installed; last seen with calf	Trapped		
			Mar 10, 1974	Found dead not pregnant	Observed		
Raquel	F	5	FY 1975	Not processed; With no calf	Observed	Tame	9
Rastus	M	1	Nov 20, 1974	Weight: 322kg Antlers: 76cm	Trapped	Tame	10
			Dec 12, 1974	Force fed-Copper sulfate (200ml)			
Wally, Jr.	MN	3	Aug 15, 1974	Rumenotomy performed for *in vitro* digestion trial	Trapped	Tame	8
			Dec 12, 1974	Force fed-Copper sulfate (200ml)	Trapped		
			Jan 21, 1975	Given 200mg Testosterone	Trapped		
			Mar 6, 1975	Found dead			

Table 1. Histories of individual moose in Kenai Moose Research Center enclosures, May 1, 1974-April 30, 1975.

PEN II cont.

			Significant Observations				
Moose No.	Sex	Age (years)	Date	Event	Circumstances	No. Times Observed	No. Times Captured
61	F	12	June 17, 1974	With no calf	Observed-helicopter	3	1
			Aug 8, 1974	Died: dart hit vein Weight: 357kg	Trapped		
73	M	5	June 13, 1974	Antlers-64cm-broken	Trapped	15	4
			July 18, 1974	Weight: 322kg	Trapped		
			Sept. 9, 1974	Weight: 391kg	Trapped		
			Oct. 4, 1974	Weight: 384kg	Trapped		
79	F	5	May 31, 1974	With calf Condition 5	Trapped	45	7
			July 24, 1974	Weight: 343kg Condition 7	Trapped		
			Oct. 15, 1974	Radio collar installed	Trapped		
			Jan. 28, 1975	Last seen with calf, chased calf away	Observed		
117	F	Calf	Sept 11, 1974	First tagged (#79's calf)	Trapped	10	2
			Oct. 15, 1974	Radio collar installed	Trapped		
			Feb. 2, 1975	Found dead	Observed		
119	F	Calf	Dec. 17, 1974	First tagged Radio collar install (#40's calf) last seen with mother	Trapped	2	1
			Jan. 22, 1975	Found dead	Observed		
120	F	3+	Jan. 2, 1975	Broke into Pen 2	Observed	4	1
			Jan. 14, 1975	First tagged Condition 6	Trapped		
UC	?	Calf	July 17, 1974	Orphaned (R70-4 died)	Near trap	4	0
			Jan. 24, 1975	Last seen, assumed dead	Observed-supercub		
UC	?	Calf	Jan. 25, 1975	Last seen with #670, assumed dead	Observed	11	0

Table 1. Histories of individual moose in Kenai Moose Research Center enclosures, May 1, 1974-April 30, 1975.

PEN III

			Significant Observations				
Moose No.	Sex	Age (years)	Date	Event	Circumstances	No. Times Observed	No. Times Captured
27	F	7	June 7, 1974	With calf (#114) Condition 5	Trapped	5	3
			Dec. 10, 1974	Cow/calf pair last seen together	Trapped		
			Jan. 24, 1975	Last Seen	Observed-supercub		
2870	F	4	June 12, 1974	No calf, not pregnant	Trapped	6	4
			July 16, 1974	Weight: 363kg Condition 7	Trapped		
			Sept. 3, 1974	Weight: 387kg Condition 6	Trapped		
39	F	9	June 17, 1974	No calf this year	Observed	12	1
72	F	4	May 29, 1974	Yearling (#98) still with her, PG	Trapped	9	4
			June 17, 1974	With calf	Observed-helicopter		
			Aug. 8, 1974	Weight: 263kg Condition 5	Trapped		
			Dec. 3, 1974	Last seen with calf	Observed-supercub		
75	F	5	June 4, 1974	Not pregnant, no calf	Trapped	5	2
80	M	5	Oct. 9, 1974	Weight: 420kg Rt. antler broken	Trapped	6	3
98	M	1	Aug. 7, 1974	Last seen, assumed dead	Trapped	4	2
114	F	Calf	June 7, 1974	First tagged (#27's calf)	Trapped	2	2
			Feb. 3, 1975	Last seen, mother not in vicinity assumed dead	Observed		
UC	?	Calf	Dec. 3, 1974	Last seen with mother (#72) assumed dead	Observed	3	0

Table 1. Histories of individual moose in Kenai Moose Research Center enclosures, May 1, 1974-April 30, 1975.

PEN IV

			Significant Observations				
Moose No.	Sex	Age (years)	Date	Event	Circumstances	No. Times Observed	No. Times Captured
7	M	5	July 17, 1974	Weight: 395kg Antlers: 94cm	Trapped	21	4
			Oct. 1, 1974	Antler spread: 99cm	Trapped		
22	F	9	June 17, 1974	With no calf this year	Observed-helicopter	12	1
			Jan. 29, 1975	Pregnant Condition 6	Trapped		
			Feb. 25, 1975	Found dead	Observed		
36	F	11	June 17, 1974	With one calf	Observed-helicopter	23	4
			July 16, 1974	No longer lactating, abondon calf	Trapped		
				Weight: 288kg Condition 4	Trapped		
			Sept.19, 1974	Weight: 398kg Condition 6	Trapped		
			Dec. 17, 1974	Weight: 402kg Condition 6	Trapped		
37	F	5	June 17, 1974	With no calf this year	Observed-helicopter	8	1
			July 19, 1974	Weight: 329kg Condition 6	Trapped		
57	F	4	June 17, 1974	With no calf this year	Observed-helicopter	17	2
			Aug. 9, 1974	Weight: 338kg Condition 6	Trapped		
59	M	6	Oct. 4, 1974	Weight: 388kg Antlers: 84cm	Trapped	11	1
71	F	5	June 11, 1974	With no calf this year; Weight: 229kg Condition 4	Trapped	19	1
81	F	5	July 16, 1974	With no calf this year	Trapped	15	1

Table 1. Histories of individual moose in Kenai Moose Research Center enclosures, May 1, 1974-April 30, 1975.

PEN IV cont.

			Significant Observations				
Moose No.	Sex	Age (years)	Date	Event	Circumstances	No. Times Observed	No. Times Captured
84	F	7	June 11, 1974	With one calf	Observed	19	5
			July 18, 1974	Weight: 325kg Condition 5	Trapped		
			Sept 12, 1974	Weight: 380kg Condition 6	Trapped		
			Dec. 3, 1974	Last seen with calf	Observed-supercub		
			Dec. 11, 1974	Weight: 370kg Condition 5 Last seen or captured	Trapped		
100	M	5	Aug. 6, 1974	Weight: 345kg Condition 6	Trapped	6	2
			Oct. 8, 1974	Antler spread: 80cm	Trapped		
102	F	4	June 17, 1974	With one calf	Observed-helicopter	20	2
			Dec. 3, 1974	Last seen with calf	Observed-supercub		
			Feb. 27, 1975	Last seen	Observed		
103	F	4	June 17, 1974	With no calves (PG in Jan 74-2 fetuses)	Observed-helicopter	5	3
			Jan. 21, 1975	Pregnant-2 fetuses	Trapped		
105	F	8	June 17, 1974	With no calf this year	Observed-helicopter	14	1
111	F	4	June 17, 1974	With one newborn calf	Observed-helicopter	24	2
			July 19, 1974	Weight: 382kg Condition 6	Trapped		
			Aug. 14, 1974	Last seen with calf	Observed		
112	F	9	April 18,1974	Last seen; assumed dead	Observed-helicopter	0	0

Table 1. Histories of individual moose in Kenai Moose Research Center enclosures, May 1, 1974-April 30, 1975.

PEN IV cont.

			Significant Observations				
Moose No.	Sex	Age (years)	Date	Event	Circumstances	No. Times Observed	No. Times Captured
115	F	11	June 17, 1974	With no calf this year	Observed-helicopter	16	4
			July 16, 1974	Weight: 347kg Condition 5	Trapped		
			Feb. 25, 1975	Not pregnant Condition 4 Prolapsed conjunctiva, last seen	Trapped		
122	M	6+	Feb. 4, 1975	Released into Pen 4 from Pen 2	Trapped	0	1
				Likely died the next day-found dead	Observed		
124	F	5+	Feb. 4, 1975	Released into Pen 4 from Pen 2 Pregnant Condition 5	Trapped	2	4
UC	?	Calf	Aug. 12, 1974	Likely #36's last seen : abandoned	Observed	6?	0
UC	?	Calf	Dec. 3, 1974	Last seen with mother #84	Observed	14?	0
UC	?	Calf	Feb. 27, 1975	Last seen with mother #102	Observed	10?	0
UC	?	Calf	Aug. 14, 1974	Last seen with mother #111	Observed	2?	0

Table 2. Populations within Kenai Moose Research Center enclosures as of June 17, 1974.

	Adult FF	Yearlings	Calves	Adult MM	Total
Pen 1	3	1	1*	3	8
Pen 2	8	0	4	4	16
Pen 3	5	1	2	1	9
Pen 4	13**	0	4	3	20
Total (All Pens)	29	2	11	11	53

* Assumed #10 has a calf; calf tracks seen, #69 & R70-8 have no calves.

** #112 may be dead, other cows in this pen may yet calve. Several were pregnant; #111 calved on this date, 17 June.

Table 3. Mortalities within Kenai Moose Research Center enclosures June 1, 1974-April 30, 1975.

Moose Number	Sex	Age	Pen No.	Date Month	Date Year	Cause
10	F	7	1	September	1974	Overdose - Anectine
109	F	1	1	August	1974	M-99
116	M	Calf	1	January	1975*	Winter
R70-4	F	7	2	July	1974	Broke femur-overdosed
40	F		2	March	1975	Winter
61	F		2	August	1974	Overdose-Anectine in vein
117	F	Calf	2	February	1975	Winter
119	F	Calf	2	January	1975	Winter
UC	?	Calf	2	Never	Found	Assumed dead
UC	?	Calf	2	Never	Found	Assumed dead
Wally Jr.	MF	4	2	March	1975	Winter
98	M	1	3	August	1974*	M-99 ? (Never found)
114	F	Calf	3	Never	Found	Assumed dead
UC	?	Calf	3	Never	Found	Assumed dead
22	F	9	4	February	1975	Winter or hyperthermia
112	F	10	4	May	1974*	Winter
122	M	6	4	February	1975	Hyperthermia
UC	?	Calf	4	Never	Found	Assumed dead
UC	?	Calf	4	Never	Found	Assumed dead
UC	?	Calf	4	Never	Found	Assumed dead
UC	?	Calf	4	Never	Found	Assumed dead

* Date of Death-Estimated.

Table 4. Populations within Kenai Moose Research Center enclosures as of December 3, 1974.

	Adult FF	Yearlings	Calves	Adult MM	Total
Pen 1	2	0	1	3	6
Pen 2	6	0	4	4	14
Pen 3	5*	0	2	1	8
Pen 4	12	0	2	3	17
	25	0	9	11	45

Pen 2 Not seen #1, #3, Rastus all observed later.

Pen 3 Not seen #39 (seen later) and #98♂.

Pen 4 Not seen #112, #36's calf and #111's calf.

these losses and showed 45 moose within the MRC enclosures (4.3 moose per km^2). Nine calves and no yearlings were in the MRC population entering the winter of 1974-75.

Snow during winter 1974-75 began early and persisted through April (Table 5). Depths over 50cm were recorded from January through early April. This was likely a major factor causing the 100 percent calf mortality experienced at the MRC during winter 1974-75 (Table 6). Spring survival counts in GMU 15 indicated extremely poor calf survival also (pers. comm. P. LeRoux).

During winter 1974-75 the Kenai National Moose Range rehabilitated approximately 600 ha in the Willow Lake Rehabilitation Area with LeTourneau crushers (Monnie 1975). Moose responded to the increased browse availability in the area and moose numbers were greater by factors of 3 to 4 than in the uncrushed control area. Calf survival also appeared much better in the rehabilitated area. A March 14, 1975 survey by Bob Richey, Kenai National Moose Range showed 27 calves/100 adults in the rehabilitated area and 11 calves/100 adults in the control area. April 1, 1975 counts showed 31 calves/100 adults and 4 calves/100 adults in these respective areas.

Several adult moose mortalities at the MRC were attributed to winter kill. Femur marrow fat content of female moose #40 was 7.4 percent and of castrated male moose "Wally Jr." was 8.6 percent (Table 7). Femur marrow fat data from other collections on Kenai Peninsula are listed in Table 7. Femurs were not obtained soon enough from the other moose to be analyzed. Condition evaluation of moose #40, at the time of last capture on December 17, 1974, was 4 and for Wally Jr. on January 21, 1975 was 5.

Other mortalities at the MRC are listed in Table 3. The May 2, 1975 census (Table 6) did not reflect these mortalities since three moose entered pen 2, one entered pen 1 and one entered pen 3 during periods of deep, drifting snow.

Population estimates on the Kenai National Moose Range, based on random stratified counts in March 1975, reflected a 31 percent decrease from the 1974 counts. The 1974 estimate was 4850 $\pm$ 1045 and the 1975 estimate was 3375 $\pm$ 900. A decline of 14.9 percent was experienced between 1973 and 1974 estimates.

With extremely poor winter calf survival through three of the last four winters this decline would be expected. Additionally, yearling survival was poor in at least two of these winters; therefore literally no recruitment was experienced in the population. Hunting, poaching, predation and other mortality forces continue to work on the population adding to the decline. Adjustments in seasons have been made to compensate for this decline, however, this can alleviate only one of many decimating factors working on the population.

A pregnancy rate of 67 percent within the MRC enclosures for 1974-75 was based only on the examination of six moose and the rate of 83 percent for moose trapped outside the MRC enclosures was also from only

Table 5. Snow depth (cm.) in each of eight habitat types, Kenai Moose Research Center, winter 1974-75.

	1974				1975										
Habitat Type	12/4	12/12	12/18	12/30	1/15	1/22	2/5	2/20	2/27	3/11	3/21	4/9	4/21	4/25	5/5
Dense Hardwoods	16	19	25	26	39	33	29	40	37	40	38	40	27*	20*	Tr*
Thin Hardwoods	25	28	32	35	50	43	38	50	50	53	54	59	39*	30*	Tr*
Sedge	25	30	35	35	46	40	37	48	45	49	48	49	20	13	0*
Spruce Regrowth	27	32	37	40	52	45	42	59	56	60	58	59	38*	35*	Tr*
Thin Birch-Spruce	28	31	37	40	55	47	46	58	53	58	59	64	41*	38*	Tr*
Dense Birch-Spruce	26*	31	38	40	52	45	44	60	54	56	55	55	33*	25*	Tr*
Spruce-Ledum	29	33	41	44	56	49	48	62	61	64	63	62	43	39	Tr*
Mature Spruce	11	16	19	23	38	32	30	38	32	40	40	37	28*	23*	Tr*

* *Vaccinium vitis-idaea, Carex sp., or Ledum sp.* visible

Table 6. Populations within Kenai Moose Research Center enclosures as of May 2, 1975.

	Adult FF	Yearlings	Calves	Adult MM	Total
Pen 1	3	0	0	3	6
Pen 2	6	0	0	3	9
Pen 3	6	0	0	1	7
Pen 4	12	0	0	3	15
Total (All Pens)	27	0	0	10	37

Pen 1 Not seen 35♂, 58♂ and 125♀ (58 and 125 seen later)

Pen 2 Not seen #3♀ and Rastus ♂ (Rastus seen later)

Pen 3 Not seen #27♀

Pen 4 Not seen 7♂, 84♀, 102♀, 115♀

No calves seen, all assumed dead.

Table 7. Percent dry weight of moose femur marrow from the MRC and other parts of the Kenai Peninsula, 1975.

Moose Number	Age	Date Collected	Sex	% Fat	Remarks
119*	Calf	23 Jan	M	8.6	Winter Kill
295	Adult	29 Jan	M	57.3	Trap mortality
117*	Calf	2 Feb	F	7.0	Winter kill
40	Adult	10 Mar	F	7.4	Winter kill
Wally Jr.	Adult	10 Mar	M	8.6	Winter kill
16295	Calf	11 Mar	-	7.7	Winter kill
16481	Adult	24 Mar	F	91.3	Coll. for rumen liquor
67362	Calf	21 Jan	F	37.8	Winter kill
67363	Calf	28 Feb	F	6.5	Winter kill
67364	Adult	11 Mar	F	6.9	Winter kill
67365	Adult	14 Mar	F	7.9	Winter kill
67368	Calf	14 Mar	F	10.0	Wolf kill
67367	Calf	14 Mar	F	9.1	Wolf kill
67366	Calf	14 Mar	F	9.2	Wolf kill
67373	Calf	20 Mar	M	16.3	Winter kill
67372	Calf	-	F	7.0	Winter kill
67369	Calf	9 Feb	F	6.7	Wolf kill
67371	Adult	-	F	90.4	Poached
67370	Adult	27 Mar	F	85.1	Poached

* Humerus used

six moose. Sample sizes were too small for meaningful interpretation. Rectal palpation for pregnancy of moose immobilized for tagging in March 1975 in GMU 13 indicated 86 percent were pregnant (59 moose examined). Similar examinations in GMU 15C in April 1975 indicated 83 percent were pregnant (29 moose examined) (Table 8).

The influence of browse quality on the Kenai moose population is reviewed and discussed in the Browse Quality section of this report.

Weights and Measurements

Table 9 lists 49 whole weights of moose from within the MRC enclosure and Table 10 lists 18 whole weights of moose trapped and immobilized outside the enclosures. No serial data were available for outside moose, but some interesting seasonal weight changes were documented for several inside moose.

Male moose #35 weighed 347 kg in May, 481 kg in August and 434 kg in October (Table 9). He experienced a 28 percent weight gain up to rut and the 10 percent weight loss into the 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 (Table 9). The weight in early September likely reflects the prime 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 (Table 9). Female moose #36 weighed 288 kg in July, 398 kg in September and 402 kg in December (Table 9). Both moose gained weight all summer and through the rut. Female moose #84 weighed 325 kg in July, 380 kg in September and 370 kg in December. She reflected a slight post-rut weight loss, however, she had a calf by side while moose #3 and #36 had no calves.

Blood Values

The sources of 409 moose blood samples collected and analyzed during this report period are listed in Table 11. Data obtained were placed on a Game Biological Input Form (cf Franzmann and Arneson 1973) and sent to the Computer Services Division of the Alaska Department of Administration where they were stored and programmed for retrieval with moose blood data previously obtained. No blood data were put into the program after April 30, 1975 and final retrieval and interpretation of these data collected from 1968 is underway and will be published in conjunction with termination of this job in June 1976.

Franzmann and Arneson (1974b) reported serial blood and hair data for several moose. For moose #58, #35, #72, #7 and Wally Jr. three additional sets of data were obtained during this report period. Four sets were collected for moose #73 and #3 but only one for moose #81 and none for Raquel.

Table 8. Reproductive status of moose based on rectal palpation, 1975.

Location	Number Moose Examined	Pregnant	Not Pregnant	% Pregnant
Inside MRC (Jan & Feb 1975)	6	4	2	67
Outside MRC (Jan & Feb 1975)	6	5	1	83
GMU - 13 (Tagging - March 1975)	59	51	8	86
GMU - 15C (Tagging - April 1975)	29	24	5	83

Table 9. Whole weights of moose of known age, sex and reproductive status inside Kenai Moose Research Center enclosures (May 1, 1974 - April 30, 1975).

Moose No.	Date	Pen	Sex	Age (mo.)	Reproductive Status and Remarks	Weight Kg	Weight Pounds
10	16 July 1974	1	F	85	With one calf	322	710
10	6 August 1974	1	F	86	With one calf	336	740
35	29 May 1974	1	M	72	Condition 5	347	765
35	7 August 1974	1	M	74	Condition 7	481	1060
35	1 October 1974	1	M	76	Condition 7 in rut	434	955
43	7 August 1974	1	M	86	Condition 7	526	1160
43	4 September 1974	1	M	87	Condition 8 in rut	549	1210
43	11 October 1974	1	M	88	Condition 6 in rut	484	1065
58	13 June 1974	1	M	48	Condition 7	354	780
58	7 August 1974	1	M	50	Condition 7	418	920
58	1 October 1974	1	M	52	Condition 6 in rut	386	850
R70-8	4 June 1974	1	F	72	With no calf	309	680
69	16 July 1974	1	F	61	With no calf	336	740
69	6 August 1974	1	F	62	With no calf (weight not perfect)	370	815
69	12 September 1974	1	F	63	With no calf	393	865
109	13 June 1974	1	F	12	With no calf - yearling	161	355
3	4 June 1974	2	F	144	With no calf	309	680
3	13 August 1974	2	F	146	With no calf	370	815
3	4 September 1974	2	F	147	With no calf	373	820
3	19 November 1974	2	F	149	With no calf	382	840
R70-4	17 July 1974	2	F	85	With one calf	270	595
36	30 May 1974	2	M	84	Condition 6	423	930
36	24 July 1974	2	M	86	Condition 8	594	1310
40	29 May 1974	2	F	72	With one calf	298	655
61	8 August 1974	2	F	146	With no calf	357	785
670	26 July 1974	2	F	50	With one calf	338	745
Rastus	20 November 1974	2	M	17	Condition 7	322	710

Table 9. Continued.

Moose No.	Date	Pen	Sex	Age (mo.)	Reproductive Status and Remarks	Weight Kg	Weight Pounds
73	18 July 1974	2	M	61	Condition 6	322	710
73	9 September 1974	2	M	63	Condition 6 Early rut	391	860
73	4 October 1974	2	M	64	Condition 6 in rut	384	845
79	24 July 1974	2	F	62	With one calf	343	755
2870	16 July 1974	3	F	49	With no calf	363	800
2870	3 September 1974	3	F	51	With no calf	387	852
72	8 August 1974	3	F	50	With one calf	263	580
80	9 October 1974	3	M	64	Condition 7 in rut	420	925
7	17 July 1974	4	M	61	Condition 7	395	870
36	16 July 1974	4	F	133	Had calf - no longer lactating	288	635
36	19 September 1974	4	F	135	With no calf	398	875
36	17 December 1974	4	F	138	With no calf	402	885
37	19 July 1974	4	F	61	With no calf	329	725
57	9 August 1974	4	F	50	With no calf	338	745
59	4 October 1974	4	M	76	Condition 7 in rut	388	855
71	11 June 1974	4	F	60	With no calf condition 4	229	505
84	18 July 1974	4	F	85	With one calf	325	715
84	12 September 1974	4	F	87	With one calf	380	835
84	11 December 1974	4	F	90	With one calf	370	815
100	6 August 1974	4	M	62	Condition 6	345	760
111	19 July 1974	4	F	49	With one calf	382	840
115	16 July 1974	4	F	133	With no calf	347	765

Table 10. Whole weights of moose of known age, sex and reproductive status outside Kenai Moose Research Center enclosures (May 1, 1974 - April 30, 1975).

Moose No.	Date	Sex	Age (mo.)	Reproductive Status and Remarks	Weight Kg	Weight Pounds
106	1 May 1974	F	119	Pregnant	359	790
243	6 June 1974	F	132	With one calf	334	737
245	10 June 1974	F	24	With no calf	291	640
249	14 June 1974	F	72	Lactating - calf not seen	359	790
251	24 July 1974	F	26	With no calf	343	755
252	24 July 1974	F	50	With no calf	361	795
253	26 July 1974	F	62	With no calf	415	915
255	9 September 1974	M	15	Condition 8	290	638
261	10 September 1974	F	183	With one calf	485	1068
264	1 October 1974	F	112	With no calf	438	965
50	4 October 1974	F	76	With no calf	454	1000
273	9 October 1974	F	40	With no calf	481	1060
179	19 November 1974	F	233	With no calf	490	1080
278	19 November 1974	F	29	With no calf (weight not perfect)	316	695
279	20 November 1974	F	unk. very old	With no calf	425	935
280	21 November 1974	F	53	With no calf	402	885
283	11 December 1974	F	18	With no calf - yearling	286	630
290	18 December 1974	M	18	Condition 6 - yearling	298	655

Table 11. Sources of moose blood and hair collected from May 1, 1974 to April 30, 1975.

Source	Serum	Whole Blood	Hair
Trapping at MRC			
Pen 1	27	27	28
Pen 2	31	31	36
Pen 3	21	20	20
Pen 4	29	29	30
Outside Pens	66	66	68
Total MRC	174	173	182
Winter 74-75 Wolf Kill GMU-15	1		4
Tagging GMU-15C			
Bald Mt. (Nov 1974)	56	56	61
Fox River Flats (Apr 1975)	31	31	31
Tagging GMU 13			
Alphabet Hills (Oct 1974)	64	64	68
Tulsona Burn (March 1975)	62	62	65
Paxson Lake (Nov 1974)			20
Tagging GMU 14C			
Ft. Richardson (Jan Feb 1975)	21	21	21
Tagging GMU 20			
Coady			9
Hunter Sample			
Nome (Aug Sept Oct Dec Jan)			106
Copper River (Aug & Sept 1974)			43
Total	409	407	610

Hair Mineral Element Values

From May 1, 1974 to May 1, 1975, 610 hair samples were collected, making a total of 1,266 samples collected since this project was initiated in May 1972. Sources of the samples since May 1, 1974 are listed in Table 11. Initial findings indicated the dynamics of mineral levels in moose hair, so the premise that it could be used to monitor mineral metabolism in moose was considered (Franzmann et al. 1974 and Franzmann et al. 1975). Further investigation helped confirm this premise and a paper entitled "Sequential hair shaft analysis as an indicator of prior mineralization in the Alaskan moose" was prepared by A. Flynn, A. W. Franzmann and P. D. Arneson. It was accepted for publication in the Journal of Animal Science. The abstract of the article follows:

> Longitudinal analysis of the moose hair shaft for ten mineral elements (cadmium, calcium, copper, iron, lead, magnesium, manganese, potassium, sodium and zinc) demonstrated the ability of hair to act as a monitor of previous mineral states. A significant mean correlation of monthly results with sequentially derived data was noted for all elements with the exception of zinc. Absorption of zinc into the hair shaft may be involved in elevated zinc levels for the sectioned hair samples. Sex influences in hair mineralization were noted, so that in females seven elements had significant correlations between the two sampling techniques (Ca, Cd, Fe, K, Mg, Na, Pb). Thus, the uptake and retention of many mineral elements in moose hair are consistent enough to allow sequential analyses to describe prior mineralization.

Arthur Flynn reported the initial findings relative to seasonal variation in moose hair mineral levels at the Second International Symposium on Trace Element Metabolism in Animals at Madison, Wisconsin (Flynn and Franzmann 1974b).

An additional year's evidence of seasonal variation in moose hair mineral element levels and a preliminary report on the moose copper deficiency syndrome was reported by Franzmann at the 10th North American Moose Workshop and Conference at Duluth, Minnesota (Franzmann et al. 1974). Flynn reported additional supportive evidence relative to Cu-Cd-Fe-Mo-Zu interractions and the moose copper deficiency syndrome to the 8th Trace Substances in Environmental Health Conference at Columbia, Missouri (Flynn and Franzmann 1974a). An abstract of that paper follows:

> Copper deficiency was determined in a large population of Alaskan moose (*Alces alces gigas*) by sequential hair analysis over a 12-month period. Three-hundred and sixteen hair samples were analyzed for 10 mineral elements in moose from the Kenai Peninsula of Southcentral Alaska. Only during three months of the late summer and early autumn were Cu levels determined to be within normal range when compared with domestic ruminant normal values. The seasonal elevation of hair Cu from animals on the Kenai Peninsula strongly related to increased browse Cu values.

Manifestation of elemental deficiencies in a population of non-restricted wild animals is difficult where predation is evident. Several samples of Cu deficiency interference with the hoof keratinization process were observed and samples were obtained to positively relate the defects with Cu deficiency. Cadmium, Cu, Fe, Mo, S and Zu were analyzed by atomic absorption and x-ray flourescence in hair and hoof material from normal and abnormal animals. Copper deficiency is known to interfere with the establishment of a proper matrix in the formation of "hard" keratin. The structural weakness in the keratin arises from the absence of cross-linking between peptide chains. Normal cross-linking results from the condensation reactions following the oxidative deamination of amino groups allowing the creation of the strengthening disulfide bonds. Copper and S levels were significantly decreased in the moose with abnormal keratinization of the hoof, whereas the limiting factors of Cu activity (Cd, Fe, Mo and Zn) were in normal ranges. Normal levels of these four elements were also noted in the browse samples. Copper deficiency appears to be the only elemental defect in the faulty keratin synthesis of the moose hoof.

A paper entitled "Molybdenum - sulphur interactions in the utilization of marginal copper in Alaskan moose" was prepared for presentation at the Symposium on Molybdenum in the Environment at Denver in June 1975.

The use of hair mineral element values to assess potential mineral intake deficits as related to other tissues was reported in a paper entitled "Moose milk and hair element levels and relationships" by A. W. Franzmann, A. Flynn and P. D. Arneson. The paper contains data relative to this report period and a summary follows:

Introduction

One aspect of studies at the Kenai Moose Research Center (MRC), Soldotna, Alaska was to monitor moose mineral metabolism. Tissues from moose, as well as forage, soil and water from the study area have been analyzed. This paper reports the results of milk analyses of selected macro-and micro-elements and compares these milk data with hair elemental values corresponding with lactation.

Limited data have been collected in characterizing the constituents of moose milk. Gross composition, fatty acid content and mineral levels (Ca, Fe, K, Mg, Na and P) have been reported on only three moose.[4] The mineral analyses were expressed as percent of ash and are not comparable to this study. We therefore, attempted to more clearly define the major and trace elemental nutrients of moose milk and their relationship to body tissue store, as indicated by hair mineral element levels.

Moose hair mineral elements have been analyzed for the past three years and marked seasonal rhythms occur for most elements.[6,7] During this study period moose hair has demonstrated an ability to correspond to changes in dietary quality and mineral element intake. This non-invasive method of sampling permits monitoring body tissue buildup and depletion of macro-and micro-elements. The comparison of hair mineral levels with milk elemental values was made to indicate apparent genetic or nutritional stress influences in moose milk composition.

In domestic cattle, macro-element composition of milk (Ca, Cl, K, Mg, Na, P, S and Si) is largely determined by genetic factors so that nutrition and other environmental factors have but little effect.[11] Certain micro-elements (Al, B, Co, I, Mn, Mo and Zn), however, can be altered by nutrition, whereas other element concentrations can be varied minimally by environmental conditions.[11] Moose milk and hair were sampled from 1971 through 1974 in an effort to determine the characteristic qualities of moose milk and the influences of genetics and environment in mineral element content.

Materials And Methods

Twenty-one trapped and immobilized[5] lactating moose were "milked" to obtain a minimum 5 ml sample. Posterior pituitary extract (10 U.S.P. units) was administered intravenously to some moose to stimulate milk let-down and facilitate "milking." Milk samples were frozen in vials until analyzed.

Hair samples were obtained by plucking hair from the shoulder hump of moose and placed in plastic containers.[7] The hair samples did not correspond to the moose from which milk samples were taken. Moose hair values for mineral elements reflect dietary intake of moose on a delayed basis.[6] We therefore, utilized the mean hair values from August and September for the years 1972, 1973 and 1974 to reflect elemental intake during the peak of lactation. Milk samples were obtained primarily in June and July during 1971, 1972 and 1973. Milk and hair samples were sent to the Department of Surgery, Cleveland Metropolitan General Hospital, Case Western Reserve University School of Medicine, Cleveland, Ohio. Samples were analyzed by flame and flameless atomic absorption spectroscopy for four macro-elements (Ca, K, Mg and Na)[1a] and 14 micro-elements (Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, and Zn).[1a,1b] Twelve milk samples were not analyzed for Cd, Hg, Pb, and Se. The 1972 and 1973 hair samples were not monitored for Al, As, Co, Cr, Hg, Mo, Ni and Se, but were determined in August and September 1974.

Results and Discussion

Moose milk and hair element values are listed in Tables 1a and 2a and compared with reported domestic cattle milk values. Mineral element requirements for moose have not been established, therefore, the role of genetic and/or nutritional influences on milk levels is unknown. Comparisons made must be evaluated in the light of potential physiologic species differences. Statistical testing for differences between moose and bovine milk was not possible due to unavailability of bovine milk raw data.

Moose and Bovine Milk Comparisons

The macro-elements (Table 1a) differences between moose and bovine milk we analzed were negligible (Ca, K, Mg, and Na). The levels of these elements in bovine milk are primarily genetically determined,[11] and we assume they are for moose since no major differences were discernible.

Table 1a. Macro-element values (ppm) of moose milk and hair with reported values of bovine milk.

Element	Milk(n=21)		Hair(n=100)		Bovine	Reference
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	Milk (ppm)	
Ca	1562.0	232.4	371.3	230.5	1240.0	15
K	1006.0	85.4	1324.3	662.1	1270.0	10
Mg	192.8	22.7	133.8	59.9	114.0	10
Na	394.3	34.8	758.0	283.4	430.0	10

Table 2a. Micro-element values (ppm) of moose milk and hair with reported values of bovine milk.

Element	Milk			Hair			Bovine	Reference
	N	$\bar{X}$	S.D.	N.	$\bar{X}$	S.D.	Milk (ppm)	
Al	21	1.24	0.5	40	1.67	0.34	0.5	3
As	21	0.05		40	0.1	-	0.03	10
Cd	9	0.06		98	1.51	1.03	0.015	12
Co	21	0.01		40	1.19	0.52	0.001	11
Cr	21	0.01		40	0.31	0.10	0.015	10
Cu	21	2.90	1.28	100	9.77	3.95	0.01	11
Fe	21	3.12	1.25	100	48.06	14.83	0.5	11
Hg	9	0.05		40	0.25	0.07	-	11
Mn	21	0.01		100	1.68	1.59	0.1	11
Mo	21	0.01		40	0.68	0.17	0.1	11
Ni	21	0.05		40	0.46	0.15	0.025	2
Pb	9	0.39		100	9.61	6.99	0.4	10
Se	9	0.11		40	2.44	0.70	0.005-0.067	8
Zn	21	6.23	2.34	100	79.09	20.48	3.9	10

Most micro-element milk levels (Table 2a) for both moose and cattle are 0.1 ppm or less (As, Cd, Co, Cr, Hg, Mn, Mo, and Ni). The Pb mean value for moose milk was 0.39 ppm and 0.40 ppm in bovine milk. The differences in milk values between species for most of the micro-elements is negligible.

Of the trace elements potentially influenced by nutrition (Al, Co, Mn, Mo, and Zn),[11] moose milk levels of Al and Zn were higher by factors of 2.5 and 1.6, respectively. This suggests that the moose sampled had higher available levels of these elements in their intake. Copper, Fe and Se are not influenced nutritionally in cattle and were higher in moose by factors of 3 or more (Cu-290.1, Fe-6.2, Se-3.0). This, in turn, would suggest that the genetic determinant for these elements in moose milk is greater than that for cattle. Unfortunately, in either case we do not have definitive data on whether any elements in moose are nutritionally or genetically influenced. We do know that moose levels are elevated for these elements.

All the elements analyzed were classified essential except As, Cd, Hg and Pb.[16] These elements are considered toxic and their presence in milk may reflect, to an unknown degree, their distribution in an area. We noted no difference in As and Pb between bovine and moose milk samples. Cadmium levels in moose milk were higher than bovine, but there was less than 1 ppm in samples from either species. High level intake of Cd in cows produced no greater than 1 ppm levels in milk with less than 0.02 percent of the extra cadium given appearing in the milk.[14] No values for Hg in bovine milk were available for comparison.

Moose milk and hair comparisons.

Moose hair element mean values for the months of August and September of 1972, 1973 and 1974 are listed in Tables 1a and 2a. The seasonal changes in moose hair element values reflect the availability and intake of these elements on a one- to two-month delayed basis.[6,7] We thereby, utilized hair sampled during these months to reflect intake during the peak of lactation and milk sampling.

Only two elements (Ca and Mg) had lower hair than milk levels. Calcium was lower by a factor of 4.2 and Mg by a factor of 1.5. Both elements are essential and both are macro-elements. We were not concerned with hair values that were higher than milk values since those elements are potentially available at a level coinciding with the milk levels. This comparison may not be totally valid with marginal levels since the storage level in hair may differ for each element and for each comparable tissue. It is, however, important to note that Ca and Mg levels are much lower in hair than milk and, therefore, may not be available at an adequate intake level during lactation. It may be necessary for moose to draw on body reserves, particularly bone, to maintain apparent genetically determined milk levels of Ca and Mg. Ninety-nine percent of body Ca is found in bones and teeth and 70 percent of Mg in the animal body is in bone.[9]

Two common diseases in lactating dairy cattle are related to Ca and Mg metabolism (milk fever-hypocalcemia and grass tetany-hypomagnesemia).[9]

There has been no clinical evidence of these syndromes in moose. It appears, however, that moose, as well as cattle, are potentially subjected to additional stress during lactation by genetically determined milk levels of Ca and Mg.

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We have sampled hair from 11 different areas of Alaska (two in Canada) during 19 different periods of time in addition to our monthly samples at the MRC over the past three years. A paper is in preparation now comparing these at corresponding time, for potential geochemical influence detectable by hair analysis. Tables 12 through 28 list mean, standard duration, and month sampled of hair values from various regions in Alaska for 17 elements. The potential of applying these data for forensic purposes is being investigated in addition to applying the mineral metabolism and cycling concept over a larger area.

Milk Values

Raw milk mineral element data were reported for 12 moose (Franzmann and Arneson 1974b). Eight additional samples have been analyzed and were summarized in the paper in the Hair Mineral Element Value section of this report.

Gross composition analysis for 20 moose milk samples was; total solids - 24.54 $\pm$ 6.11 percent, gross energy (K cal/g) - 1.42$\pm$ 0.48, and pH 6.76$\pm$ 0.30. Seventeen milk samples were available for percent crude protein (10.32$\pm$ 2.24), eight for percent lipids (5.83$\pm$ 2.78), five each for percent ash (2.01$\pm$ 0.26) and percent lactose (6.81$\pm$ 2.54). Only three milk samples were of sufficient quantity to test specific gravity (1.038$\pm$ 0.010). No interpretation will be made of these data in this report since a manuscript is being prepared comparing moose milk samples (gross composition) with milk samples from other North American ruminants. Preliminary observations of these comparative data indicate general homogeneity, however, percent lipids in moose milk appears low in relation to other ruminants while percent lactose appears high.

Mineral Metabolism and Cycling

The application of hair element analysis to monitor moose metabolism and the resulting findings which indicated potential mineral deficiency problems (Hair Mineral Element Values section of this report) have encouraged our involvement into these problems in a more complex manner. Additionally, the indication that perhaps browse quality, not quantity, may be more critical for the Kenai Peninsula moose (LeResche et al. 1973 and Oldemeyer et al. 1975) stimulated our efforts in this direction.

Table 12. Moose hair mean monthly calcium values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1972					335.0±67.7 (11)	284.7±108.1 (19)	313.3±107.0 (19)	699.7±208.8 (13)	515.5±125.5 (12)	227.8±66.4 (10)	196.4±38.0 (16)	220.9±31.8 (17)
MRC (GMU 15A) 1973	196.0±38.1 (21)	295.6±68.0 (23)	241.8±42.2 (23)	249.3±46.1 (29)		216.2±262.5 (22)	297.6±206.7 (22)	361.1±158.1 (16)	283.0±126.1 (20)	134.8±48.4 (21)	194.2±85.8 (10)	225.1±71.0 (15)
MRC (GMU 15A) 1974	203.4±50.6 (17)	280.2±45.7 (18)			226.7±74.3 (10)	258.5±87.3 (19)	514.3±398.2 (22)	382.9±255.3 (14)	207.8±119.2 (26)	93.9±48.8 (26)	195.2±38.1 (11)	222.2±67.2 (17)
MRC (GMU15A) 1975	234.9±78.8 (10)	208.7±27.5 (12)										
Benchland (GMU15A & 15B)										225.2±71.3 (58-1972)		
Fort Richardson (GMU 14C)	280.4±100.3 (44-1973)	289.9±58.5 (50-1974)										
Alaska Range (GMU 20A)										129.6±37.6 (21-1973)		
Caribou Hills (GMU 15B)										238.8±42.0 (67-1973)		
Southeast Alaska									602.2±205.9 (13-1973)			
Copper River Delta (GMU 6)			132.1±63.2 (50-1974)					712.5±71.1 (12-1974)	569.6±108.1 (27-1974)			
Nome (GMU 22)	167.6±55.7 (26-1965)							347.9±152.6 (5-1974)	293.4±209.3 (37-1974)	241.0±164.1 (21-1974)		
Glennallen (GMU 13)			321.7±51.3 (64-1975)	591.9±127.7 (10-1975)						167.6±107.0 (68-1974)	75.1±37.9 20-1974)	
Homer (GMU 15C)				192.0±41.1 (31-1975)							84.7±60.7 (60-1974)	
Fairbanks (GMU 20B)			159.2±16.3 (5-1975)									
Elmendorf (GMU 14C)		337.7±84.2 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 13. Moose hair mean monthly magnesium values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1972					38.3±6.0 (11)	29.4±12.8 (19)	31.9±16.8 (19)	107.5±40.5 (13)	149.5±61.6 (12)	92.0±17.8 (10)	80.8±19.8 (16)	64.2±12.2 (17)
MRC (GMU 15A) 1973	55.4±10.7 (21)	51.1±12.7 (23)	49.1±18.8 (23)	45.5±12.4 (29)		36.4±30.0 (22)	57.9±52.4 (22)	191.8±65.2 (16)	166.2±45.8 (20)	152.4±32.1 (21)	50.0±21.5 (10)	40.9±16.4 (15)
MRC (GMU 15A) 1974	32.0±16.0 (17)	31.4±5.7 (18)			33.8±6.2 (10)	41.6±23.2 (19)	82.6±56.3 (22)	94.0±62.0 (14)	102.6±33.5 (26)	45.6±14.3 (26)	72.1±10.3 (11)	65.8±15.2 (17)
MRC (GMU 15A) 1975	67.4±15.4 (10)	50.6±9.0 (12)										
Benchland (GMU 15A & 15B)										120.5±45.1 (58-1972)		
Fort Richardson (GMU 14C)	76.8±22.0 (44-1973)	75.2±17.1 (50-1974)										
Alaska Range (GMU 20A)										102.5±34.3 (21-1973)		
Caribou Hills (GMU 15B)										122.6±39.3 (67-1973)		
Southeast Alaska									72.0±24.6 (13-1973)			
Copper River Delta (GMU 6)			64.0±3.6 (50-1974)					122.4±20.1 (12-1974)	132.3±17.9 (27-1974)			
Nome (GMU 22)	44.9±14.4 (26-1975)							114.3±58.9 (5-1974)	72.1±47.7 (37-1974)	56.5±42.5 (21-1974)		
Glennallen (GMU 13)			68.4±9.4 (64-1975)	72.6±8.0 (10)						93.9±25.7 (68-1974)	35.1±20.5 (20-1974)	
Homer (GMU 15C)				67.0±10.8 (31-1975)							38.6±26.4 (60-1974)	
Fairbanks (GMU 20B)			62.1±8.2 (5-1975)									
Elmendorf (GMU 14C)		77.6±12.6 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 14. Moose hair mean monthly potassium values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1972					257.5±71.0 (11)	756.1±485.8 (19)	1056.4±409.0 (19)	916.8±498.4 (13)	1579.1±947.2 (12)	1943.6±693.3 (10)	1032.2±569.4 (16)	467.8±203.2 (17)
MRC (GMU 15A) 1973	326.9±66.1 (21)	379.4±134.6 (23)	429.4±124.0 (23)	435.0±112.7 (29)		1001.1±535.7 (22)	964.8±511.4 (22)	1669.9±611.8 (16)	1653.1±343.4 (20)	1125.2±144.7 (21)	1479.6±579.9 (10)	863.3±444.4 (15)
MRC (GMU 15A) 1974	497.1±163.2 (17)	473.0±90.2 (18)			697.1±373.4 (10)	898.1±407.2 (19)	1215.1±532.5 (22)	1161.0±593.0 (14)	1046.0±607.2 (26)	1800.2±1066.7 (26)	950.9±233.6 (11)	537.7±148.7 (17)
MRC (GMU 15A) 1975	502.6±126.6 (10)	454.6±124.4 (12)										
Benchland (GMU 15A & 15B)										2090.4±781.5 (58-1972)		
Fort Richardson (GMU 14C)	406.2±239.0 (44-1973)	445.9±144.9 (50-1974)										
Alaska Range (GMU 20A)										854.9±324.0 (21-1973)		
Caribou Hills (GMU 15B)										1972.1±443.2 (67-1973)		
Southeast Alaska									1367.1±953.9 (13-1973)			
Copper River Delta (GMU 6)			501.2±172.5 (50-1974)					784.5±250.4 (12-1974)	906.6±266.9 (27-1974)			
Nome (GMU 22)	653.8±144.5 (26-1975)							1285.7±326.1 (5-1974)	1185.9±592.3 (37-1974)	1101.9±631.0 (21-1974)		
Glennallen (GMU 13)			633.8±77.5 (64-1975)	552.5±41.1 (10-1975)						868.2±554.5 (68-1974)	571.1±246.3 (20-1974)	
Homer (GMU 15C)				558.3±71.8 (31-1975)							1034.8±602.9 (60-1974)	
Fairbanks (GMU 20B)			743.6±107.7 (5-1975)									
Elmendorf (GMU 14C)		471.8±90.0 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 15. Moose hair mean monthly sodium values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis) January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1972					633.5±113.3 (11)	460.4±141.7 (19)	618.0±185.8 (19)	448.2±148.2 (13)	714.2±140.7 (12)	1073.2±279.4 (10)	1191.6±292.7 (16)	1277.1±285.0 (17)
MRC (GMU 15A) 1973	1174.9±384.3 (21)	870.0±185.3 (23)	787.2±149.8 (23)	644.7±146.0 (29)		670.1±308.4 (22)	791.9±161.4 (22)	1037.2±170.9 (16)	1025.4±230.7 (20)	1125.2±144.7 (21)	1964.3±569.5 (10)	1088.6±233.5 (15)
MRC (GMU 15A) 1974	1250.9±441.2 (17)	914.8±391.8 (18)			687.6±170.3 (10)	771.6±250.0 (19)	606.9±181.1 (22)	556.8±183.8 (14)	674.7±191.1 (26)	1181.3±253.1 (26)	1250.1±176.4 (11)	1206.1±189.8 (17)
MRC (GMU 15A) 1975	1131.7±322.3 (10)	738.6±109.1 (12)										
Benchland (GMU 15A & 15B)										1235.4±328.5 (58-1972)		
Fort Richardson (GMU 14C)	1189.5±503.1 (44-1973)	1257.3±452.0 (50-1974)										
Alaska Range (GMU 20A)										1374.6±381.4 (21-1973)		
Caribou Hills (GMU 15B)										1258.1±296.9 (67-1973)		
Southeast Alaska									1438.1±328.2 (13-1973)			
Copper River Delta (GMU 6)			894.7±182.2 (50-1974)					600.9±123.8 (12-1974)	859.2±137.8 (27-1974)			
Nome (GMU 22)	705.8±106.1 (26-1975)							652.6±260.1 (5-1974)	897.9±267.7 (37-1974)	902.1±360.7 (21-1974)		
Glennallen (GMU 13)			816.1±71.2 (64-1975)	702.8±78.4 (10-1975)						601.9±210.8 (68-1974)	758.4±238.2 (20-1974)	
Homer (GMU 15C)				703.1±100.3 (31-1975)							935.3±331.3 (60-1974)	
Fairbanks (GMU 20B)			489.8±137.7 (5-1975)									
Elmendorf (GMU 14C)		939.1±221.5 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 16. Moose hair mean monthly cadmium values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis) January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1972					0.28±0.23 (11)	0.32±0.31 (19)	0.26±0.20 (19)	0.50±0.61 (13)	1.35±1.30 (12)	1.71±1.61 (10)	0.75±1.09 (16)	0.34±0.31 (17)
MRC (GMU 15A) 1973	0.02±0.07 (21)	0.88±1.89 (23)	0.18±0.26 (23)	0.15±0.32 (29)		0.35±1.42 (22)	0.32±0.31 (22)	0.88±0.35 (16)	1.42±1.80 (20)	1.38±0.46 (21)	0.39±0.26 (10)	0.96±0.26 (15)
MRC (GMU 15A) 1974	0.59±0.23 (17)	0.64±0.14 (18)			0.65±0.22 (10)	0.81±0.29 (19)	2.27±0.64 (22)	2.34±0.73 (14)	2.30±0.81 (26)	1.93±1.13 (26)	0.82±0.28 (11)	0.23±0.30 (17)
MRC (GMU 15A) 1975	0.12±0.14 (10)	0.62±0.26 (12)										
Benchland (GMU 15A & 15B)										1.50±1.46 (58-1972)		
Fort Richardson (GMU 14C)	0.47±0.34 (44-1973)	0.42±0.36 (50-1974)										
Alaska Range (GMU 20A)										1.20±0.80 (21-1973)		
Caribou Hills (GMU 15B)										1.16±1.22 (67-1973)		
Southeast Alaska									0.52±0.21 (13-1973)			
Copper River Delta (GMU 6)			0.48±0.20 (50-1974)					1.73±0.63 (12-1974)	4.17±1.81 (27-1974)			
Nome (GMU 22)	0.32±0.29 (26-1975)							1.88±1.01 (5-1974)	1.93±1.27 (37-1974)	1.71±0.87 (21-1974)		
Glennallen (GMU 13)			0.58±0.23 (64-1975)	0.79±0.31 (10-1975)						1.93±0.82 (68-1974)	2.24±0.86 (20-1974)	
Homer (GMU 15C)				0.56±0.16 (31-1975)							1.51±1.07 (60-1974)	
Fairbanks (GMU 20B)			0.84±0.30 (5-1975)									
Elmendorf (GMU 14C)		0.38±0.24 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 17. Moose hair mean monthly copper values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1](GMU[2]15A)1972					3.4±1.4 (11)	3.4±1.3 (19)	3.5±1.9 (19)	4.8±1.8 (13)	13.3±3.3 (12)	14.0±2.8 (10)	12.2±6.6 (16)	1.5±1.0 (17)
MRC(GMU 15A)1973	2.6±1.2 (21)	4.8±3.6 (23)	7.5±3.8 (23)	7.8±4.0 (29)		7.0±3.7 (22)	8.0±3.2 (22)	11.2±2.4 (16)	12.3±3.7 (20)	10.6±3.6 (21)	1.7±0.6 (10)	1.5±0.4 (15)
MRC(GMU 15A)1974	1.4±0.3 (17)	1.3±0.3 (18)			2.0±0.7 (10)	2.1±0.7 (19)	6.0±3.0 (22)	5.2±2.9 (14)	10.4±2.3 (26)	8.7±1.3 (26)	11.8±2.6 (11)	3.7±2.2 (17)
MRC(GMU 15A)1975	2.4±0.9 (10)	2.7±1.2 (12)										
Benchland (GMU 15A & 15B)										14.7±5.0 (58-1972)		
Fort Richardson (GMU 14C)	7.1±2.5 (44-1973)	7.5±2.6 (50-1974)										
Alaska Range (GMU 20A)										13.0±3.5 (21-1973)		
Caribou Hills (GMU 15B)										11.5±3.1 (67-1973)		
Southeast Alaska									10.2±1.9 (13-1973)			
Copper River Delta (GMU 6)			10.0±2.8 (50-1974)					17.7±3.8 (12-1974)	24.2±4.2 (27-1974)			
Nome (GMU 22)	9.2±1.6 (26-1975)							14.5±10.1 (5-1974)	12.5±6.3 (37-1974)	11.7±4.0 (21-1974)		
Glennallen (GMU 13)			7.8±2.5 (64-1975)	4.6±1.1 (10-1975)						11.7±2.4 (68-1974)	9.0±1.6 (20-1974)	
Homer (GMU 15C)				7.0±2.1 (31-1975)							9.2±1.6 (60-1974)	
Fairbanks (GMU 20B)			6.0±1.4 (5-1975)									
Elmendorf (GMU 14C)		8.5±2.1 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 18. Moose hair mean monthly iron values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis) January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1972					33.4±12.1 (11)	52.9±19.4 (19)	50.5±16.7 (19)	35.1±9.9 (13)	41.9±14.9 (12)	47.9±17.4 (10)	42.1±12.3 (16)	51.9±18.8 (17)
MRC (GMU 15A) 1973	59.0±23.6 (21)	55.5±19.5 (23)	64.1±18.2 (23)	67.7±20.7 (29)		32.9±33.8 (22)	55.4±75.4 (22)	51.2±15.9 (16)	62.7±3.4 (20)	67.0±4.6 (21)	31.4±8.4 (10)	36.9±7.2 (15)
MRC (GMU 15A) 1974	48.8±21.1 (17)	48.2±15.9 (18)			65.8±16.4 (10)	68.1±29.0 (19)	39.3±9.0 (22)	35.2±6.6 (14)	51.3±18.1 (26)	59.5±10.8 (26)	48.9±8.6 (11)	52.0±10.0 (17)
MRC (GMU 15A) 1975	50.9±8.1 (10)	52.2±7.7 (12)										
Benchland (GMU 15A & 15B)										51.4±14.6 (58-1972)		
Fort Richardson (GMU 14C)	55.8±14.4 (44-1973)	53.1±16.8 (50-1974)										
Alaska Range (GMU 20A)										68.0±7.0 (21-1973)		
Caribou Hills (GMU 15B)										55.9±13.6 (67-1973)		
Southeast Alaska									69.1±34.7 (13-1973)			
Copper River Delta (GMU 6)			28.4±9.8 (50-1974)					48.9±13.6 (12-1974)	51.7±6.5 (27-1974)			
Nome (GMU 22)	44.4±9.8 (26-1975)							51.9±14.4 (5-1974)	49.4±12.4 (37-1974)	49.0±8.1 (21-1974)		
Glennallen (GMU 13)			52.8±5.9 (64-1975)	50.1±5.7 (10-1975)						74.2±41.5 (68-1974)	62.8±11.8 (20-1974)	
Homer (GMU 15C)				51.2±12.9 (31-1975)							50.1±9.4 (60-1974)	
Fairbanks (GMU 20B)			63.6±10.7 (5-1975)									
Elmendorf (GMU 14C)		46.9±10.6 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 19. Moose hair mean monthly lead values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1972					5.6±1.8 (11)	5.1±2.5 (19)	8.8±3.7 (19)	7.2±3.2 (13)	9.1±3.9 (12)	12.3±6.3 (10)	13.8±9.9 (16)	10.7±5.3 (17)
MRC (GMU 15A) 1973	4.0±2.7 (21)	5.5±2.5 (23)	5.4±2.7 (23)	5.6±3.3 (29)		5.5±5.0 (22)	12.2±7.2 (22)	17.6±1.1 (16)	15.7±7.7 (20)	11.5±3.4 (21)	0.4±0.9 (10)	0.9±2.1 (15)
MRC (GMU 15A) 1974	0.0±0.0 (17)	0.1±0.2 (18)			1.4±0.5 (10)	3.9±2.4 (19)	4.0±1.7 (22)	5.2±2.4 (14)	4.1±1.4 (26)	2.5±2.3 (26)	10.4±3.3 (11)	10.0±2.2 (17)
MRC (GMU 15A) 1975)	5.6±3.0 (10)	5.7±2.0 (12)										
Benchland (GMU 15A & 15B)										12.3±5.9 (58-1972)		
Fort Richardson (GMU 14C)	5.1±7.1 (44-1973)	5.2±3.8 (50-1974)										
Alaska Range (GMU 20A)										14.8±5.8 (21-1973)		
Caribou Hills (GMU 15B)										10.2±5.0 (67-1973)		
Southeast Alaska									3.7±2.1 (13-1973)			
Copper River Delta (GMU 6)			4.3±3.3 (50-1974)					12.8±5.4 (12-1974)	13.5±4.3 (27-1974)			
Nome (GMU 22)	0.5±0.7 (26-1975)							7.6±3.8 (5-1974)	2.6±2.7 (37-1974)	1.5±6.4 (21-1974)		
Glennallen (GMU 13)			7.4±2.1 (64-1975)	1.1±0.6 (10-1975)						4.1±2.7 (68-1974)	1.3±1.3 (20-1974)	
Homer (GMU 15C)				0.3±0.4 (31-1975)							1.7±1.3 (60-1974)	
Fairbanks (GMU 20B)			3.8±0.4 (5-1975)									
Elmendorf (GMU 14C)		3.9±1.9 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 20 Moose hair mean monthly manganese values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A)1972					3.6±1.8 (11)	0.8±1.4 (19)	0.1±0.2 (19)	0.2±0.4 (13)	2.2±1.4 (12)	5.1±3.0 (10)	5.2±3.4 (16)	6.5±4.8 (17)
MRC (GMU 15A)1973	1.6±2.0 (21)	0.7±1.2 (23)	1.8±1.2 (23)	1.7±1.6 (29)		0.1±0.4 (22)	0.4±0.6 (22)	1.3±0.4 (16)	0.9±0.4 (20)	3.9±3.6 (21)	2.8±1.3 (10)	2.8±1.1 (15)
MRC (GMU 15A)1974	1.7±1.3 (17)	2.3±1.3 (18)			1.5±1.0 (10)	2.4±0.8 (19)	1.4±0.7 (22)	1.2±0.6 (14)	3.7±1.2 (26)	1.6±0.6 (26)	4.6±1.9 (11)	4.8±1.7 (17)
MRC (GMU 15A)1975	2.2±1.2 (10)	0.2±0.2 (12)										
Benchland (GMU 15A & 15B)										11.6±8.4 (58-1972)		
Fort Richardson (GMU 14C)	1.6±2.1 (44-1973)	1.2±1.5 (50-1974)										
Alaska Range (GMU 20A)										10.3±4.3 (21-1973)		
Caribou Hills (GMU 15B)										11.0±8.6 (67-1973)		
Southeast Alaska									0.9±0.4 (13-1973)			
Copper River Delta (GMU 6)			0.6±0.3 (50-1974)					3.6±1.3 (12-1974)	4.2±0.8 (27-1974)			
Nome (GMU 22)	0.5±0.3 (26-1975)							1.3±0.2 (5-1974)	1.2±0.9 (37-1974)	1.2±0.8 (21-1974)		
Glennallen (GMU 13)			2.0±0.8 (64-1975)	1.2±0.3 (10-1975)						2.7±1.1 (68-1974)	0.9±0.7 (20-1974)	
Homer (GMU 15C)				1.3±0.5 (31-1975)							0.8±0.4 (60-1974)	
Fairbanks (GMU 20B)			0.6±0.2 (5-1975)									
Elmendorf (GMU 14C)		1.9±1.3 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 21. Moose hair mean monthly zinc values from various regions in Alaska, 1972-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1972					65.5±9.6 (11)	49.6±8.7 (19)	45.3±14.5 (19)	54.9±13.5 (13)	78.4±12.9 (12)	86.3±32.4 (10)	71.6±8.0 (16)	63.1±4.9 (17)
MRC (GMU 15A) 1973	66.7±6.0 (21)	81.0±13.2 (23)	74.3±24.1 (23)	74.0±21.2 (29)		82.8±21.5 (22)	75.4±15.4 (22)	67.1±7.1 (16)	68.1±5.9 (20)	63.0±6.4 (21)	103.3±27.0 (10)	102.6±16.9 (15)
MRC (GMU 15A) 1974	95.9±3.5 (17)	96.3±11.3 (18)			95.5±8.8 (10)	79.8±20.3 (19)	93.8±21.0 (22)	94.6±19.3 (14)	97.8±12.2 (26)	92.7±6.6 (26)	68.2±9.4 (11)	57.1±7.7 (17)
MRC (GMU 15A) 1975	59.0±11.4 (10)	54.6±12.0 (12)										
Benchland (GMU 15A & 15B)										89.1±26.5 (58-1972)		
Fort Richardson (GMU 14C)	65.2±9.2 (44-1973)	61.6±9.1 (50-1974)										
Alaska Range (GMU 20A)										60.1±6.6 (21-1973)		
Caribou Hills (GMU 15B)										69.5±14.2 (67-1973)		
Southeast Alaska									112.9±14.6 (13-1973)			
Copper River Delta (GMU 6)			102.0±16.1 (50-1974)					135.6±10.5 (12-1974)	133.9±11.6 27-1974)			
Nome (GMU 22)	71.7±11.4 (26-1965)							99.8±6.0 (5-1974)	106.7±16.0 37-1974)	104.9±24.6 (21-1974)		
Glennallen (GMU 13)			109.7±19.0 (64-1975)	57.7±10.0 (10-1975)						105.5±13.5 (68-1974)	95.2±15.2 (20-1974)	
Homer (GMU 15C)				74.6±8.2 (31-1975)							91.1±8.6 (60-1974)	
Fairbanks (GMU 20B)			65.6±1.8 (5-1975)									
Elmendorf (GMU 14C)		61.7±6.5 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 22 Moose hair mean monthly aluminum values from various regions in Alaska, 1973-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1973											0.57±0.12 (10)	0.48±0.23 (15)
MRC (GMU 15A) 1974	0.33±0.28 (19)	0.39±0.27 (18)			0.86±0.40 (10)	0.89±0.45 (20)	1.31±0.35 (22)	1.65±0.47 (14)	1.68±0.26 (26)	0.71±0.15 (26)	0.76±0.15 (11)	0.28±0.2[illegible] (17)
MRC (GMU 15A) 1975	0.19±0.11 (10)	0.73±0.12 (12)										
Alaska Range (GMU 20A)										1.85±0.31 (4-1974)		
Caribou Hills (GMU 15B)												
Southeast Alaska (GMU 5)									0.35±0.11 (13-1973)			
Copper River (GMU 6)			0.52±0.22 (50-1974)					0.72±0.22 (12-1974)	1.04±0.41 (27-1974)			
Nome (GMU 22)	0.70±0.32 (26-1975)							1.40±0.39 (5-1974)	1.56±0.64 (17-1974)	0.93±0.31 (20-1974)		
Glennallen (GMU 13)			0.81±0.44 (64-1975)	0.18±0.20 (10-1975)						20.02±0.65 (68-1974)	0.78±0.24 (20-1975)	
Homer (GMU 15C)				0.25±0.15 (31-1975)							0.72±0.22 (60-1974)	
Fairbanks (GMU 20D)			0.62±0.16 (5-1975)									
Elmendorf (GMU 14C)		1.01±0.54 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 23 Moose hair mean monthly chromium values from various regions in Alaska, 1973-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU15A) 1973											0.28±0.10 (10)	0.17±0.04 (15)
MRC (GMU 15A) 1974	0.08±0.06 (19)	0.17±0.06 (18)			0.13±0.04 (10)	0.24±0.09 (20)	0.24±0.05 (22)	0.25±0.07 (14)	0.35±0.10 (26)	0.37±0.09 (26)	0.20±0.07 (11)	0.18±0.07 (17)
MRC (GMU 15A) 1975	0.14±0.06 (10)	0.14±0.05 (12)										
Alaska Range (GMU 20A)											0.21±0.06 (4-1974)	
Caribou Hills (GMU 15B)												
Southeast Alaska (GMU 5)									0.60±0.15 (13-1973)			
Fort Richardson (GMU 14C)		ND[3] (50-1974)										
Copper River (GMU 6)			0.53±0.15 (50-1974)					0.72±0.17 (12-1974)	0.76±0.15 (27-1974)			
Nome (GMU 22)		0.38±0.07 (26-1974)						0.21±0.03 (5-1974)	0.26±0.05 (17-1974)	0.40±0.10 (20-1974)		
Glennallen (GMU 13)			0.40±0.09 (64-1975)	0.16±0.11 (16-1975)						0.31±0.09 (68-1974)	0.27±0.09 (20-1974)	
Homer (GMU 15C)				0.10±0.04 (31-1975)							0.33±0.12 (60-1974)	
Fairbanks (GMU 20B)			0.38±0.08 (5-1975)									
Elmendorf (GMU 14C)		0.07±0.08 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit
3. ND - Not detectable

Table 24 Moose hair mean monthly cobalt values from various regions in Alaska, 1973-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis) January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1973								2.41±0.82 (15)	2.52±0.81 (20)	2.93±0.43 (20)	0.26±0.05 (10)	0.21±0.05 (15)
MRC (GMU 15A) 1974	0.16±0.05 (19)	0.28±0.07 (18)			0.27±0.09 (10)	0.41±0.14 (20)	0.68±0.20 (22)	0.79±0.13 (14)	1.41±0.52 (26)	0.83±0.34 (26)	0.26±0.13 (11)	0.19±0.07 (17)
MRC (GMU 15A) 1975	0.14±0.05 (10)	0.19±0.14 (12)										
Alaska Range (GMU 20A)										3.41±0.83 (21-1973)		
Caribou Hills (GMU 15B)										3.03±0.51 (67-1973)		
Southeast Alaska (GMU 5)									0.39±0.14 (13-1973)			
Fort Richardson (GMU 14C)		1.28±0.38 (50-1974)										
Copper River (GMU 6)			0.54±0.14 (50-1974)					1.44±0.24 (12-1974)	1.84±0.47 (27-1974)			
Nome (GMU 22)	0.72±0.35 (26-1975)							0.64±0.11 (5-1974)	0.79±0.22 (17-1974)	1.00±0.65 (20-1974)		
Glennallen (GMU 13)			0.60±0.18 (64-1975)	0.19±0.07 (10-1975)						1.79±0.69 (68-1974)	0.67±0.27 (20-1974)	
Homer (GMU 15C)				0.19±0.11 (31-1975)							0.68±0.25 (60-1974)	
Fairbanks (GMU 20B)			0.50±0.14 (5-1975)									
Elmendorf (GMU 14C)		0.75±0.21 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 25 Moose hair mean monthly mercury values from various regions in Alaska, 1973-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1973											0.11±0.06 (10)	0.09±0.04 (15)
MRC (GMU 15A) 1974	<0.05 (19)	<0.05 (18)			0.15±0.09 (10)	0.18±0.05 (20)	0.22±0.07 (22)	0.24±0.07 (14)	0.26±0.07 (26)	<0.05 (26)	0.11±0.02 (11)	0.10±0.02 (17)
MRC (GMU 15A) 1975	0.08±0.2 (10)	<0.05 (12)										
Alaska Range (GMU 20A)										0.24±0.02 (4-1974)		
Caribou Hills (GMU 15B)												
Southeast Alaska (GMU 5)									<0.05 (13-1973)			
Copper River (GMU 6)			0.11±0.05 (50-1974)					0.09±0.03 (12-1974)	<0.05 (27-1974)			
Nome (GMU 22)	0.03±0.04 (26-1975)							0.18±0.05 (5-1974)	0.23±0.06 (17-1974)	<0.05 (20-1974)		
Glennallen (GMU 13)			0.07±0.04 (64-1975)	<0.05 (10-1975)						0.26±0.06 (68-1974)	0.08±0.05 (20-1974)	
Homer (GMU 15C)				<0.05 (31-1975)							<0.05 (60-1974)	
Fairbanks (GMU 20B)			0.08±0.03 (5-1975)									
Elmendorf (GMU 14C)		<0.05 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 26 Moose hair mean monthly molybdenum values from various regions in Alaska, 1973-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A)1973											<0.1 (10)	<0.1 (15)
MRC(GMU 15A)1974	<0.1 (19)	<0.1 (18)			0.32±0.10 (10)	0.38±0.09 (20)	0.53±0.13 (22)	0.57±0.14 (14)	0.73±0.16 (26)	0.68±0.24 (26)	<0.1 (11)	<0.1 (17)
MRC (GMU 15A)1975	<0.1 (10)	<0.1 (12)										
Alaska Range (GMU 20A)										0.80±0.00 (4-1974)		
Caribou Hills (GMU 15B)												
Southeast Alaska (GMU 5)									<0.1 (13-1973)			
Copper River (GMU 6)			<0.1 (50-1974)					0.63±0.18 (12-1974)	0.69±0.15 (27-1974)			
Nome (GMU 22)	0.50±0.21 (26-1975)							0.64±0.30 (5-1974)	0.68±0.27 (17-1974)	0.88±0.42 (20-1974)		
Glennallen (GMU 13)			0.41±0.16 (64-1975)	<0.05 (10-1975)						0.70±0.22 (68-1974)	0.57±0.23 (20-1974)	
Homer (GMU 15C)				<0.05 (31-1975)							0.59±0.20 (60-1974)	
Fairbanks (GMU 20B)			0.58±0.22 (5-1975)									
Elmendorf (GMU 14C)		0.30±0.28 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 27 Moose hair mean monthly nickel values from various regions in Alaska, 1973-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU15A) 1973											0.30±0.08 (10)	0.29±0.08 (15)
MRC (GMU 15A) 1974	0.35±0.09 (19)	0.44±0.07 (18)			0.39±0.11 (10)	0.47±0.11 (20)	0.43±0.17 (22)	0.44±0.18 (14)	0.47±0.13 (26)	1.98±1.89 (26)	0.30±0.08 (11)	0.20±0.07 (17)
MRC (GMU 15A) 1975	0.16±0.07 (10)	0.15±0.11 (12)										
Alaska Range (GMU 20A)										0.33±0.05 (4-1974)		
Caribou Hills (GMU 15B												
Southeast Alaska (GMU 5)									0.48±0.25 (13-1973)			
Fort Richardson (GMU 14C)		ND (50-1974)										
Copper River (GMU 6)			0.31±0.09 (50-1974)					0.62±0.14 (12-1974)	0.61±0.17 (27-1974)	0.84±1.27 (20-1974)		
Nome (GMU 22)	0.22±0.24 (26-1975)							0.34±0.07 (5-1974)	0.34±0.07 (17-1974)	0.48±0.13 (68-1974)	1.26±1.37 (20-1974)	
Glennallen (GMU 13)			0.43±0.16 (64-1975)	0.33±0.12 (10-1975)							2.04±1.53 (60-1974)	
Homer (GMU 15C)				0.39±0.19 (31-1975)								
Fairbanks (GMU 20B)			0.42±0.15 (5-1975)									
Elmendorf (GMU 14C)		<0.05 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

Table 28 Moose hair mean monthly selinium values from various regions in Alaska, 1973-1975 (ppm).

Area and Year Sampled	Month Sampled (Sample size and year in parenthesis)											
	January	February	March	April	May	June	July	August	September	October	November	December
MRC[1] (GMU[2] 15A) 1973											1.16±0.33 (10)	0.79±0.19 (15)
MRC (GMU 15A) 1974	0.71±0.27 (19)	0.64±0.40 (18)			1.75±0.80 (10)	1.84±0.69 (20)	1.96±0.64 (22)	2.12±0.83 (14)	2.62±0.56 (26)	1.58±0.49 (26)	1.15±0.30 (11)	1.16±0.37 (17)
MRC (GMU 15A) 1975	0.83±0.25 (10)	0.08±0.29 (12)										
Alaska Range (GMU 20A)										1.75±0.10 (4-1974)		
Caribou Hills (GMU 15B)												
Southeast Alaska (GMU 5)									1.83±0.61 (13-1973)			
Copper River (GMU 6)			1.60±0.50 (50-1974)					1.08±0.42 (12-1974)	1.47±0.30 (27-1974)			
Nome (GMU 22)	0.85±0.27 (26-1975)							2.46±0.26 (5-1974)	2.34±0.65 (17-1974)	1.72±0.51 (20-1974)		
Glennallen (GMU 13)			1.46±0.27 (64-1975)	0.17±0.17 (10-1975)						2.34±0.61 (68-1974)	1.12±0.41 (20-1974)	
Homer (GMU 15C)				0.24±0.36 (31-1975)							1.24±0.44 (60-1974)	
Fairbanks (GMU 20B)			0.88±0.19 (5-1975)									
Elmendorf (GMU 14C)		0.64±0.35 (20-1975)										

1. MRC - Kenai Moose Research Center
2. GMU - Game Management Unit

The potential applicability of this type of information was outlined in the following paper entitled "Minerals and Moose" by A. W. Franzmann, J. L. Oldemeyer and A. Flynn:

The concept that wild animals do not suffer from mineral deficiencies since most elements are widespread in their environment may be false. Similar consideration may be given to the statement "...it is doubtful whether deficiencies of trace elements are a matter for serious consideration for any class of livestock" (Abrams 1968).

The problem with these statements, we believe, concerns degree of deficiency. Classic symptomatology associated with deficiencies created artificially in a laboratory are not likely experienced in wild populations. It is also unlikely that we will observe "barnyard" type deficiencies in free-ranging animals. What are the effects of subtle deficiencies that do not exemplify themselves with known signs, but may affect the well being of the animal or animals and possibly interfere with reproductive success or calf viability?

To help understand the role of minerals, let us begin by reviewing the essential mineral elements. These have been classified as macro-elements and micro- or trace-elements. The classification difference corresponds to concentration in tissues, with the trace elements generally expressed in concentrations of parts per million (ppm) and macro-elements in percent. The classic definition of a trace element is any element that exists in concentration equal to or less than Fe in the body, with iron being the first of the trace-elements. The essential macro-elements are calcium (Ca), chlorine (Cl), potassium (K), magnesium (Mg), sodium (Na), phosphorus (P) and sulphur (S) and they have long been known to be required (Church 1971). The essential micro-elements are iodine (I), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), cobalt (Co), molybdenum (Mo), selenium (Se) chromium (Cr), tin (Sn), vanadium (V), fluorine (F), silicon (Si) and nickel (Ni) (Underwood 1971, and Schwarz 1974). Schwarz (1974) indicated 20 additional elements should be considered and investigated as possibly essential.

There is some variability in standards for determining essentiality of an element. The standards originally set by Cotzias (1967) are by far the most restrictive, but perhaps the best. Some standards used are listed in Appendix I.

To elucidate the physiology of these elements and the symptomatology associated with their deficiencies would require a symposium in itself. We will only generalize and state that they all have been established as essential to normal function and their deficiencies are associated with malfunction in basic physiological systems. Some symptoms associated with deficiencies of these elements are listed in Appendix II. In addition, all essential elements, have recognized toxic levels and associated pathology. The field of mineral metabolism is so complex and interrelated with itself and with other systems, primarily neural and hormonal, that no element can be considered alone. Two classic examples of this are the detrimental effect of high molybdenum intake on copper metabolism (Underwood 1971), and the shift of the Ca:P ratio influenced primarily by phosphorus levels. There are other examples of these types of interractions between minerals which confound our understanding of mineral metabolism.

Research in mineral metabolism has progressed rapidly in recent years with the advent of technological equipment for analysis, however, much needs to be done. The extremes are identifiable, such as the effects of toxic levels of these elements and conversely the effects of extreme deficiencies. The difficult areas to assess are the continuum between the extremes and the requirements for the animal in question.

We know that the tissue and plant concentrations of these elements are dynamic. Research at the Kenai Moose Research Center (MRC) has demonstrated this through seasonal sampling of moose hair and plants that moose browse (Franzmann et al. 1974). Botkin et al. (1973) discussed the dynamics of Na associated with the Isle Royale moose. Kubota (1974) reviewed the complexity of mineral cycling influenced by rock and soil parent materials, soil development, weathering and variation in species of plants. He demonstrated the variation in concentration of the elements in selected plants in Alaska, Minnesota and Wisconsin and postulated that the adaptability of the moose to its habitat may reflect its ability to utilize mineral elements from different feed plants. Morrison (1974) demonstrated variation in mineral content of leaves of young balsam fir within each tree. The importance of moisture and the complexity of mineral cycling was reviewed by Wilkinson and Lowrey (1973) and they stressed that life is essentially aqueous, and the behavior of an element and the compounds in which it functions are critical to reactivity, distribution, and transport in the ecosystem.

The problems associated with plant mineral absorption were reviewed by Loneragan (1973). Butler and Jones (1973) discussed the complexity of mineral interactions and plant and animal mineral requirement.

So what can a wildlife manager do and why should he add the burden of this potential problem to the many he already has?

First of all he or she need not be concerned with the specifics of mineral element metabolism, but should be aware of the possibility of deficiencies. More specifically, the manager should be concerned with the possible consequences that land use and management practices may have regarding mineral utilization of the animal in question. Our present state of knowledge will not specifically guide the manager, but awareness of the potential alteration of mineral availability, in general, may influence management and land use decisions.

Some examples that illustrate this are:

1. Land-Use Planning and Management

Moose may assimilate and store the majority of their mineral requirements within the short span of summer. The bulk of their mineral requirements are obtained from primary plant species, but they may require additional supplemental sources such as licks. On the Kenai Peninsula and elsewhere (Krefting 1974) a minor source of total food intake comes from submerged vegetation, however, results from Kubota (1974) and Oldemeyer et al. (1975) show these plants to be high in mineral content. Jordan et al. (1973) indicated that aquatic macrophytes had 500 times more Na than found in terrestial vegetation. Land use planning and management decisions should consider these potentially important mineral sources (licks and submerged vegetation) and not exclude access and use by moose.

It is important that moose not be excluded from areas of traditional use by highways, campgrounds or land development. It may be these excluded areas that provide the minerals, among other nutrients, that balance the moose's intake.

For most moose populations these considerations may not be valid, due to the extent, diversity and/or remoteness of their habitat, but they should be made when changes in land use or management are contemplated.

2. Fire Suppression and Prescribed Burning

Viereck (1973) indicated that whatever the actual cause, there does seem to be a release of nutrients and a fertilizing effect of fire on the organic soils in Alaska. Unfortunately, little is known regarding the uptake of micro-elements following fire, but the increase in macroelements has been noted (Lutz 1956 and Scotter 1971). Ascherin (1973) observed a "favorable" decrease in the Ca:P ratio after a burn. He determined that shrubs in the control had a higher than recommended ratio and burning reduced the ratio to a more acceptable level. Perhaps more important is the demonstrated population response to fire, such as by moose on the Kenai Peninsula, Alaska (Spencer and Hakala 1964).

Changes in soil and plant composition and quality following fire are influenced by many variables such as parent material, moisture, plant composition prior to fire, intensity of fire and climatic events following fire. Nevertheless, the generalization can be made that browse quality and palatability improve and moose populations respond. Mineral content, including trace minerals, must be considered a positive factor in these events.

3. Forestry Practices

The alteration of mineral cycling in forestry practices is influenced by many factors, however, parent material and subsequent weathering basically determine mineral availability in the forest. The mineral content of hardwood litter usually is higher than that of conifer litter, and bark usually contains 3 to 10 times as high a concentration of minerals as wood (Kramer and Kozlowski 1960). Removal of overstory permits revegetation in an area and browsing animals respond to the increase in available vegetative biomass; however, with harvest, appreciable amounts of nutrients are removed (Smith 1966). The long-term affects that removal of the forest overstory has on mineral cycling and subsequent availability to animals are difficult to establish, but the ecosystem can remain productive only if the nutrients withdrawn are balanced by an inflow of replacements (Smith 1966).

4. Vegetative Rehabilitation and Fertilization

The variation among plants in their ability to assimilate mineral elements may be cause for consideration in selection of areas for vegetative rehabilitation or chemical fertilization of moose browse.

These practices are not widespread at present, but their application in relation to mineral metabolism will increase as more intensive management practices are stimulated by new information on moose mineral requirements and mineral status of the area.

It would not be wise to invest great sums of money on mechanical or chemical rehabilitation in areas where vegetative response may favor plants that poorly assimilate certain mineral elements. We could, instead, divert our activity to an area that would stimulate plants that have the ability to assimilate desirable elements.

In all the above examples, we are not inferring that the decision rests with mineral cycling alone. We have but utilized the mineral viewpoint to stress that it is an additional factor to be considered.

Much research is required to assess the various affects our management plans have on mineral cycling, and even more is required to assess the often subtle affects mineral deficiencies may have on a population. The advent of atomic absorption spectroscopy permits intensive mineral element investigations. Perhaps the lack of definitive information regarding wildlife mineral metabolism and the general lack of information on the mineral aspect of forage quality for wildlife, stems from our previous inability to study minerals on a practical level. Research projects at the MRC have incorporated mineral research into present and future studies, and we suggest that those planning research projects consider adding to the sparse information available relative to minerals and moose by incorporating this into their studies, when feasible. The need for mineral metabolism information is certainly not intrinsic to moose and these studies on other species should also be encouraged.

Results of plant mineral element analyses are listed in Table 29. Soil analyses are listed in Table 30, and water analyses in Table 31. These are preliminary data and no interpretation will be made, however, several comments regarding these data are warranted.

Botkin et al. (1973) and Jordan et al. (1973) indicated that Na was a critical nutrient for Isle Royale moose. They determined that aquatics supply 88 percent of these animals' annual Na, implying that the animals must store Na to provide minimum requirements through the months when submerged vegetation was not available. Analysis of an aquatic (*Potamogeton* sp.) at the MRC (Table 29) indicated it contained 3919 ppm Na. Buckbean (*Menyanthes trifoliata*), a lowland bog forb, contained 718 ppm Na while no other grasses, forbs or shrubs contained more than 106 ppm Na. Several moose within the MRC enclosures chewed creosote log frame supports, and we analyzed some log chips for mineral elements. Sodium concentration in the log chips was extremely high (1134 ppm). The Na "dilemma" may be real.

Other observations concern the element Zn which was extremely high in three plants (Table 29); *Potamogeton* sp. (140.3 ppm), willow (*Salix* sp.) leaves (115.0 ppm), and aspen (*Populus tremuloides*) bark (168.5 ppm). Lowbush cranberry (*Vaccinium vitis-idaea*) had the lowest Zn levels followed closely by willow twigs, aspen twigs, and *Epilobium annotiaum* (Table 29).

Table 29. Mineral element analysis of selected moose browse plant and plant parts on the Kenai Peninsula, Alaska, July 1974.

	Macroelements (ppm)				Microelements (ppm)[1]									
Grass	Ca	K	Mg	Na	Al	Cd	Co	Cu	Fe	Mn	Mo	Pb	Se	Zn
Calamagrostis sp.	617	9799	1481	74	36	<0.5	0.1	22.3	58	30.9	0.20	<0.1	0.10	21.6
Carex sp	2107	8330	2056	93	93	<0.5	0.05	33.1	70	38.7	0.23	<0.1	0.27	42.7
Forbs														
Menyanthes trifoliata	1080	10954	1007	718	187	<0.5	0.2	19.1	113	36.6	0.34	3.8	0.46	42.0
Epilobium annotiaum	4588	7863	2008	76	84	<0.5	0.05	12.2	62	23.7	0.18	<0.1	0.15	15.3
Lupinus sp	11425	7413	1052	75	74	0.8	0.2	20.6	119	7.1	0.11	<0.1	0.18	38.1
Potamogeton sp	5690	10032	1072	3919	400	<0.5	0.6	24.2	130	28.2	0.48	<0.1	0.42	140.3
Shrubs														
Betula papyrifera leaves	1543	7273	2128	23	142	<0.5	0.1	20.9	105	181.8	0.28	1.8	0.30	77.3
Betula papyrifera twigs	586	4905	1842	81	38	<0.5	<0.05	16.6	67	62.8	0.19	3.4	0.11	46.2
Betula papyrifera combined	773	7479	1892	63	86	<0.5	0.1	16.7	78	141.0	0.26	2.9	0.21	53.5
Betula nana	631	5503	646	74	64	0.7	0.4	15.4	86	109.1	0.26	2.8	0.30	63.6
Populus tremuloides leaves	2377	10478	1997	100	120	<0.5	0.2	14.5	96	31.3	0.52	<0.1	0.17	43.3
Populus tremuloides twigs	791	7492	1286	88	41	<0.5	<0.05	11.3	78	9.4	0.30	<0.1	0.09	15.9
Populus tremuloides combined	2126	7516	1818	106	88	<0.5	0.05	11.9	81	15.1	0.36	<0.1	0.13	33.3
Salix sp leaves	2613	8519	1891	93	160	<0.5	0.1	15.8	115	66.2	0.15	0.5	0.26	115.0
Salix sp twigs	791	7492	1286	88	83	<0.5	<0.05	11.3	78	9.4	0.10	<0.1	0.15	15.9
Salix sp combined	788	5055	893	105	102	<0.5	<0.05	22.7	92	21.9	0.10	<0.5	0.20	38.3
Vaccinium vitis idaea	699	3691	1426	72	75	<0.5	0.1	13.8	44	111.8	0.12	<0.1	0.26	8.6
Viburnum edule	3284	10798	2112	106	62	<0.5	0.05	21.0	50	24.4	0.05	<0.1	0.18	23.5
Populus tremuloides bark	4677	4213	2042	82	88	<0.5	0.1	18.1	38	40.9	0.05	<0.1	0.11	168.5
Creosote log chips	417	210	1492	1134	117	<0.5	<0.05	13.4	70	21.0	0.34	<0.1	0.06	27.7

1 As, Cr and Ni values were all <0.05 ppm and Hg values were all <0.01 ppm

2 Samples collected October 1974 (Heavy use by moose at MRC)

Table 30. Mineral element analysis of soil at selected sites on the Kenai Peninsula, Alaska, October 1974.

Sample Number	Location	Macroelements (ppm)				Microelements (ppm)[1]								
		Ca	K	Mg	Na	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Zn
1	Portage Lake (regrowth)	6079	1279	1056	1434	1.6	3.5	83.6	9152	73.8	0.5	126.2	<0.05	45.9
3	N. of Pen 1 (mature timber)	7214	262	620	902	2.6	5.2	26.2	10046	38.9	0.4	102.5	<0.05	24.6
4	N. of Pen 1 (regrowth)	7315	364	703	712	2.1	6.8	26.7	10238	57.5	0.3	108.2	6.2	28.8
5	N. of Pen 1 (aspen grove)	6925	221	625	902	1.9	7.2	5.7	8561	22.1	0.7	17.8	3.3	36.1
6	S. of Pen 1 (regrowth)	8252	462	971	762	0.8	7.1	4.6	11342	40.0	1.1	26.3	3.8	53.1
7	Pen 2 (mature timber)	7386	404	758	994	1.5	5.6	1.9	8655	17.4	0.6	19.7	3.7	72.7
8	Pen 2 (regrowth)	6740	327	486	1009	1.8	3.8	5.5	8873	28.2	0.8	37.5	4.5	50.9
9	S.Shore Vixen Lake (regrowth)	9084	509	1122	1281	1.3	6.3	<0.05	8827	27.2	0.8	24.7	0.9	54.4
10	Pen 3 (aspen grove)	7388	310	607	889	1.9	6.4	4.8	10167	32.5	0.3	27.7	3.2	34.1
11	Pen 3 (mature timber)	5217	319	746	966	1.4	4.2	0.0	9874	49.1	0.3	30.5	10.3	41.4
12	Pen 3 (regrowth)	6615	285	552	763	0.8	5.0	3.7	9641	31.1	0.3	47.2	1.5	21.5
13	Pen 2 (mature timber)	13100	236	567	1136	1.9	6.8	2.7	9337	34.5	0.3	62.8	7.3	32.7
14	Pen 3 (regrowth)	8180	253	651	1092	1.8	3.4	3.4	9546	24.4	0.6	31.6	2.5	30.3
15	Pen 3 (regrowth)	6217	407	858	1021	0.7	3.8	1.4	10727	22.1	0.3	47.4	1.4	30.7
16	S. E. of Pen 4 (regrowth)	7465	287	617	876	1.6	4.4	2.3	9181	20.2	0.5	39.9	<0.05	29.5
17	S. shore Muskrat Lake (timber)	8081	198	315	892	1.4	5.1	3.8	11434	20.8	0.5	53.5	6.4	24.2

1 As, Cd, Hg and Se values were all <0.05 ppm and Al values were not valid due to technical difficulties.

Table 31. Water mineral element levels from the Kenai Moose Research Center, October, 1974. (ppm).

Sampling Site	Macroelements				Microelements[1]			
	Ca	K	Mg	Na	Co	Cu	Fe	Mn
Coyote Lake	<0.001	6.50	0.97	7.10	0.004	<0.001	<0.001	0.016
Pen 1 Lake	<0.001	6.80	0.77	6.60	0.002	0.010	<0.001	0.011
Pen 2 Lake	4.20	18.60	1.23	6.10	<0.001	<0.001	<0.001	0.013
Pen 3 Lake	<0.001	6.10	1.14	8.20	0.008	<0.001	<0.001	0.012
Pen 4 Lake	<0.001	17.00	0.89	5.40	<0.001	0.010	<0.001	0.014
Well (cabin)	17.10	9.00	9.01	2.12	0.005	0.010	0.030	0.037
Fresh Water Norms (Flynn, pers. comm.)	15.10	4.10	2.30	6.30	0.0009	0.010	0.670	0.012

1 Al values were all less than 0.01 ppm and As, Cd, Cr, Hg, Mo, Ni, Pb, Se, and Zn values were all less than 0.001 ppm. Fresh water norms for these elements are:

Al-0.24	Cr-0.00018	Ni-0.01	Zn-0.01
As-0.0004	Hg-0.00008	Pb-0.005	
Cd-0.08	Mo-0.00035	Se-0.02	

The variability in mineral element content of plant parts within the same plant as well as differences between plants should be noted (Table 29). Based upon mineral elements alone, the advantages of diversity of forage availability are evident.

Soil mineral element analyses (Table 30) indicate that on a ppm basis soil generally has higher levels than plants (Table 29) except for the elements Cu and K. This is only an observation since many factors influence these levels and their concentrations must be considered. The extremely high Fe concentration in the soil with much lower concentration in plants indicates limited and/or controlled assimilation by the plant.

Water mineral element analyses at the MRC (Table 31) indicate lower Ca levels and higher K levels than listed for fresh water norms. [Bathing in Coyote Lake has the added attraction of "soft-water".]

Excitability Evaluation

A paper was prepared by A. W. Franzmann, A. Flynn and P. D. Arneson entitled "Serum corticoid levels relative to handling stress in Alaskan moose," Can. J. Zool. 1975, which summarizes our efforts during this report period with moose excitability evaluation. The paper follows:

Abstract: A method to classify and compare Alaskan moose (*Alces alces gigas*) blood samples for evaluating blood chemistries by utilizing analyses of 11-hydroxycorticosteroids was tested at the Kenai Moose Research Center (MRC). Moose were evaluated for handling excitability prior to and during handling when trapped and were graded on a scale from 1 (not excited) to 5 (highly excited). There were significant differences ($a=0.1$) between each class comparison, except between classes 4 and 5, suggesting that this analysis provided a means to classify and compare other blood chemistry values from similarly stressed moose. Other factors may influence the 11-hydroxycorticosteroid levels, but handling stress had an overwhelming influence. Other methods to evaluate handling stress, such as body temperature, should also be considered, but when not feasible this method may be utilized.

INTRODUCTION

Evaluating blood chemistry parameters from animals, particularly wild trapped and immobilized animals, may be confounded by handling stress (Franzmann 1972, Franzmann and Thorne 1970, Gartner et al. 1969, Gartner et al. 1965, LeResche et al. 1974 and Seal et al. 1972). The need was recognized to standardize the potential effects of handling stress, and an evaluation of individual animal excitability based on heart rate, respiratory rate and rectal temperature was developed for bighorn sheep (*Ovis canadensis*) (Franzmann 1972). Each sheep was classified into one of five classes of excitability (1- not excited, 2- slightly excited, 3- moderately excited, 4- excited and 5- highly excited).

LeResche et al. (1974) suggested that some measured blood values may be more plastic than others under stress and provide a means to standardize blood samples. Studies at the Kenai Moose Research Center (MRC), Alaska have utilized a subjective classification of excitability based upon activity prior to and during handling of Alaskan moose. This paper reports the use of the Franzmann classification system and the subsequent analysis of blood serum for 11-hydroxycorticosteroids. These endocrines in serum are of clinical significance in the evaluation of adrenocortical function (Catt 1970), and we believed they had potential use as a measured blood value that could potentially reflect handling stress and provide a method to classify and compare samples from similarly stressed animals for other blood chemistry evaluation.

STUDY AREA AND METHODS

Moose were sampled at the MRC which consists of four 2.6 km^2 enclosures located in the area of the 1947 Kenai burn, 35 km northeast of Soldotna, Alaska. Twenty-two fence line traps are strategically located (13 within and 9 outside the enclosures) to facilitate the capture and handling of moose (LeResche and Lynch 1973). The traps, when set, were checked daily and when a moose was trapped and immobilized (Franzmann and Arneson 1974a), the excitability of the animal prior to and during immobilization and handling was subjectively evaluated and given a score from one to five (increasing with excitability). Heart rate, respiratory rate and body temperature were not determined or recorded prior to the evaluation to remove the effect of potential bias in the evaluation.

Blood was collected, centrifuged and the serum was frozen. In early 1974, samples were selected from each month sampled during 1973 to compare samples through all seasons. An attempt was made to obtain samples from each of the five excitability classes. No samples were available for May, but 11 were selected from the January sample and 10 were selected from each of the remaining months of the year for a total sample of 111. No selection was made based upon sex or age, however, a representative sample of the sex and age structure of the population was obtained.

The serum samples were sent to the Department of Surgery, Cleveland Metropolitan General Hospital, Case Western Reserve University School of Medicine, Cleveland, Ohio to be fluorometrically analyzed for plasma 11-hydroxycorticosteroids by the rapid procedure for clinical screening as outlined by Mejer and Blanchard (1973).

RESULTS

Table 32 lists sample size, mean and standard deviation for 11-hydroxycorticosteroids for each moose excitability class. Class 1 (not excited) had 7 samples with a mean of 26.6 µg/100 ml, class 2 (slightly excited) had 51 samples with a mean of 48.3 µg/100 ml, class 3 (moderately excited) had 28 samples with a mean of 61.9 µg/100 ml, class 4 (excited) had 10 samples with a mean of 104.2 µg/100 ml, and class 5 (highly excited) had 15 samples with a mean of 114.5 µg/100 ml.

Table 32. Average 11-hydroxycorticosteroid levels (μg/100 ml) in moose blood serum for 5 excitability classes.

	Excitability Class 1	2	3	4	5
Sample Size	7	51	28	10	15
Mean	26.6	48.3	61.9	104.2	114.5
Standard Deviation	9.06	13.71	11.90	14.26	20.72

An analysis of variance was computed with the hypothesis of no differences between excitability classes. This hypothesis was rejected (a=0.1). Scheffe's S-value test was computed to determine where the differences occurred, and we found all classes were significantly different from each other except classes 4 and 5.

DISCUSSION

With the array of excitability class means distributed in an increasing manner corresponding to the increase in excitability, and with significant differences between each excitability class, except between classes 4 and 5, we concluded that serum analysis of 11-hydroxycorticosteroids provided a means to identify samples of similarly stressed moose for other blood chemistry analyses. It also was evident that a subjective evaluation of excitability stress prior to and during handling of captured moose was a valid procedure since the distinct corticosteroid class averages indicated that experienced observers consistently evaluated the excitability stress of moose.

Since the two most highly rated excitability classes (4 and 5) were not significantly different, it may be feasible to utilize 4 rather than 5 excitability classes for moose. This would permit less dilution of sample size for standardization of sample. A suggested classification based on these data would be; class 1 - all values below 35 µg/100 ml, class 2 - all values from 35 to 55 µg/100 ml, class 3 - all values from 55 to 75 µg/100 ml, and class 4 - all values from 75 µg/100 ml and above.

We believed that seasonal, as well as age and sex, differences would influence findings; therefore, we made sure the data contained a generous number of samples comprising all seasons, sexes and ages. The results indicate that the influence of these other factors on corticosteroid levels was minor compared to handling stress. In this study, the overwhelming influence of handling stress was represented by 11-hydroxycorticosteroid levels.

We do not suggest that 11-hydroxycorticosteroid analysis be the sole criteria for evaluating handling stress, but that it be considered as an additional tool to supplement this evaluation. Body temperature has provided a means to do this (Franzmann 1972), but may not be feasible in all instances. Without body temperature a handling stress evaluation can be made by this proceedure. Other blood chemistries that potentially could reflect handling stress should be investigated.

<u>Browse Production and Utilization</u>

John L. Oldemeyer, U. S. Fish and Wildlife Service, has conducted the browse production and utilization studies at the MRC since May 1971. He prepared a paper entitled "Methods for estimating production and utilization of paper birch saplings" which is in review. The following is the abstract:

> Current production of paper birch saplings (*Betula papyrifera*) was estimated using a relationship between weight of current annual growth and stem circumference, crown length and number of current

annual growth twigs. The coefficients of determination (R^2) ranged from 0.46 to 0.94 for 49 sets of data and exceeded 0.75 for 40 of these. Utilization was estimated by three methods: (1) percent saplings browsed, (2) percent current annual growth twigs browsed and (3) percent production, by weight, browsed. Good correlations were obtained between percent saplings browsed and percent production browsed ($r = 0.74-0.99$) and between percent current annual growth twigs browsed and percent production browsed (0.93-0.99).

Another paper prepared by John L. Oldemeyer relative to browse production and utilization was titled "Characteristics of paper birch saplings browsed by moose and snowshoe hares". This paper was presented at the 11th North American Moose Workshop and Conference at Winnipeg, Manitoba in March, 1975. The following is an abstract of that paper:

Moose (*Alces alces gigas*) and snowshoe hare (*Lepus americanus*) browsing on paper birch (*Betula papyrifera*) was studied at the Kenai Moose Research Center, Alaska. During the winters of 1972-73 and 1973-74 moose browsed 40.9 and 43.0 percent, respectively, of 1,464 permanently tagged saplings while hares browsed 67.8 and 56.3 percent, respectively, of these saplings. Seventy percent of the saplings browsed by hares were shorter than 1.5 meters and produced 28 percent of the total current annual growth of birch. An average of 87 percent of the annual growth by weight was removed from those plants. Moose concentrated on the saplings between 1.0 and 3.0 meters tall and browsed an average of 60 percent of the current growth of those saplings. Since a large portion of current growth remained on the taller plants, it appears that competition was not detrimental to moose.

The hare population crashed, but it was probably due to intra-specific competition, not competition with moose.

In conjunction with Robert K. Seemel, U. S. Fish and Wildlife Service, John L. Oldemeyer wrote a paper entitled "Quantity and quality of lowbush cranberry on the Kenai Peninsula, Alaska" which is in review. The abstract of the paper follows:

The quantity and quality of lowbush cranberry (*Vaccinium vitis-idaea L.*) were studied on the Kenai National Moose Range, Alaska. We determined that its highest aerial cover and frequency occurred in mature hardwood stands and its lowest in mature spruce-hardwood stands. We estimated that biomass ranges from 1000-3000 kg per hectare in this area. Dry matter digestibility ranged from 41.2 percent in winter to 50.8 percent in summer, but the amount of protein (5.4 - 5.7 percent) did not change throughout the year. Determinations of percent of cell walls, ADF, lignin and of eleven minerals were made.

Browse Quality

John L. Oldemeyer, U. S. Fish and Wildlife Service, has conducted browse quality studies at the MRC in conjunction with our studies. He has regularly collected plant specimens and parts for quality analysis.

We obtained moose rumen liquor for the in vitro digestibility trials at the MRC. Initial digestibility information was reported (Oldemeyer 1974). Plants were analyzed for fiber, protein and minerals resulting in a publication entitled "Browse quality and the Kenai moose population" which was prepared by J. L. Oldemeyer, A. W. Franzmann, A. L. Brundage, P. D. Arneson and A. Flynn. The paper follows:

The quality of plants that wild ungulates eat has been given little scrutiny. Yet, on summer and winter ranges, quality is equally as important as quantity in maintaining healthy ungulate populations. Cowan et al. (1950) recognized the relationships between range quality, carrying capacity and the successional stage of the forest. They noted specifically that ether extracts, total carbohydrates, and proteins in the vegetation of a six- and a twenty-year-old forest were superior to a seventy-year-old forest; and that density of palatable browse was higher in the younger forests. Klein (1970) has discussed the relationship between quantity of high quality plants and growth rate and body size of deer, productivity and survival, and changes in age and sex ratio; and he concluded that high quality range was necessary for healthy deer populations.

Dietz (1970) defined a high quality plant as one that is palatable to the animal, has desirable levels of various nutrients in the proper ratios, has a high apparent digestibility, produces desirable proportions of volatile fatty acids, has adequate levels of minerals and vitamins and is efficiently converted into components required by the consuming animal. Some researchers have looked at one or several of these characteristics, but no one has looked into all of them with respect to wild ungulates, and optimum nutrient levels have not been established. This paper presents data we have collected to compare and define the quality of the important plant components of the moose diet in the summer and winter on Alaska's Kenai Peninsula. The characteristics that we have used to describe browse quality are: in vitro dry matter disappearance (IVDMD), fiber content, protein content and the content of 18 mineral elements.

The study took place on the Kenai National Moose Range at the Kenai Moose Research Center, a cooperative research project of the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service. The Center is located in the northwestern lowlands of the Kenai Peninsula which were part of a 125,455 hectare fire in 1947. This is rolling and glacially scoured topography covered by podsol soils and dotted with numerous lakes and bogs. Mature trees; white spruce (*Picea glauca)*, paper birch and aspen; are located as islands within the burn. Regrowth consists mostly of black spruce *(P. mariana)*, birch, willow and aspen, with birch producing over 80 percent of the annual production of those latter three species. The major shrubs of the unburned stands are aspen saplings and highbush cranberry (*Viburnum edule)*. Ground vegetation in both the burned and unburned stands is dominated by lowbush cranberry, bunchberry (*Cornus canadensis)*, rose (*Rosa acicularis)*, twinflower *(Linnea borealis)* and fireweed (*Epilobium angustifolium)*.

Woody browse is the mainstay of the moose's winter diet, but is poorest in quality of the year's food supply. LeResche and Davis (1973) have studied food selection by moose at the Kenai Moose Research Center and have shown that paper birch and lowbush cranberry are by far the most important species in volume eaten during the winter. Willow, aspen, and alder have very low density in this area in comparison to birch (1971 Ann. Prog. Re., D.W.R.C. Work Unit DC-101.1); thus, they are not as important here as in Interior Alaska (Coady 1973) or other parts of the range of moose (Peek 1974).

METHODS

We collected plants at two periods of their annual life cycle. In order to sample nutrients present during the growing season, we collected current annual growth stems and leaves during early August 1973 and early July 1974. All plants in these collections came from in or near the Moose Research Center, except for one sample of each species in Table 33 which came from the Kenai Mountains (elevation 610 m). In late January 1974, we collected current growth twigs to represent the dormant period. Because lowbush cranberry does not drop its leaves in winter and moose appear to browse it to near ground level, that sample consisted of all above ground portions of the plant. The winter collections came from in or near the Moose Research Center. Earlier studies (Oldemeyer 1974) showed that there was little variation in dry matter disappearance among individual plants of one species; therefore, all samples consisting of at least 100 grams were collected.

After collection, the plants were oven dried at 40°C for 48 hours and ground to pass a 30 mesh screen. Each sample was divided into three portions: one for in vitro digestion, one for fiber and protein analysis and one for mineral determination.

The in vitro digestion trial began within three weeks of the forage collection and followed the procedure described by Tilley and Terry (1963) as modified by Pearson (1970). Duplicate or triplicate tubes were run of each sample. Six blank tubes and six tubes with a standard calf ration were run as a standard. Rumen liquor was collected into a preheated vacuum bottle from live or freshly killed moose on a normal diet, and the trial was begun within three hours of the liquor collection. In vitro digestion trials at the Palmer Research Center used rumen inocula from a rumen fistulated Holstein dairy cow on a diet of mixed grass hay and blended dairy concentrates. The two-stage Tilley and Terry (1963) procedure was modified by the use of a carbonate-limited buffer and direct acidification in lieu of centrifugation prior to the second stage digestion with pepsin (Meyer, R.M., Personal Communication). The digestion trials using dairy cow inocula followed those using moose inocula by 8, 4 and 0 weeks, respectively.

Fiber was analyzed using the fiber analysis procedure outlined in the USCA Agriculture Handbook #379 (Goering and Van Soest 1970). Crude protein was determined from Kjeldahl nitrogen using the factor 6.25 (AOAC 1970).

Plant samples designated for mineral analysis were sent to the Trace Element Center, Cleveland Metropolitan General Hospital where they were dried at 55°C for 48 hours. One hundred mg of dried material was placed in a plastic vial for digestion at room temperature by 10 ml of

Table 33. Quality of moose forage collected during July 1974.

	IVDMD (%)*		Fiber (%)			Protein (%)	Macroelements (ppm)				Microelements (ppm)			
	Moose	Dairy Cow	Cell Walls	ADF	Lignin		Ca	K	Mg	Na	Cu	Fe	Mn	Zn
Grass														
Bluejoint	48.1	55.9	69.8	37.8	3.7	9.8	617	9799	1481	74	22.3	58	30.9	21.6
Carex sp.	41.4	53.8	78.4	33.4	5.9	9.9	2107	8330	2056	93	33.1	70	38.9	42.7
Forbs														
Menyanthes trifoliata	92.3	85.9	30.4	16.1	3.6	13.9	1080	10954	1007	718	19.1	113	36.6	42.0
Fireweed	62.2	64.7	23.8	19.3	5.4	11.9	4588	7863	2008	76	12.2	62	23.7	15.3
Lupine	56.9	84.4	23.1	18.8	3.7	24.3	11425	7413	1052	75	20.6	119	7.1	38.1
Potamogeton sp.	73.1	80.7	32.2	17.7	2.4	17.1	5690	10032	1072	3919	24.2	130	28.2	140.3
Shrubs														
Birch leaves	43.1	47.6	29.0	19.5	8.3	16.9	1543	7273	2128	23	20.9	105	181.8	77.3
Birch twigs	25.8	23.5	56.1	43.2	16.8	9.0	586	4905	1842	81	16.6	67	62.8	46.2
Combined birch	42.6	38.6	38.3	26.0	11.0	13.9	773	7479	1892	63	16.7	78	141.0	53.5
Bog birch	42.6	38.1	36.5	27.3	14.5	16.8	631	5503	646	74	15.2	86	109.1	63.6
Aspen leaves	56.8	57.6	36.3	29.9	17.6	13.8	2377	10478	1997	100	14.5	96	31.3	45.3
Aspen twigs	64.1	56.1	46.2	36.5	13.4	8.3	791	7492	1286	88	11.3	78	9.4	15.9
Combined	-	57.4	36.8	28.6	14.4	12.6	2126	7516	1818	106	11.9	81	15.1	33.3
Willow leaves	54.8	41.2	27.6	22.2	11.6	13.5	2613	8519	1891	93	15.8	115	66.2	115.0
Willow twigs	42.6	43.3	44.9	40.6	18.2	6.9	1198	3878	714	110	20.3	87	13.0	24.1
Combined willow	57.8	41.7	26.6	23.9	12.7	13.2	788	5055	893	105	22.7	92	21.9	38.3
Lowbush cranberry	44.3	38.5	50.5	44.6	23.8	7.6	699	3691	1426	72	13.8	44	111.8	8.6
Highbush cranberry	52.8	64.4	37.8	28.2	13.1	10.3	3284	10798	2112	106	21.0	50	24.4	23.5

In vitro dry matter disappearance

a 4:1 mixture of concentrated nitric and perchloric acids. After digestion the material was diluted with distilled, deionized water for analysis by atomic absorption spectroscopy.

RESULTS AND DISCUSSION

In the past, analysis of forage quality has almost solely concentrated on carbohydrates, fats, proteins and minerals. While these indicate the potential value of the plant, digestibility is an important additional step that gives a measure of the availability of those nutrients to the animal. Dry matter disappearance of browse we sampled is within the range found by others working with mule deer and elk forage (Dietz 1972, Ward 1971), and similar to what LeResche and Davis (1973) found with early growing season plants. During the summer, alder and lowbush cranberry were significantly more digestible than the other four plant species (Table 34). In the winter, aspen and lowbush cranberry were most easily digested, willow and birch were not different from each other, and alder had the lowest dry matter disappearance (Table 33). Dry matter disappearance in summer was greater than in winter for four of the five species tested at both seasons. Dietz (1972) also observed this and related it to lower acid-detergent fiber and lignin content in summer.

The correlations of IVDMD as determined with moose inocula and dairy cow inocula seemed to improve when we decreased the time interval between trials. Pearson (1967) found that digestibility of forage changed when inoculum collection was delayed. He concluded that inoculum-source animals should be grazing the kind of forage being tested, and trials should begin soon after forage collection.

In our August 1973 trial, the Holstein-source trial began eight weeks after the moose-source trial and almost 11 weeks after forage collection. We observed a low correlation ($r = 0.24$) between the two sources. We do not acknowledge the probability of a radical change in digestibility of forage while in storage, and since the Holstein food supply was constant, we cannot explain the poor correlation. The winter trial improved ($r = 0.84$) and the summer 1974 ($r = 0.83$) trial was designed specifically for comparing the digestibilities between the two inocula sources. As would be expected, moose inocula tended to digest woody material better, and dairy cow inocula tended to digest the grasses and forbs of the summer 1974 trial better.

The analysis of carbohydrates was done following Van Soest (1966) descriptions rather than the Weende system which describes carbohydrates as nitrogen-free extract and crude fiber. According to Van Soest (1966) the newer methods relate carbohydrates in categories of cell wall constituents, acid detergent fiber (ADF) and lignin; and these reflect the value of carbohydrates to the animal. The cell contents (100-cell walls) are the more readily utilized nutrients and include protein, soluble carbohydrates, soluble minerals and lipids. Van Soest (1971)

Table 34. Quality of moose browse collected in August 1973 and January 1974. Analysis of variance was performed within seasons, and means superscripted by the same number or letter were not significantly different (= 0.1).

Species, Season, and number of sites sampled	IVDMD (%)* Moose	IVDMD (%)* Dairy cow	Fiber (%) Cell walls	Fiber (%) ADF	Fiber (%) Lignin	Protein (%)	Macroelements (ppm) Ca	Macroelements (ppm) K	Macroelements (ppm) Mg	Macroelements (ppm) Na	Microelements (ppm) Cu	Microelements (ppm) Fe	Microelements (ppm) Mn	Microelements (ppm) Zn	Sum of ranks Summer	Sum of ranks Winter
Alder																
Summer 3	48.0[1]	34.6[2]	33.4[1,2]	26.9[2]	10.9[2]	15.8[1]	6063[1,2]	5913[1]	2022[1,2]	66.7[1]	17.5[1]	87.3[1]	ND**	23.3[1,2]	36.0	
Winter 6	29.6[c]	28.1	41.2[b]	33.5	14.7[b]	9.6[a]	19[b]	26[b]	5[b]	22.8[a]	0.3[a]	5.6[a]	0.9[c]	0.2[c,d]		41.5
Dwarf birch																
Summer 2	41.4[1]	34.2[2]	29.4[2]	23.3[2]	13.9[2]	14.9[1]	3920[2]	5550[1]	1730[2]	55.0[1]	11.3[1]	60.5[1,2]	4.9	45.0[1,2]	50.0	
Paper birch																
Summer 3	37.7[1]	30.8[2]	37.4[1]	30.5[1,2]	13.9[2]	13.7[1]	4608[2]	6520[1]	2038[1,2]	66.7[1]	7.5[1]	82.7[1,2]	12.3	69.2[1]	46.0	
Winter 6	33.8[b,c]	25.8	47.1[b]	38.7	18.4[a]	8.5[b]	11[c]	22[b]	5[b]	22.7[a]	0.3[a]	5.3[a]	1.4[b]	0.7[a]		45.5
Aspen																
Summer 3	40.8[1]	42.1[1]	38.2[1]	39.3[1]	21.8[1]	12.5[1]	8672[1]	7217[1]	2147[1]	65.0[1]	5.2[1]	51.0[2]	ND	50.0[1,2]	50.0	
Winter 6	44.8[a]	42.0	52.9[a]	39.8	14.2[b]	6.1[c]	17[b]	58[a]	6[a]	23.2[a]	0.3[a]	5.9[a]	0.7[c]	0.6[a,b,c]		31.5
Willow																
Summer 5	42.2[1]	40.3[1]	32.4[1,2]	33.8[1,2]	16.1[1,2]	14.0[1]	8759[1]	5906[1]	2100[1,2]	65.0[1]	14.9[1]	85.0[1,2]	ND	41.0[1,2]	37.5	
Winter 6	34.7[b]	32.2	51.1[a]	44.5	13.8[b]	6.4[c,d]	21[b]	37[b]	4[b]	22.7[a]	0.3[a]	5.1[a]	0.8[c]	0.6[a,b,c]		40.0
Lowbush Cranberry																
Summer 3	50.7[1]	39.1[1]	33.1[1,2]	29.3[2]	12.6[2]	5.7[2]	4920[2]	4383[1]	1328[3]	55.0[1]	5.8[1]	51.3[2]	17.6	8.3[2]	53.5	
Winter 6	41.8[a]	40.8	37.7[b]	31.9	13.2[b]	5.4[d]	27[a]	30[b]	5[b]	22.8[a]	0.2[a]	3.2[a]	1.9[a]	0.3[b,c,d]		36.5

* *In vitro* dry matter disappearance
** Not detected

regards the cell walls as the most important components of feeds of plant origin because they are related to net energy, to the efficiency ratio (net energy/total digestible nutrients), and to voluntary intake of feeds by the animal. Acid detergent fiber is the ligno-cellulose portion of the plant, and its determination allows one to calculate hemicellulose (cell walls - ADF) and cellulose (ADF - lignin). Hemicellulose tends to be of greater benefit to the animal than cellulose, and lignin is the undigestible portion of the plants.

Tables 33 and 34 show data for cell walls, ADF, and lignin. Aspen and willow had significantly higher cell walls in the winter than the other three species we examined, and the levels in all five species was greater during the winter than during the summer. The major reason for this was probably our combining leaves with twigs. Cell walls made up a greater part of the grasses than of the forbs, and woody plants contained intermediate amounts. The pattern has been demonstrated before (Van Soest 1971).

Lignin content during the summer was higher in aspen than the other species. It was higher in aspen and willow in the summer than winter. Interestingly, lignin content of aspen leaves exceeded that of twigs during the summer and may explain the higher summer than winter lignin content; however, willow did not follow that pattern. The lignin content of the shrubs' twigs and leaves was higher than any of the grasses, forbs or aquatics. During the winter, lignin content of birch was significantly greater than any of the other species we analyzed.

Most workers (Bissell and Strong 1955, Morrison 1954, Dietz 1970) consider protein the most important plant nutrient because it provides nitrogen required by rumen micro-organisms for growth, and is essential for body maintenance, growth, reproduction and lactation (Cowan et al. 1970, Dietz 1970). With the exception of lowbush cranberry, protein levels of the plants we examined were considerably higher in the summer than winter (Tables 33 and 34). During the summer, all values except for lowbush cranberry were greater than 12 percent while during the winter, no protein content was as high as 10 percent and lowbush cranberry was lowest at 5.4 percent. The seasonal changes in protein level of shrubs have been well documented (Tew 1970, Dina and Klikoff 1973, Bissell and Strong 1955) and are considered to reflect moisture and phenology differences, thus the changes between summer and winter are to be expected. The lack of change in protein in lowbush cranberry, and evergreen shrub, is of special interest and we have no explanation for it (Oldemeyer and Seemel 1975). Alder and paper birch had winter levels higher than the 7 percent Dietz et al. (1962) recommended as minimum for browse on good deer range. Milke (1969) reported winter protein levels in three of four species he analyzed to be lower than 7 percent, and they were not too different from the values we observed.

Others (Short 1966, Brown and Radcliffe 1971) have attempted to correlate dry matter digestibility with various other nutritive parameters (digestibility, organic matter, energy digestion) in an effort to more easily describe browse quality. We obtained low or insignificant correlation coefficients between IVDMD and cell walls ($r = 0.15$), acid-detergent fiber ($r = 0.04$) and lignin ($r = 0.44$) when using winter browse. However, the summer 1974 data contained a greater variety of plant types and we obtained better correlations between dry matter digestibility and cell walls (r = 0.36), acid-detergent fiber (r = 0.54), and lignin (r = 0.51). While these show a real and expected relationship between digestibility and the factions of fiber, the relationships are not strong enough to warrant estimation through regression.

Walters (1971), Ammann et al. (1973) and Van Soest (1971) have discussed the relation between rate of digestion and voluntary intake of forage. They found lower intake with lower quality forage. Since lower quality forage is in the rumen longer, it probably had more complete ligno-cellulose digestion but less available energy than forage with a high rate of passage through the animal. Thus, the animal will not obtain enough energy from the browse to maintain its energy requirements. Crampton (1957) thought that if a forage were consumed in amounts to meet energy needs, it would normally meet the animals' need with respect to protein, calcium and phosphorus. While we have not determined energy relationships of the winter moose browse we examined birch, the most common and most used species ranks fourth in digestibility and has the highest lignin content.

Kubota (1974) and Franzmann et al. (1975) discussed the importance of dietary minerals to the basic body processes and the difficulties of interpreting the results of forage mineral analyses. In our study, only eight elements consistently appeared in amounts over 1 ppm (Tables 33 and 34). Of the others Pb occurred in trace amounts in alder, Co occurred sporatically at trace levels in all species, Hg and Se consistently occurred in trace amounts in all species, and Cr, Cd, Ni, Mo, As, and Al did not occur in detectable concentrations.

The seasonal differences observed in Table 16 are striking. Ca differences were higher in summer by factors from 184 to 501, K by factors of 126 to 302, Mg by factors of 289 to 277, Na by factors of 2 to 3, Cu by factors of 16 to 70, Fe by factors of 9 to 17, and Zn by factors of 28 to 129. Winter mineral levels, in general, were low for optimum intake based on domestic cattle requirements (Church 1971), however, most elements attained acceptable levels during summer. Manganese levels in summer 1973 were not detected in alder, birch and willow. In the winter, Mn values were measureable but extremely low (1 ppm). Rojas et al. (1965) observed deficiency symptoms in calves from cows fed less than 17 ppm Mn. Our levels exceeded 17 ppm only in lowbush cranberry in summer 1973, however, the summer 1974 samples of twigs, leaves and combined in birch, willow and lowbush cranberry were much higher than the summer 1973 sample and in most cases greater than 17 ppm (Table 26). Kubota (1974) reported higher Mn levels in birch (788 ppm) willow (309 ppm) and aspen (61 ppm) collected from the Kenai Peninsula.

Consistent differences were observed between twigs and leaves in the summer 1974 samples. Birch leaves had higher mineral levels than twigs and the total sample was between the two, except for K and Na. Aspen leaves contained higher mineral levels than twigs for all elements, and willow followed that pattern except for Cu and Na.

Table 33 lists mineral values for other shrubs and some herbaceous plants browsed by moose in the summer. Kubota et al. (1970) reported some mineral values for fireweed, bluejoint (*Calamagrostis canadensis*) and lupine (*Lupinus* sp.) from the Kenai Peninsula. There were substantial differences between his sample and those reported in Table 33. Since we have observed great differences in the same species between years and many of the samples were collected from the same or nearby areas, the differences between Kubota et al. (1970) and our results may perhaps be explained as natural yearly variation.

Mineral levels were compared between plants sampled the same season. We observed significant differences between species in the summer for all minerals except Cu, K, and Na and in the winter for all minerals except Cu, Fe, and Na.

There is a great deal of variability in mineral element levels in moose browse. We observed differences between summer and winter, between years, between plant species and between plant parts. Mineral levels in plants are dynamic, and the importance of these differences are unknown. The low Mn levels for some plants in both summer and winter indicate that browse selectivity by moose may be very important.

CONCLUSIONS

The determination of the highest quality forage species is probably impossible. There are complex interactions between the plant's components and its dry matter digestibility, between minerals and their efficeint use by the animal, in the organic chemistry of the plant and in minimum requirements of the animal. However, in an attempt to rank the species in terms of quality, we used a sum of ranks test. Within each analysis (Table 25) we ranked the species from highest (rank 1) to lowest, and summed those ranks over all the analyses performed. We determined that alder and willow were the best summer browse plants and lowbush cranberry the poorest. During the winter, aspen and lowbush cranberry were best.

The effect of high and low quality ranges on deer productivity has been adequately demonstrated (Cheatum and Severinghaus 1950, Klein 1964, and Verme 1965). Klein (1970) demonstrated that deer on poor quality ranges are lighter. The average weight of 18 moose trapped outside the Kenai Moose Research Center during the fall, winter and spring 1973 was 385 kg compared to 409 kg of 19 moose from the Tanana Valley near Fairbanks where Coady (1973) felt the weights and growth of moose indicated favorable range conditions. Klein (1970) also reported that deer on poor quality ranges have lower fertility and poorer fawn survival. Franzmann and Arneson (1973:23) reported pregnancy rates of 62 percent within the Kenai Moose Research Center and 76 percent for cows outside the Moose Research Center during the period of January-April 1973. Lower rates were observed the next year (Franzmann and Arneson 1974b:31). In contrast, Houston (1968) and Rausch and Bratlie (1965) reported pregnancy rates nearer 90 percent. Most importantly, the Kenai moose population is decreasing. Based on mid-winter aerial surveys, the moose population on the northern two-thirds of the Kenai National Moose Range has decreased from an estimated 7,900 in 1971 to 3,500 in 1975 (Kenai National Moose Range files).

What nutrients are deficient? When death due to starvation is commonly observed, the logical conclusion is that the winter range is not sufficient in either quality or quantity to support the population. If the range supported a larger population five or ten years earlier, why won't it do the same now? Our data show a low winter protein level; but that level is common among all species and presumably was common five years ago. Our data also show low levels of Mn and several other trace elements, but again, we see no reason that those levels are greatly different from what they were several years ago. The only change that is apparent on the northwestern Kenai is the change in species composition. We essentially have a single species winter range that once was a multispecies range of birch, willow, aspen, and perhaps some alder. The results of our analyses demonstrate the importance of variation in the diet of moose. Alder and birch supply higher winter levels of protein, whereas willow and lowbush cranberry are better digested and contain higher levels of Ca. A sufficient quantity of five winter browse species can more adequately meet the nutritional needs of moose than one species.

Spencer and Hakala (1964) have estimated that the productive life of a burn as good moose range is 20 years. The 1947 burn on the Kenai National Moose Range should be well into its declining productivity as moose range; there is a preponderance of lower quality winter browse and the moose population is declining.

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APPENDIX I. Proposed sets of criteria required to fulfill the requirements of essentiality of mineral elements.

1. Criteria listed by Hopkins (1974) and Nielsen (1974).

   a. Chemically suitable for biological function.

   b. Ubiquitous in the geosphere.

   c. Generally present in all plants and animals.

   d. Relatively low toxicity.

   e. Mammalian homeostatic mechanisms are implied by serum levels.

   f. Low intake demonstrates impaired physiologic functions.

2. Criteria listed by Cotzias (1967).

   a. Present in all healthy tissues of all living things.

   b. Concentration from one animal to the next is fairly constant.

   c. Withdrawal from the body induces reproducibly the same structural and physiological abnormalities regardless of the species studied.

   d. Addition either prevents or reverses these abnormalities.

   e. Abnormalities induced by deficiency are always accompanied by pertinent, specific biochemical changes.

   f. Biochemical changes can be prevented or cured when the deficiency is prevented or cured.

3. Criteria listed by Schwarz (1974).

   a. Experiment should produce highly significant responses.

   b. It should be reproducible at will, and in a series of tests over a lengthly period of time.

   c. A dose-response curve should be established and the minimum effective dose level of the element should be determined.

   d. Several compounds of the same element should be tested and compared in potency.

   e. The effect should be physiological, i.e., it must be obtained using amounts which are normally present in food and tissues.

APPENDIX II. An outline of some recognized mineral deficiency symptoms and signs.

1. Macro-elements

<u>Calcium</u> (Church 1971)

a. Skeletal disorders (osteomalacia, osteodystrophy, and ricketts).

b. Anorexia and weight loss.

c. Lowered milk production.

d. Tetany and muscular dysfunction.

<u>Chlorine</u> (Hays and Swenson 1970)

a. Principal anion in body fluids.

b. Alkalosis.

<u>Potassium</u> (Church 1971)

a. Anorexia and weight loss.

b. Listlessness and weakness.

c. Pica (depraved appetite).

d. Impaired response to disturbance.

e. General stiffness.

f. Kidney degeneration.

g. Histologic change in muscles.

<u>Magnesium</u> (Church 1971)

a. Opisthotonus - retracted head - muscle tremors - convulsions.

b. Ataxia.

c. Hypersensitivity.

d. Increased heat production and fall in energy retention due to tonic muscular activity.

e. Reduced appetite.

f. Rumen flora changes and reduced digestibility.

g. Anemia and jaundice.

h. Impaired blood clotting.

i. Liver damage and reduced serum albumin and alpha and gamma globulins.

j. Serum enzyme changes.

Sodium (Church 1971)

a. Pica.

b. Decreased body weight.

c. Anorexia.

d. Listlessness.

e. Harsh skin.

f. Tetany - collapse and death.

Phosphorus (Church 1971)

a. Anorexia and weight loss.

b. Pica.

c. Listlessness and dullness.

d. Osteomalacia and ricketts.

e. Impaired fertility in females.

Sulphur (Church 1971)

a. Anorexia and weight loss.

b. Emaciation.

c. Pica.

d. Hair and wool growth impaired.

e. Excessive lacrimation and profuse salivation.

f. Dullness and weakness.

g. Heart, liver, skeletal muscle and splenic histologic changes.

h. Reduced digestibility.

2. Micro or trace-elements.

Iodine (Underwood 1971)

a. Thyroid deficiency (enlarged thyroid - goiter).

b. Lowered metabolic rate.

c. Birth of hairless, weak or dead young - cretinism.

d. Reduced reproductivity (suppressed estrus in females and reduced libido in males).

e. Relatively non-toxic.

Iron (Underwood 1971)

a. Anemia.

b. Anorexia and weight loss.

c. Listlessness.

d. Gastritis.

e. Relatively non-toxic.

Copper (Underwood 1971)

a. Anemia (iron transfer related).

b. Severe diarrhea.

c. Depigmentation of hair and defective keratinization of wool and hooves.

d. Ataxia and paralysis.

e. Fibrosis of cardiac muscles and heart failure.

f. Bone deformities (osteoporosis).

g. Reduced fertility and impaired reproductive performance.

h. Toxic symptoms recognized.

Zinc (Underwood 1971)

a. Skin irritability, inflammation and parakeratosis.

b. Difficult conception.

c. Abnormal estrus and cystic degeneration of ovary.

d. Retained placenta.

e. Excessive salivation.

f. Impaired digestibility by reduction of volatile fatty acids.

g. Cessation of spermatogenesis.

h. Growth retardation.

i. Anorexia.

j. Impaired wound healing.

k. Relatively non-toxic.

Manganese (Underwood 1971)

a. Impaired estrus and conception.

b. Enlarged joints and stiffness - skeletal abnormalities.

c. Weakness and impaired growth.

d. Pica.

e. Liver degenerative changes.

f. Ataxia of new-born.

g. Relatively non-toxic.

Chromium (Underwood 1971)

a. Impaired growth and longevity.

b. Disturbances in glucose, lipid and protein metabolism.

c. Eye disorder - corneal opacity.

d. Toxic symptoms recognized.

Cobalt (Underwood 1971)

a. Listlessness and emaciation.

b. Anemia.

c. Anorexia.

d. Depressed synthesis of B_{12} in rumen.

e. Relatively non-toxic.

Molybdenum (Underwood 1971)

a. Closely related to Cu and S. High levels depress Cu and S.

b. Renal calculi.

c. Relatively non-toxic, but high levels depress other elements.

Selenium (Underwood 1971)

a. Nutritional muscular dystrophy.

b. Impaired fertility.

c. Persistent diarrhea.

d. Depressed growth rate.

e. Associated with diseases responding to Vitamin E therapy.

f. Toxic symptons recognized.

Vanadium (Hopkins 1974)

a. Reduced body and feather growth.

b. Impaired reproduction and survival of young.

c. Altered RBC levels and iron metabolism.

d. Impaired hard tissue metabolism.

e. Altered blood lipid levels.

f. Toxic symptoms recognized.

Fluorine (Messer et al. 1974)

a. Retarded growth rate.

b. Infertility.

c. Anemia.

d. Toxic symptoms demonstrated.

Silicon (Schwarz 1974)

a. Postulated as structural element in metabolism.

b. Growth stimulating effect in rats.

c. Relatively non-toxic.

Nickel (Nielsen 1974)

a. Suboptimal reproductive performance.

b. Reduced oxidative ability in liver.

c. Toxic symptom recognized.

Tin (Schwarz 1974)

a. No definite signs recognized, but it has been demonstrated to have a growth stimulant effect.

b. Relatively non-toxic.

JOB PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: Paul D. Arneson, Paul A. LeRoux, Spencer Linderman and Albert W. Franzmann

Project No.: W-17-7 Project Title: Big Game Investigations

Job No.: 1. 7R Job Title: Kenai Peninsula Moose Population Identity Study

Period Covered: July 1, 1974 through June 30, 1975

SUMMARY

Ninety-one moose were tagged with individually identifiable collars during the reporting period: 37 outside the enclosures at the Kenai Moose Research Center, 59 in the Bald Mountain, Eagle Lake and Ninilchik Dome area, 22 on Fox River Flats and Clearwater Slough and 10 in the Deep Creek and Ninilchik River Valleys.

A total of 2,242 resightings and/or recoveries of tagged moose have been recorded since the inception of this project. In Game Management Subunit (GMSU) 15C, 474 collared moose observations have been made.

To date, 86.4 percent of the GMSU 15C moose collared in October 1973 and 84.5 percent of those tagged in November 1974 have been relocated at least once. The public has seen 24.2 percent and 24.1 percent of the two respective groups. Alaska Department of Fish and Game reconnaissance flights have accounted for an additional 25.8 and 19.0 percent of the two groups, respectively.

Moose collared on Bald Mountain moved southward and southwestward to winter. Ninilchik Dome collared moose wintered south of the tagging area and west along the lower Anchor River Valley. Half of the winter observations of moose tagged near Eagle Lake were in the Fritz Creek Valley and half on Fox River Flats.

The Beaver Creek - Fritz Creek Flats appears to be an important wintering area for moose from the southern portion of GMSU 15C.

BACKGROUND

The basis for this study was outlined by Franzmann and Arneson (1974). During this report period the study was continued in that portion of GMSU 15C southwest of the Kenai National Moose Range. Only data collected in the past fiscal year are included in this report.

OBJECTIVE

To identify populations and key habitat areas and to learn seasonal movement patterns of moose (*Alces alces*) on the Kenai Peninsula.

PROCEDURES

Equipment and techniques used in tagging operations are the same as previously described (Franzmann and Arneson 1974, Franzmann and Arneson 1973). A total of 91 moose were tagged in various parts of GMSU 15C during this report period (Table 1). Types of markings used are shown in Table 2. Figure 1 shows the tagging areas and numbers of moose tagged in each area since 1968. Weekly reconnaissance flights in search of collared moose conducted by the Alaska Department of Fish and Game (ADFG) are listed in Table 3.

FINDINGS

Since October 1968, when moose were first collared on the Kenai Peninsula, 2,242 resightings and/or recoveries have been recorded (Table 4). Resightings from GMSU 15C (tagging began there in October 1973) total 474. Due to a vigorous program to get the public involved with collared moose observations, many more observations were recorded than could have been obtained by weekly reconnaissance flights alone. Sole credit for this project goes to the late Spencer Linderman, ADF&G biologist in Homer, who conducted radio and TV shows, wrote newspaper articles, talked with various schools and other groups, placed posters in strategic locations and did whatever else he could to make the public aware of the Kenai Peninsula tagging project and to get the public interested in ADFG projects in general. The Department will sorely miss the enthusiastic Spencer who was killed in an airplane crash on July 10, 1975 while flying a goat survey.

In GMSU 15C during FY 1975, the public saw almost 35 percent (Table 5) of 66 blue-collared moose that were marked in October 1973. Over 24 percent of these animals were observed only by the public. Of 74 observations of these moose during FY 1975 (Table 4), 39 (53 percent) were public sightings. To date, 57 (86.4 percent) of the 66 blue-collared moose have been relocated at least once.

Of the white-collared moose tagged in November 1974, public sightings have accounted for 38 individuals with 14 (24.1 percent) seen only by the public (Table 5). In the seven months since tagging, 274 resightings of these moose have been recorded (Table 4). The public reported 223 (81.4 percent) of these moose observations. Almost 85 percent (49 of 58) of these moose have been resighted at least once.

Table 1. Moose Tagged in Game Management Units 15 and 7, Kenai Peninsula, October 1968 - April 1973.

Tagging Location	Number Tagged			
	Males	Females	Calves	Total
Mystery-Dike Creek (highlands) October 1968	11	17	0	28
Bottenintnin Lake (lowlands) March 1970	14	53	0	67
Moose River Flats (lowlands) June 1970	26	42	0	68
Moose Research Center (lowlands) continuous	25	154	39	218
Moose River Flats May 1971	10	50	0	60
Skilak-Tustumena Bench April 1971	2	2	0	4
Big Indian Creek October 1972	2	10	0	12
Tustumena Benchland October 1972	19	8	0	27
Lower Funny River Airstrip October 1972	12	21	0	33
Caribou Hills October 1973	32	34	0	66
Bald Mtn., Eagle Lake, Ninilchik Dome November 1974	8	51	0	59
Fox River Flats & Clearwater Slough April 1975	0	22	0	22
Deep Creek & Ninilchik River April 1975	1	9	0	10
Totals	162	473	39	674

Table 2. Collar, Ear Tag and Pendant Combinations Used to Identify Moose in Game Management Units 15 and 7, Kenai Peninsula.

	Identification Code				
	Male		Female		
Area	Collar	Ear	Collar	Ear	Pendant
Mystery Creek	Yellow	Left orange	Red	Right orange	None
Bottenintnin Lake	Blue	Left orange	White	Right orange	None
Moose River Flats (1970)	Blue	Left green	White	Right green	Red A1-A100
MRC (prior to March 1972)	Blue	Left silver	White	Right silver	White 51-100
Moose R. Flats (1971)	Yellow/orange*	Left yellow	Pink/red*	Right yellow	Red C1-C100
Skilak-Tustumena Benchland (1971)	Yellow/orange*	Left yellow	Radio	Right yellow	Red: "C" series
MRC (Post March 1972)	YBWRP**	Left silver	YBWRP**	Right silver	None
Big Indian Creek (1972)	YBWRP**	White "Roto"	YBWRP**	White "Roto"	None
Tustumena Benchland (1972)	YBWRP**	White "Roto"	YBWRP**	White "Roto"	None
MRC (Post July 1973)	White with blue no.	Left silver	White with blue no.	Right silver	None
Caribou Hills (1973)	Blue with yel. no.	Yellow "Roto" w/gr. flag	Blue with yel. no.	Yellow "Roto" w/gr. flag	None
Southwest of Caribou Hills (1973)	Blue with yel. no.	Yellow "Roto" and/or org. flag	Blue with yel. no.	Yellow "Roto" and/or org. flag	None
Bald Mtn., Eagle Lk. Ninilchik Dome (1974)	White with org. no .	Blue,white or org. flag-left***	White with org. no.	Blue, white or org. flag-right***	None
Fox River Flats, Clearwater Slough (1975)	None	Tagged	Blue with	Right-pink	None
Deep Creek, Ninilchik River (1975)	White with org. no.	Yellow flag	Blue with yel. no. or white with org. no.	Right-yellow (2-right-pink)	None

* Colored stripes on both sides or top of collar make the moose identifiable as individuals.

** Collars comprised of 4 quarters (left front; right front; left rear; right rear) consisting of some combination of from 2 to 4 of the following colors make these moose individually identifiable: yellow, blue, white, red, pink.

*** Blue used in Bald Mtn. area, white in hills SW of Ninilchik Dome and orange in Eagle Lake.

Fig. 1. Tagging locations and numbers of moose collared in Game Management Subunit 15C, November 1974 and April 1975.

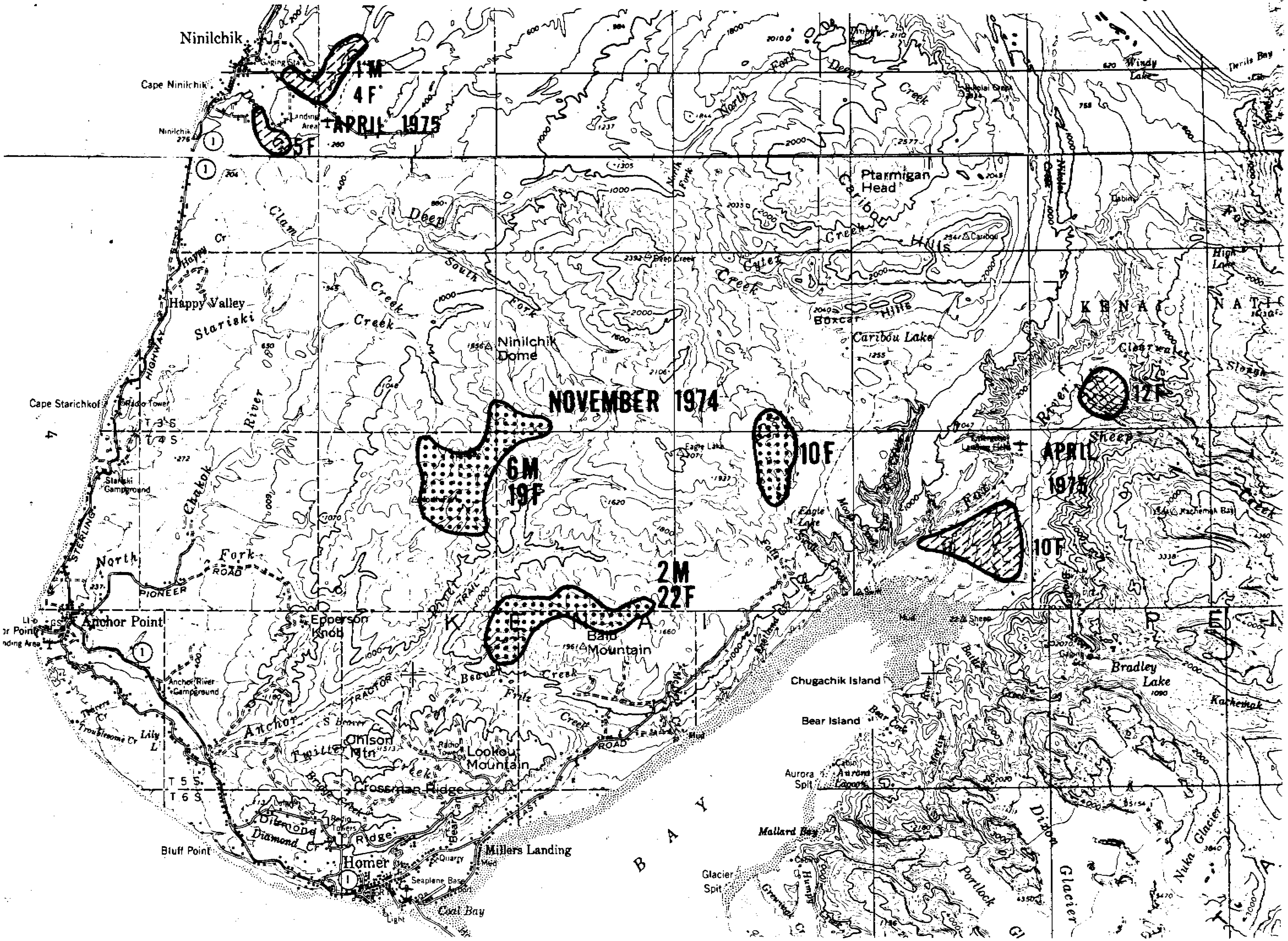

Table 3. Reconnaissance Flights by Alaska Dept. of Fish and Game for Collared Moose, FY 1975

Date	Area	Collared Moose Located *
July 18, 74	15B Benchland & Skilak Lake	1 LFRS
July 26, 74	15C Caribou Hills	0
July 27, 74	15A Lowlands, 1947 & 1969 Burns	1 MRC, 1 Unk
July 28, 74	15A Kenai Mts. N. of Sterling Hwy.	1 MRC, 1 BI, 1 MRF, 3 Unk
Aug. 20, 74	15B Benchland	1 LFRS, 1 BEN, 4 Unk
Sept. 10, 74	15A Lowlands and foothills	0
Sept. 30, 74	15A Lowlands and foothills	1 MRC, 1 MRF, 1 Unk
Sept. 30, 74	15C Caribou Hills	6 CH
Oct. 5, 74	15A Kenai Mts.	0
Oct. 9, 74	15B Benchland	4 BEN
Oct. 16, 74	15C Caribou Hills and SW Hills	3 CH
Oct. 29, 74	15A Lowlands	0
Nov. 4, 74	15B Benchland and LFRS	6 BEN, 2 LFRS
Nov. 5, 74	15C Recon. for tagging	1 CH
Nov. 23-5, 74	15C Sex and Age Comp. Counts	17 BM, 9 CH
Dec. 23, 74	15A Lowlands, 1947 Burn	8 MRC, 1 Unk
Jan. 16, 75	15C Anchor River	5 BM
Jan. 21, 75	15C Fox River Flats, Caribou Hills	5 BM, 2 CH
Jan. 24, 75	15A Kenai Mts. N. of Sterling Hwy.	1 BI, 1 MRC, 1 MRF, 2 Unk
Feb. 5, 75	15B Benchland, Skilak	2 LFRS
Feb. 24, 75	15C Ninilchik to Cohoe	0
Feb. 28, 75	15A Kenai Mts. and Lowlands	10 MRC, 2 MRF, 2 Unk
Feb. 28, 75	15C Anchor River	9 BM, 1 CH
Mar. 6, 75	15C Bald Mt. to Ninilchik to Anchor Pt.	0
Mar. 8, 75	15C Fox River Flats and Caribou Hills	2 BM
Mar. 25, 75	15A Lowlands and Skilak Loop	10 MRC, 1 BI, 1 MRF, 1 BEN, 2 Unk
April 9, 75	15C Bald Mt. and Fox River Flats	6 BM, 2 CH
May 3, 75	15A Lowlands, Calving Flats	13 MRC, 2 MRF, 5 Unk
May 5, 75	15B Survival Counts	1 Unk
May 5-6, 75	15C Survival Counts	7 FRF, 3 CH, 1 NIN
May 7, 75	15B Benchland, Funny & Killey Rivers	0
June 3, 75	15C Fox River Flats to Ninilchik	2 BM, 1 CH
June 26, 75	15C Bald Mtn, Anchor River, Ninilchik	1 BM, 1 FRF
June 30, 75	15C Fox River Flats, Caribou & Eagle Lks.	2 BM, 1 FRF

* Code:

MC	Tagged at Mystery Creek 1968
BL	Tagged at Bottenintnin Lake 1970
MRF	Tagged at Moose River Flats 1970, 1971
MRC	Tagged at Moose Research Center 1968 to date
BEN	Tagged at Tustumena-Skilak Benchland 1971, 1972
LFRS	Tagged at Lower Funny River Strip 1972
BI	Tagged at Big Indian and American Pass 1972
CH	Tagged at Caribou Hills 1973
Unk	Tagging site unknown (misidentified or not all markings present)
BM	Tagged at Bald Mtn., Eagle Lake or Ninilchik Dome 1974
FRF	Tagged at Fox River Flats, Clearwater Slough 1975
NIN	Tagged at Ninilchik River and Deep Creek 1975

Table 4. Recoveries and Resightings of Collared Moose
Kenai Peninsula Through June 1975

Tagging Site	Recoveries & Sightings April 1974-June 1975	Total No. of Recoveries and Sightings
Mystery Creek	5	152
Bottenintnin Lake	1	143
Moose Research Center	189	406
Moose River Flats	20	394
Tustumena Benchland 1971	0	10
Big Indian-Am. Pass	11	46
Lower Funny River Strip	13	114
Tustumena Benchland 1972	15	106
Caribou Hills	74	187
Bald Mt., Eagle Lake, etc.	274	274
Ninilchik River, Deep Creek	2	2
Fox River Flats, Clearwater Slough	11	11
Unknown or improperly identified	117	397
Total	732	2242

Table 5. Resightings of Moose Collared in Game Management Subunit 15C for Fiscal Year 1975.

	Blue Collars - October 1973		White Collars - November 1974	
	No. Individuals Observed	% of Total	No. Individuals Observed	% of Total
Seen by public	16	24.2	14	24.1
Seen by ADFG	17	25.8	11	19.0
Seen by both public/ADFG	7	10.6	24	41.4
Not seen this FY	17	25.8	9	15.5
Never relocated	9	13.6	N/A	N/A
Total collared	66	100.0	58	100.0

Most of the Bald Mountain collared moose moved in a southerly direction for winter (Fig. 2). Eleven individuals were observed on the south side of Bald Mountain or in the Fritz Creek area. Six others were resighted in Homer or its vicinity. Two females moved southwestward into the Anchor River Valley for winter. Apparently none moved east to Fox River Flats, west to Anchor Point or north to Ninilchik or the Caribou Hills.

Several of the moose collared southwest of Ninilchik Dome moved westerly or southwesterly to the Anchor River and Stariski Creek Valleys (Fig. 3). This movement involved three males and six females. Nine individuals also moved south; four wintered in Homer, four in the Beaver Creek-Fritz Creek flats area and one just south of the tagging area along the Anchor River. One individual also moved north, wintering in the Ninilchik River Valley. None was observed in the Fox River Flats area.

Only four relocations of moose collared in the Eagle Lake area were recorded during the winter: two of these moose moved eastward to the Fox River Flats area and two moved southwest to Fritz Creek (Fig. 4).

It appears that the Beaver Creek-Fritz Creek flats and lower Anchor River are important wintering areas for moose in lower GMSU 15C. This should be considered in formulating land-use plans for these areas.

RECOMMENDATIONS

Reconnaissance flights should continue in Subunits 15C and 15B to derive maximum information from collared moose.

Accrued results of the tagging program should be considered in formulation of management decisions.

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Figure 2. Winter resightings of moose collared on Bald Mountain, November 1974.

X - Female
0 - Male

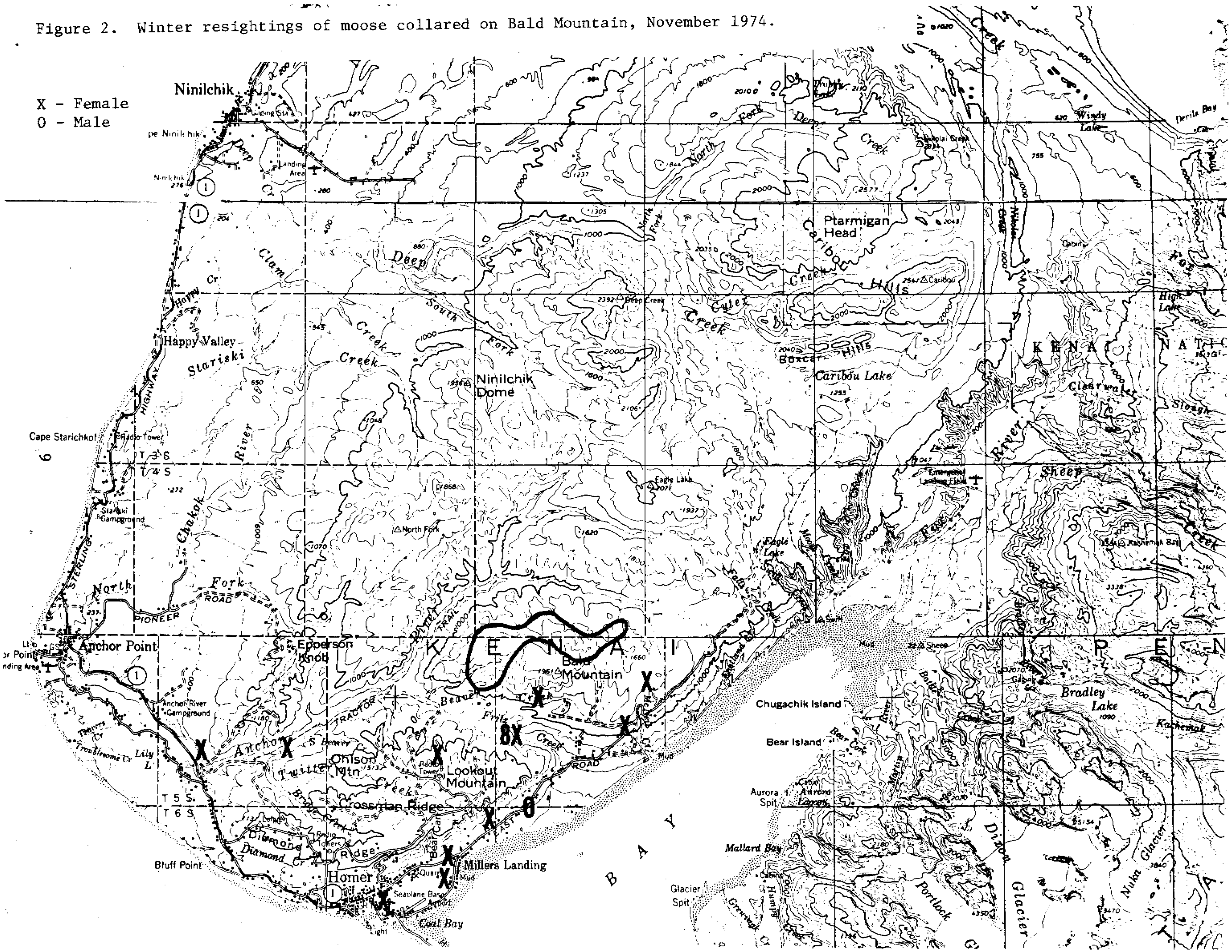

Figure 3. Winter resightings of moose collared near Ninilchik Dome, November 1974.

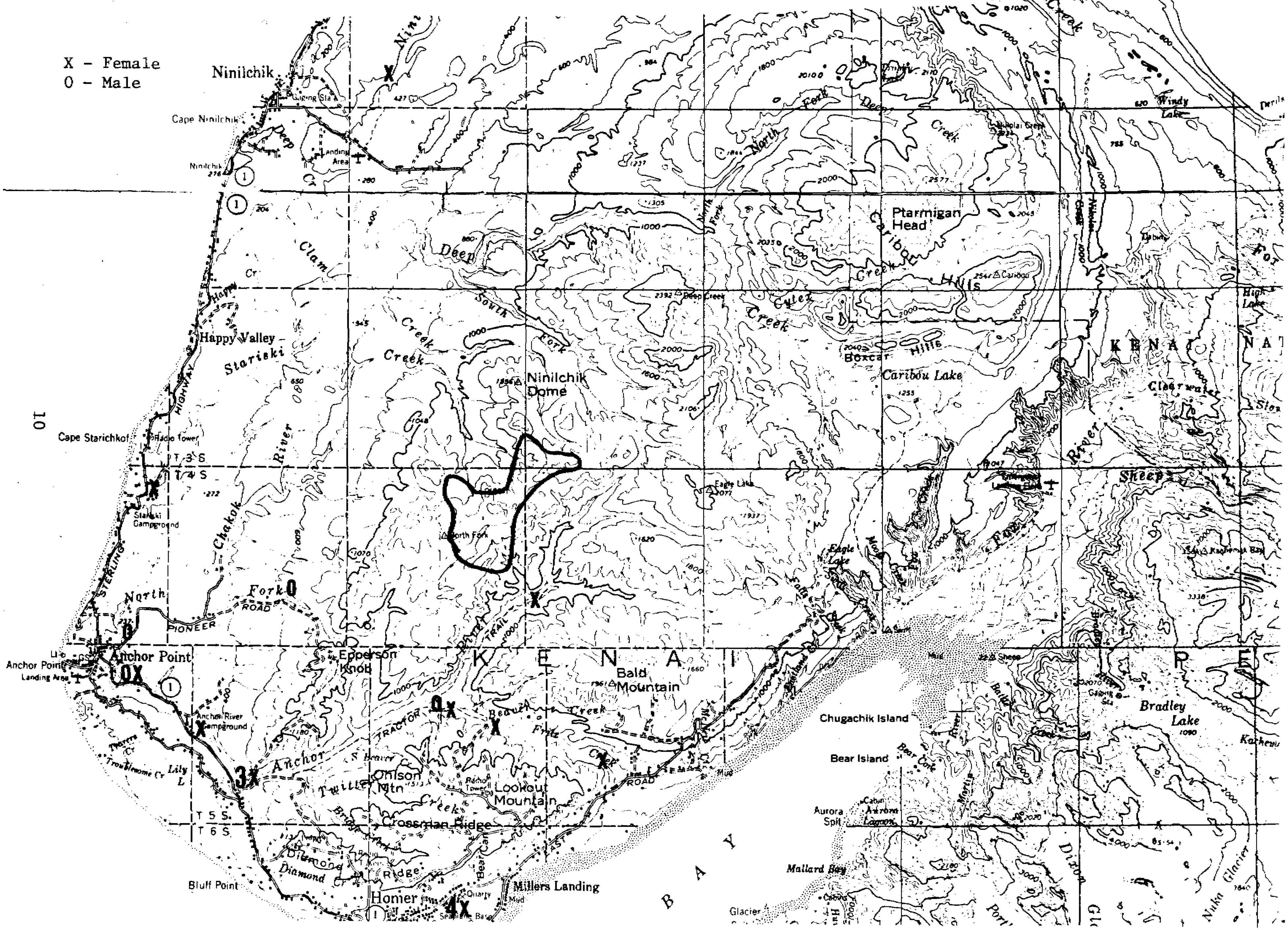

Figure 4. Winter resightings of moose collared near Eagle Lake November 1974.

X - Female
0 - Male

JOB PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperator: Julius Reynolds

Project Nos.: W-17-6 and W-17-7 Project Title: Big Game Investigations

Job No.: 1.12R Job Title: Copper River Delta Moose Population Identity Study

Period Covered: March 8, 1974 to June 30, 1975

SUMMARY

Fifty moose (38 females and 12 males) were captured on the Copper River Delta by use of succinylcholine chloride (Anectine) in syringes projected from helicopters. Twenty-five moose in each of the two major wintering areas which are separated by the Copper River were neck-collared and ear-tagged. Color-coded and numbered neck collars were used because each wintering area was suspected to support a distinct moose population.

Thirty-one surveys were flown from March 1974 to June 30, 1975. During this 16-month period, 299 sightings were recorded.

Intermingling of the two collared groups was relatively rare and no moose wintered (1974-75) on the opposite side from which they were collared.

Mortality to collared moose was estimated at 18 percent.

BACKGROUND

Moose (*Alces alces*) are not native to the Copper River Delta. They are the result of introductions made by the Izaak Walton League of America (Cordova Chapter) in cooperation with the Alaska Game Commission. During the 1950's (1949-1959) 6 male and 14 female calves were released along the Copper River Highway, west of the Copper River (Sheets 1960, Robards 1954). The transplant was an immediate success with a rapid increase in numbers of animals and area utilized (Robards 1954). By 1960 the herd was of sufficient size to allow a limited harvest of 25 bulls. Annual harvests have been held on the Copper River Delta each year with the exception of 1961. Regulations separating the east and west sides of the delta were enacted in 1968 to distribute the harvest and hunting pressure. Utilization of the female segment of the population commenced in 1968 west of the Copper River and in 1969 east of the Copper River. Present regulations provide for a post-season population of 175-200 west and 150-175 east of the Copper River. These regulations are established in the spring after winter survival and calf production have been assessed.

The Copper River Delta moose herd lends itself to intensive management primarily due to its restricted range, vulnerability to hunting and the cooperative attitude of the public. Knowledge of population identities and seasonal movements is needed to properly manage this resource and to protect its critical habitat.

The Copper River Delta lies at the east side of Prince William Sound and is bounded by the Chugach Mountains on the north and the Gulf of Alaska on the south. This entire area is a flat, glacial plain of deposited silt, gradually sloping up from sea level. The Delta is a mosaic of freshwater ponds, lakes and marshes disected by silty glacial streams and intertidal sloughs. Its seaward portion is covered by sedges and small forb-shrub communities. An alder-willow association occupies the slightly higher elevations further inland with scattered stands of cottonwood and spruce. The steep mountainous fringe is heavily timbered with spruce and hemlock. Moose almost exclusively use the willow-alder zone.

The climate on the Copper River Delta is typical of coastal Alaska; heavy precipitation and cool temperatures. The average annual precipitation is 92.5 inches and the temperature averages 38.2° F with a range during 1974 of -13° to 79° (Nt. Oceanic and Atmospheric Admin. 1974). Snow depth varies with the winter, from almost nonexistant to a maximum of 261 inches, recorded during the winter of 1971-72.

Roughly 80 percent of the Delta (330,000 acres) is managed under a cooperative agreement, entitled "Copper Delta Management Area", by the United States Forest Service, Alaska Department of Fish and Game and Alaska Department of Natural Resources. The purpose of the agreement is to preserve the habitat in its present quality and condition for wildlife (U.S. Forest Service 1967).

OBJECTIVE

To identify populations and key habitat areas and to learn seasonal movement patterns of moose on the Copper River Delta.

PROCEDURES

Fifty moose (38 females and 12 males) were captured on the Copper River Delta on March 5, 8 and 9, 1974 utilizing 22-24 mg. of Anectine (Succinycholine chloride) in projected syringes shot from helicopters. Wydase (hyaluronidase) was added to speed reaction time of the immobilizing agent. One mortality occurred during tagging when the drug was accidentally injected intravenously.

Twenty-five moose were tagged in each of the two major wintering areas (Fig. 1). Separate color-coded and numbered neck collars (Franzmann and Arneson 1974) were used because each wintering area was suspected to support a distinct moose population. East of the Copper River, white canvas collars with red numbers were used to mark 17 females and eight males whereas yellow canvas collars with blue numbers were placed on 21 females and four males west of the Copper River. No calves were collared and yearlings were avoided. Numbered metal ear-tags were placed in each ear and a 3-inch x 9-inch strip of flourescent flagging, red denoting males and yellow denoting females, was attached to one ear with an ear tag.

Monthly surveys were flown on each side of the Copper River to monitor movements of collared animals. Time and weather permitting, the same areas were flown each month with the same Department biologist, aircraft (PA 18 Supercub) and pilot. Normally the west bank of the Copper River and Castle Island Slough was the boundary between the two survey areas but some overlap did occur.

FINDINGS

During the 16-month period from March 1974 through June 1975, 31 collared moose surveys were flown by the reporting biologist (Tables 1 and 2). A total of 299 collared moose sightings were recorded: 149 east and 150 west of the Copper River. Mean percentages of collared moose observed during surveys east and west of the Copper River were surprisingly similar (44.2 percent west versus 44.5 percent east). In the winter months of December through March, 70-90 percent of the collared moose were observed during each survey. Analysis of the December-March survey data indicates collared moose comprised a substantial portion of the moose population: east 9.3 to 12.4 percent and west 11.4-13.5 percent.

Intermingling of the two collared groups occurred only rarely throughout the 16-month period. Collared moose number 23, a male, moved approximately 15 miles immediately after being collared but this movement may have resulted from handling stress. Two bulls made noteworthy movements during the spring months: (1) in May 1974, number 20 had moved from the east side to west side but was later killed east of the Copper River during the hunting season and (2) in May 1975, number 46 moved from west to east of the Copper River. Probably the most significant movements were made by females collared west of the Copper River: collared moose

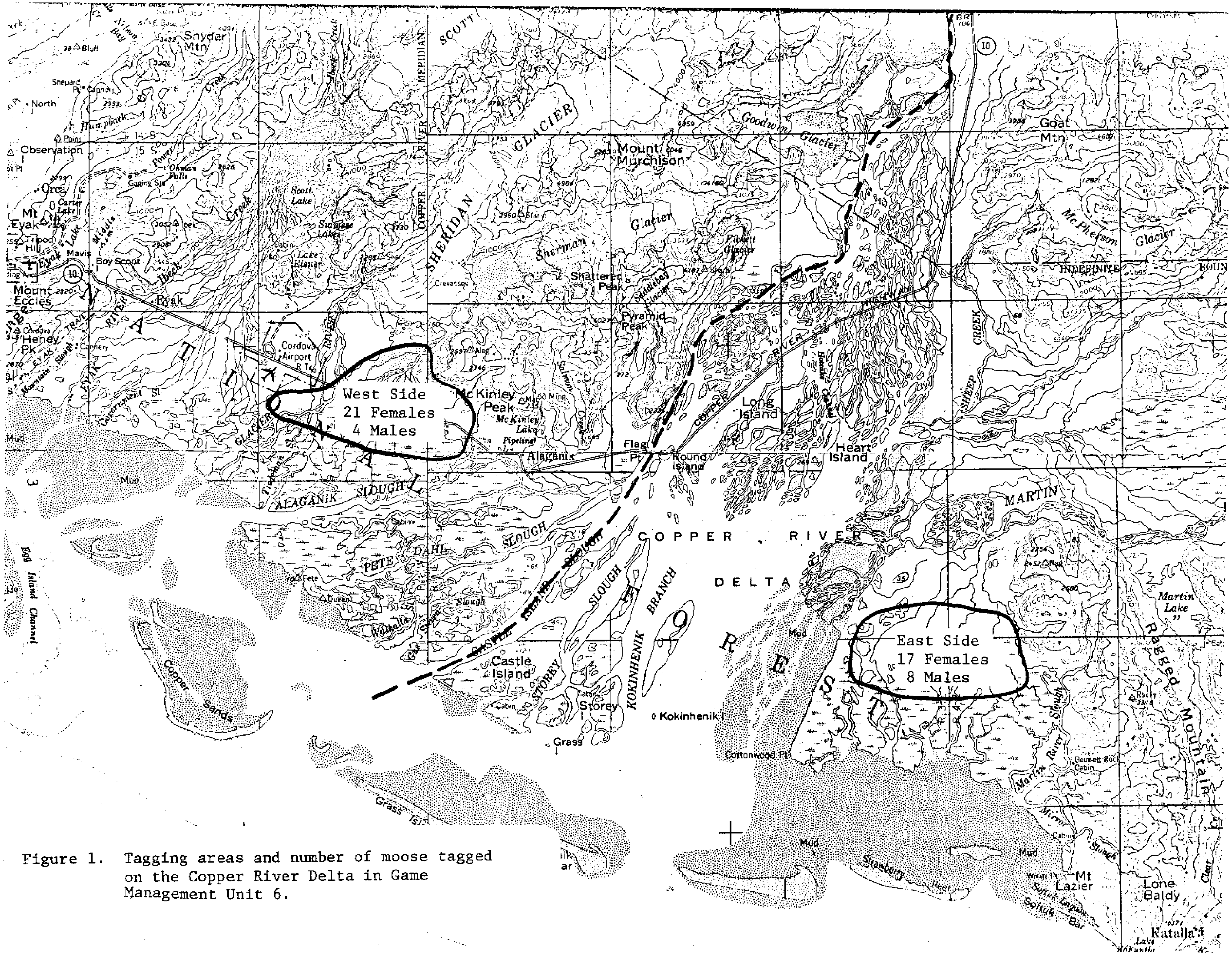

Figure 1. Tagging areas and number of moose tagged on the Copper River Delta in Game Management Unit 6.

Table 1. Collared Moose Survey Data, West of the Copper River.

Survey Date	Number Collared Moose Seen	Number Collared Moose Present 1/	Total Moose Observed	Percent of Observed Moose Collared	Percent Collared Moose Seen
3/26/74	8	25	--	--	32.0
4/25/74	12	25	74	16.2	48.0
5/28/74	6 + 1 2/	24	88	6.8	25.0
6/11/74	8	24	84	9.5	33.3
6/26/74	8	24	54	14.8	33.3
7/18/74	8	24	83	9.6	33.3
8/23/74	4	24	64	6.3	16.7
9/27/74	10	22	75	13.3	45.5
11/7/74	8	22	107	7.5	36.4
12/20/74	18	22	158	11.4	81.8
1/29/75	19	21	141	13.5	90.5
3/3/75	16	21	131	12.2	76.2
4/28/75	10	21	76	13.2	47.6
5/28/75	5	20	53	9.4	25.0
6/6/75	9	20	92	9.8	45.0
Total	150	339			44.2

1/ Estimated number of collared moose present west of the Copper River.
2/ 7 collared moose seen: 6 collared west and 1 collared east.

Table 2. Collared Moose Survey Data, East of the Copper River.

Survey Date	Number Collared Moose Seen	Number Collared Moose Present 1/	Total Moose Observed	Percent of Observed Moose Collared	Percent Collared Moose Seen
3/27/74	21	24	123	17.1	87.5
4/26/74	13	24	82	15.9	54.2
5/22/74	8	23	59	13.6	34.8
6/10/74	2 + 1 4/	21	38	5.3	9.5
6/12/74 2/	1 + 3 4/	21	32	3.1	4.8
6/27/74	2	21	27	7.4	9.5
7/17/74 3/	1	21	6	16.7	4.8
10/8/74	7	20	67	10.4	35.0
11/6/74	10	20	108	9.3	50.0
12/26/74	16	20	136	11.8	80.0
1/27/75	14	20	137	10.2	70.0
2/28/75	14	20	151	9.3	70.0
3/25/75	18	20	145	12.4	90.0
4/24/75	9	20	100	9.0	45.0
5/31/75	8 + 1 4/	20	93	8.6	40.0
6/12/75 2/	0	20	7	0.0	0.0
Total	149	335			44.5

1/ Estimated number of collared moose present east of the Copper River.
2/ Copper River Islands only.
3/ "Random Survey" - surveyed timbered fringe area.
4/ First number denotes a moose collared east of the Copper River, second number denotes a moose collared west of the Copper River.

numbers 34 and 45 utilized the lower Copper River islands during summer 1974 and collared moose number 33 was observed on Long Island several times that summer. The summer range of these three females is in the "Eastern" management area. All three females (#34, 45 and 33) returned to the west side prior to hunting season. No collared moose wintered (1974-75) on the opposite side of the Copper River from which they were collared.

Mortality of collared moose during the reporting period is believed to be 18 percent (9 of 50): four west and five east of the Copper River. Three were taken by hunters (two west and one east) and one was poached (west). Only one collared moose, number 22, has never been seen since being collared and is believed to have died shortly after being tagged. The remaining four collared moose probably succumbed to natural mortality. All four were last seen in April or May 1974.

RECOMMENDATIONS

Monthly reconnaissance flights should be continued for one more year and a mid-winter survey of Controller Bay and possibly the Tsin and Bremner River areas should be conducted.

Islands in the Copper River should be intensively surveyed during the hunting season to determine if the present management boundary is appropriate.

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JOB PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: Marilyn Sigman, Albert W. Franzmann and Paul D. Arneson

Project No.: W-17-7 Project Title: Big Game Investigations

Job Nos.: 1.13R & 19.15R Job Title: Moose Behavior

Period Covered: July 1, 1974 through June 30, 1975

SUMMARY

In January 1975 a student project was initiated to study the cow-calf bond during the critical winter period. Two cow-calf pairs, a single cow, and a lone calf were radio-collared in order that their activity might be observed.

Early, total calf mortality again occurred in the pens, yielding scanty data on cow and calf behavior. The opportunity to observe a single radio-collared cow throughout the winter provided daily activity data for energy budget analysis, however. Overall observations of penned moose were comparable to those in other winters. Exceptional feeding activity this year was the barking by moose of aspens downed by a severe storm. Twenty-five percent of the time spent in animal observations was devoted to observing barking activity.

The proximity of an area undergoing mechanical habitat rehabilitation by the staff of the Kenai National Moose Range afforded a unique research opportunity. High concentrations of moose utilized the approximately 23 km^2 area, forming large aggregations in scattered areas of downed mature vegetation. Ground observations, coupled with aerial observations by Bob Ritchey of the Kenai National Moose Refuge staff and Paul Arneson of the Alaska Department of Fish and Game, yielded sightings of moose previously collared in the long-term study of moose population identity on the Kenai Peninsula. Observations of these moose supplemented moose counts on the area. Occupation of this newly-created habitat by moose provided some insight into wintering patterns and, in particular, exploitation of a concentrated food supply.

Areas of downed aspen and birch trees allowed observations of aggregating behavior and daily activity patterns of large numbers of moose under conditions of an abundant and concentrated food supply. Comparison of activity patterns for these moose and the winter record of penned moose #79 suggests the amount of activity during winter daylight hours is related to nutritional plane.

Interractions between tame and semi-tame moose during periods of feeding and parturition stress were also observed.

CONTENTS

BACKGROUND

Determination of the seasonal or annual energetics of a wild animal species is an extremely desirable goal; one which has not been attained by any combination of available methods for a single wild species. A certain amount of energy is required to maintain the animal's existence. The amount of additional energy that the animal's metabolic capacity is able to obtain from current food supplies and fat stores is the energy that provides for, and yet limits, the subsequent behavioral range of the animal. At one extreme, behavior that seeks to obtain food for maintenance is alone possible; at the other extreme, energy is available for species-specific activities, growth, reproduction and even non-goal-directed behavior such as play.

The detailing of behavior by direct observation in order to arrive at an estimate of energetics is a difficult task and one that incurs the bias of human observation of other species. However, the task in moose (*Alces alces*) is less difficult because observation of the cow and calf, the sole, long-term social unit of the species, may yield critical information for the species as a whole.

Winter is a season when energetics are considered critical. Winter range is classically considered the limiting factor in moose abundance. More recent examinations of this concept include an analysis of the individual's energy budget and food intake, employing crude estimates of quantities of kilocalories involved. This analysis indicates moose cows are in negative energy balance during much of the winter (Gasaway and Coady 1974). To make up the deficit necessary for maintenance, energy must be utilized from summer fat stores (in this sense, summer range is also critical), but the intake of low-quality food in winter and expenditure to actually obtain that food are the critical maintenance activities of the individual.

Two opposing views of the cow-calf bond have been suggested. This association is either mutually advantageous under most conditons, an evolved social structure similar to larger social groups in other ungulate species (De Vos et al. 1967 and Etkin 1964); or it is care-taking behavior, wherein an immature animal is being protected and "socialized" by its parent for the environment in which it must survive

(Altmann 1958). The distinction is necessary because the strength of the association, based in part on the purpose it serves in the species, should be reflected in energy allocation in a hierarchical fashion. That is, either individual maintenance requirements of cow and calf determine the behavior of both, leading to separation when those needs cannot be met by travelling together, or hormonally-mediated maternal behavior is determining, and ceases only in extreme conditions of low energy or low supplies of nutrients that are utilized in the metabolic pathways of specific hormones. In either case, availability of energy and nutrients is largely determined by snow conditions and weather patterns. In the latter case, common bond distruption is a more serious condition for the population. The correlation of bond disruption with specific factors relates directly to the energy balance or vigor of individual animals.

A Review of Moose Energetics

In order to comprehend why the winter period is crucial for the cow and calf, it is necessary to outline the energy flow in ruminants, which can be expected to vary seasonally. The following discussion is abstracted from the excellent summaries by Blaxter 1962, Gessaman 1973 and Gasaway and Coady 1974.

Obviously, the simplest equation of digestive efficiency is in terms of assimilated energy being equal to energy ingested in food less that egested in feces and urine. In ruminants, another factor modifies this picture; 7-8 percent of ingested energy is converted to methane by rumen bacteria, so ingested energy must be partitioned into apparent digestible energy (DE), the portion not excreted as feces, and metabolizable energy (ME), the portion not lost as urine or methane. ME is energy available to or needed by an animal at a particular time for metabolic requirements.

The ME available is utilized in various types of metabolism: basal metabolism (the maintenance of minimum physiological function in a post-obsorptive state of complete inactivity under comfortable microclimatic conditions [Benedict 1938]), thermoregulatory metabolism, activity metabolism (work of obtaining food and eating) and "specific dynamic action" metabolism (the liberation of heat as food is digested and assimilated). ME in excess of these maintenance requirements can be stored as fat. ME may also be used for production in the form of weight gain or growth, reproduction, pregnancy and lactation.

Quantities of kilocalories involved in this flow have been estimated for many animals by the use of various methods. The combination of methods necessary to construct the total energy budget and flow is limited to use on small mammals and birds. Nevertheless, sufficient measurements have been made on large domestic mammals and some wild animal species to allow estimation of some of the components of the flow which may be comparable to those in moose.

The following discussion will attempt to: (1) report those values which have been obtained or estimated for moose, (2) review the applicability to moose of techniques applied to other large domestic and wild mammals, and (3) summarize comparable values for components of the flow that have not been studied in moose.

Measurement of energy intake and actual assimilation involves either direct observation of food habits and eating rates or calculations based on observation of rumen contents of dead animals, coupled with in vitro and in vivo disgestibility studies of forage components. These methods have been applied to moose (food habit studies reviewed in Peek 1974; general review in LeResche and Davis 1971). A reliable estimate of defecation rates, based on tracking over 24-hour periods is just emerging (Franzmann et al. 1975). No quantitative measurement of feces and urine excretion has been attempted, due to the difficulty of collection, however a tame moose might tolerate a collecting bag. Determination of the rate at which forage is turned over in the rumen has likewise not occurred. The difficulties associated with applicable methods are compounded by the high cost of radioactive tracers which would provide the most reliable estimates.

A fairly reliable estimate of digestible energy (DE) intake can be calculated from a measurement of volatile fatty acids (VFA) produced by ruminal fermentation of forages. The amount of energy passing through the ruminal VFA pool constitutes approximately 57 percent of total digestible energy (Gasaway and Coady 1974). These estimates of DE intake can be combined with the various studies of forage intake and together they provide an overall estimate of the range of energy available to moose seasonally with given forage types.

On the other hand, the determination of energy expenditure is problematical, since the standard method of measuring basal metabolism or metabolic work is that of indirect calorimetry (measurement of gas exchange as an index of metabolic rate). This involves placing the animal in a calorimetric chamber, which may be stressful for most wild animals. Nevertheless, wild animals have been placed in chambers and reliable estimates of metabolic rate have been made on white-tailed deer (Silver 1968; Silver et al. 1969), black-tailed deer (Nordan et al. 1970), pronghorn antelope (Wesley et al. 1973), red deer (Brockway and Maloiy 1968), wildebeest and eland (Rogerson 1968), caribou (McEwan 1970), and caribou calves (Hart et al. 1961). Due to the difficulty of meeting the requirements for a measurement of basal metabolic rate (BMR), fasting metabolic rate (FMR) is often measured in wild animals. To make reproducible estimates, animals should be in a post-absorptive state and in a comfortable microclimate, but energy of standing and small postural movements is included in this minimum physiological function measurement.

At present, the only estimate of a BMR for moose is based on Kleiber's empirical formula, based on the metabolic rate measurements of a large number of mammals. This relates heat production (Q) for basal metabolism (mb) to body weight (W) in kilograms: $Q_{mb} = 70\ W_{kg}^{.75}$ (.75 being the exponent accepted by the National Research Council in 1966). Generally, FMR values have been higher than that predicted by the quation and consistent individual differences have been noted. Hopefully, moose empirical values of FMR will soon be available.

Various experiments have indicated factors that modify FMR or BMR in addition to body weight. Differences have appeared due to sex of the animal, age of the animal (very young animals having a high metabolic rate which drops rapidly to adult level with maturity, then gradually slows throughout the lifetime), season, nutritional plane prior to the trial, training and habituation to the apparatus of measurement, and temperature (critical temperatures at which thermoregulatory heat production begins being different for young and mature animals).

Above and beyond basal or resting metabolism, the types of activity, and thus energy utilized in the other components of metabolism, that can be measured in a calorimeter are limited. Thermoregulatory metabolism can be determined fairly easily by varying temperature below critical temperatures. For moose, Gasaway and Coady (1974) cite theoretical considerations of body size, heat productiion due to rumen fermentation, and behavioral responses to cold, as well as observations of moose activity at cold temperatures, to arrive at the assumption that metabolic thermoregulation is an insignificant energy requirement. Digestive metabolism is also easily measured during rumination. In domestic species and in some wild ungulate species, it appears to make a negligible contribution to energy flow. This is also probably the case for moose. Thus, the assumption can be made that energy expenditure associated with obtaining food and ingesting the food represent the major cost of maintenance of a wild animal such as the moose. Energy associated with production of weight or young, social bonds or displays, or response to predators or disturbance represent other major, but highly variable costs in the budget.

For domestic animals, calorimetric measurements have been made for standing, walking at various speeds on a level or inclined treadmill, running on a treadmill, and eating forage in various forms and of different types. These studies and the values obtained (most often in kilocalories/kg./ unit of time) are summarized in Table 1.

Some inter-specific generalizations about energy costs have recently emerged, which may bear on the applicability of the obtained values to wild animals. Gold (1973) hypothesized that all animals require the same quantity of energy to carry a unit of their own body mass one "step," i.e., one unit of locomotive effort involving a single contraction of the animal's propulsive muscle mass. The energy expenditure per step for one species might be easily measurable via indirect calorimetry; the resulting value could be extrapolated to an individual of similar body mass of a wild species with a similar locomotion pattern and ratio of propulsive muscle mass to body mass. Apparently, differences are more significant across modes of locomotion, such as flying versus walking or swimming, than within the mode as a study by Taylor et al. (1974) indicates. They compared energy expenditure during running in cheetahs, goats, and gazelles, species with markedly dissimilar limb configuration, and concluded that energy expenditure was predictable on the basis of body weight and nearly identical over the wide range of speeds reached by the three species. Presumably, the ratio of propulsive muscle mass to body mass varies considerably with variations in limb configuration, and this finding confounds rather than confirms Gold's hypothesis.

Table 1. Summary of energy expenditure estimates for various activities.

Activity	Animal	Estimate of Energy Expenditure	Method	Reference
Standing (vs. Lying)	Sheep	.06-.12 kcal./kg./hr. (4 studies)	Calorimetry	
		.34 -.38 kcal./kg./hr. (2 studies)		Summarized in Osuji, 1974
		Metabolic increase of 70%		Pullar, 1962
	Cattle	.09-.12 kcal./kg./hr. (4 studies)		Summarized in Osuji, 1974
Walking Horizontal	Sheep	Increase with speed .59 cal./kg./ horizontal m.	Calorimetry	Clapperton, 1961, 1964
	Horse	.40 cal./kg./ horizontal m.		Brody, 1945
	Cow	.48 cal./kg. horizontal m.		Blaxter, 1962
	Dog	.58 cal./kg./ horizontal m.		Lusk, 1931
Vertical		Independent of gradient, increase with speed		
	Sheep	6.45 cal./kg./ vertical m.		Clapperton, 1961 1964
	Horse	6.83 cal./kg./ vertical m.		Brody, 1945
	Dog	7.26 cal./kg./ vertical m.		Lusk, 1931
Grazing Grazing, along (Eating)	Sheep	.54 kcal./hr./kg.	Calorimetry	Graham, 1964

Table 1. Cont.

Activity	Animal	Estimate of Energy Expenditure	Method	Reference
Grazing				
Eating		Increase above maintenance reqts.		
	Sheep	+ 60%	Mask calorimeter & tracheostomy	Ustjanzew, 1911
Fresh vs. dried gress		+ 12%	Calorimetry	Osuji, 1973
Hay		7.01-14.7 cal./kg./min. (8 forms)		Reviewed in Osuji, 1974
Prepared forms (dried, pelleted)		4.4-10.3 cal./kg./min. (9 forms)		
Grazing outside (includes movement)		increase above indoor maintenance reqts.		
	Sheep	+ 11%	Extrapolation from calorimetry	Blaxter, 1962
		6X indoor reqts.		Graham, 1964, 1965
	Cattle	+ 15%		Blaxter, 1962
	Sheep	+25-100% (3 studies)	Live-weight changes at pasture	Summarized in Osuji, 1974 Criticized in Whitelaw, 1974
	Cattle	+50-100% (3 studies)		
	Sheep	+43-64%	Mobile calorimetry CO_2 Entry Rate	Young & Corbett, 1972
	Reindeer (moderate insect harassment)	4.04 kcal./kg. hr.	CO_2 Entry Rate	Luick & White, 1971

Table 1. Cont.

Activity	Animal	Estimate of Energy Expenditure	Method	Reference
Over-all Energy Budget	White-tailed deer	1.24-1.45 x BMR	Daily activity monitoring	Jeter & Marchington, 1964
		1.59-1.70 x BMR		Montgomery, 1963
	Wild animals	1.23-1.98 x BMR	Various	Reviewed in Moen,

The next step in estimating the cost of free-ranging existence is to either extrapolate from calorimetric measurements or use mobile apparatus. Results of both approaches are also presented in Table 1, based on attempts to estimate the energy costs of grazing in domestic species. Mobile methods include the Mobile Indirect Calorimeter (Corbett et al. 1969) and the Carbon Dioxide Entry Rate Technique (Young et al. 1969). The latter technique consists of infusing $Na\,H\,C^{14}O_3$ which equilibrates with the carbon dioxide pool of the animal, where the concentration of isotope in the pool can be measured by sampling blood or urine. In practice, the rate of entry of carbon dioxide into the pool is highly correlated with the rate of carbon dioxide respiration. Thus energy expenditure can be calculated from the calorific value of carbon dioxide (Brody 1945). The method has been used on domestics, including reindeer, and a study by Young and McEwan (1972) indicates that the method produces reliable values for sheep, cattle, reindeer and caribou, a wild species. Such a technique, using portable equipment for infusion and continuous blood sampling (Farrell et al. 1970) might be suitable for tame moose activity.

Overall, values obtained for domestic animal energy expenditures appear applicable to wild species for crude estimates of energy expenditure or the relative costs of different activities. Certain generalizations have been made, related to grazing activity. Osuji (1974) stated that the time spent eating and rate of feeding are directly related to the quality of the pasture, and further, that the energy costs associated with eating, a major cost of free-living existence, may be increased substantially by the form of the forage which may result in requiring the animal to eat more in order to obtain the same energy content that other forms provide with reduced intake. Movement, both the horizontal and vertical distances moved, and eating would appear to be the major costs of wild animal existence over that required for maintenance. Certainly, observation of these activities over time and in various seasons would aid in estimation of expenditure yield estimates of 1.5 to 2 as the multiple of basal metabolism necessary for maintenance energy requirements. Gasaway and Coady (1974) use the value of 1.7 for moose. Such an estimate might be validated by compiling time/activity records and attempting analyses of those behaviors unique to moose.

The analysis of energy expenditure in activities unique to the wild may result from techniques of cinematographic analysis, highly developed for human motion (Plagenhoef 1971). The forces involved in component movements can be analyzed, although energy expenditure during the motion must still come from inter-specific comparisons of animals performing similar motions in calorimeters. Dagg and De Vos (1968a,b) performed an extensive cinematographic analysis on the walking and running gaits of various Pecoran species, including moose. Although no estimates of energy expenditure were made at the time, these are still possible. All Cervidae exhibited a walking gait that involved diagonal legs (e.g. right front leg and left rear leg) or three legs for support a greater percentage of the time than any other Pecoran group. The use of diagonal legs for support, as opposed to the use of lateral legs (e.g. right front leg and right rear leg), increases stability but also increases energy expenditure, with the involvement of two sets of body musculature in movement. Within the group of Cervidae, moose used three legs rather than diagonal legs a greater percentage of the time, except in deep snow when the use of diagonal legs, and thus, energy expenditure, increased. In the fast gaits, characterized as the trot, gallop, and bound; moose preferred the more stable trot, mainly due to the difficulty of support and thrust forward from one leg of a heavy animal on an often soft substrate and the turns necessitated by moving through cover. In short, the locomotion pattern of moose has undergone selective pressure for stability, not minimum energy expenditure. Energetic analysis of moose moving through different snow depths, especially calves, may provide insight into the relationship between energy balance and snow depths and snow structure over the winter period. Finally, the uncommon behavior of cratering for food, observed in Kenai moose, may indicate whether it is, indeed, an adaptive feeding activity or one for which energy expended greatly exceeds subsequent energy intake. Caribou, which regularly crater for food, may someday provide values of energy expenditure via respiratory analysis or the Carbon Dioxide Entry Rate technique. On the other hand, future calorimetric studies might be expanded to include social behaviors, including maternal behavior, in those species amenable to such measurement.

Aside from interest in the cost of a free-living existence, as opposed to a domestic one, a consideration of large herbivore energetics is a key to the overall flow of energy in the ecosystem. Since all herbivores occupy the same trophic level, it would not be surprising to learn that the range of energy available for maintenance and other behaviors is fairly narrow, although the selective pressures of human domestication have been effective in altering behavioral patterns and energy flow (Kretchmer and Fox 1975). Gasaway and Coady (1974) concluded that a viable wild ungulate population can consist of individuals in negative energy balance for part of the year. At a certain point, however, a change in plant species due to succession may decrease the total energy available to the species to a level below that necessary for the full range of species behavior.

Given the preceding discussion of energy flow, the diagnosis of such a limiting condition would result from observation of those activities not related to individual maintenance, i.e. the social or species-specific behaviors. In moose, the social structure comprised of a single long-term association of cow and calf has proved successful in colonizing areas in early successional stages. Perhaps the continued succession of such a successfully-colonized area delivers a final blow to even this minimal social structure unless a new area is colonized before this stage. Physiologically, the reduction in overall energy intake may simply preclude maternal behavior when such behavior curtails the cow's activity of obtaining food to meet maintenance demands. Short-term selection might also be intense in an area like the Kenai Peninsula, where three out of four winters have resulted in heavy, early calf mortality, so that many cows surviving during these years are those in which adaptive strategy somehow resulted in loss of the calf. Indeed, the situation would approximate that in other species in which an energetic trade-off between adult survival for further reproduction and successful rearing of present young is presumed to exist (Goodman, 1974). Thus, the present stage of succession on the Kenai Peninsula, combined net effect of survival of cows who will not rear their calves successfully in most years of their reproductive life.

The variability in energy expenditure due to inherent individual differences (age, sex, activity patterns) needs to be pursued, as well as changes in expenditure or intake due to environmental variables; for example, snow depth and structure may affect expenditure in movement through and cratering through it. The long-term successful occupation of the Kenai Peninsula by moose suggests that the recurring winter calf mortality may be tied to present range conditions.

OBJECTIVES

To observe maternal behavior that would increase the calf's chance of survival and/or decrease the cow's chances.

To gain knowledge of the conditions of snow cover, weather, and food availability under which bond disruption occurs.

PROCEDURES

Two cow-calf pairs, one lone cow, and one long calf were provided with radio collars in late fall. These animals are listed in Table 2. The cows and calves were observed when they could be located in early winter, those surviving until late February were observed on a weekly basis.

Any cows and calves without radio collars that could be located were also observed.

Types of behavior that were recorded included interactions of the cow and calf, distances between the two, synchrony of activity and rest, reactions to disturbance, and any behavior that constituted "helping" of the calf by the cow or distinct following on the part of the calf.

All observations of cows, calves and other moose seen included a detailing of the various activities engaged in over time. These data were gathered incidental to cow-calf observations in early winter, but they later became the focus of behavioral observation.

Specific behaviors, cratering and aspen-eating, were filmed when possible.

FINDINGS

Observation of Cow-Calf Pairs

Total calf mortality within the pens early in the winter precluded long-term observations. The approximate time of death of those animals found dead is included in Table 2. Calf #119, calf of cow #40 was never observed alive. Cow #79 was observed alone several times between January 20 and January 28, and her calf was assumed dead. However, on

Table 2. Moose observed in Cow-Calf Bond Study.

Moose #	Pen		Collar Type	Approximate Date of Death
40	Cow	2	Radio	March 1, 1975
119	Calf	2	Radio	January 14, 1975
79	Cow	2	Radio	–
117	Calf	2	Radio	February 1, 1975
R-70-8	Cow	1	Radio	–
116	Calf	1	Radio	Late January-Early February
–	Calf	2	Unmarked	?
670	Cow	2	#670	–
–	Calf	2	Unmarked	Late January
138	Cow	Outside		–
–	Calf	Outside	Unmarked	Late January

January 28, her calf #117 was radio-tracked and found with her. They travelled together and fed in the same area for fifteen minutes. Then, the calf approached the cow from 15 meters away. The cow vocalized and charged the calf. After this display, the cow proceeded to a downed aspen feeding site, while the calf moved off in another direction. The calf was found dead two days later.

An attempt to locate the lone calf in Pen 1 was undertaken in early February. Only a faint signal could be heard then and the carcass was located under the snow in March. Cow #R-70-8 was located a few times in February, but always in dense regrowth. No long-term observations of her were attempted.

Cow #670 and her unmarked calf were located and observed together three times, including two days (January 24 and 25) which were spent feeding at a site with many downed aspens. The pair exhibited synchrony in their feeding and bedding activities, although the calf moved off to feed alone on two occasions, as did the cow on one occasion. The two spent a high percentage of total time active (67 percent) compared with a range of 30-45 percent in all long-term observations of single moose. However, this comparison is based on a single observation period of the pair and observations later in the winter for single moose.

The calf dug snow craters and pawed at the base of aspen branches to eat below the level of the snow, both of which are activities not reported regularly in areas other than the Kenai Peninsula. Several times the calf approached the cow closely and she yielded her feeding site. Overall, the calf exhibited intermittent feeding interspersed with periods of standing or looking around, compared to the cow's steady method with occasional pauses to attend to the environment.

#670 was observed alone on February 3 and several times after this date. The calf was not seen again, nor was its carcass found.

An uncollared calf, tentatively identified as one orphaned in July, 1974, was seen from an airplane on Janaury 24 (Arneson, ADF&G) and observed again on January 27. The calf appeared in poor condition, exhibiting circular, wandering travel and intermittent browsing of various foods, including dead aspen leaves and branches. This last behavior, eating unnatural foods, suggests malnutrition.

The orphan calf also ate aspen bark and pawed at the buried branches, although the behavior could have been observed and learned from moose other than a particular cow. In particular, the barking of aspen trees may have been learned through signs of the presence of other moose around the downed trees.

Cow #138, a collared moose outside the pens, was observed with her calf on January 16 and January 17. The calf's behavior on the latter date indicated that she was in poor condition. The cow moved along the north fenceline of Pen 2 and crossed through a hardwood stand moving west. The calf moved slowly and was very reluctant to enter the hardwoods. It stopped at the edge of the stand, the cow stopped in the middle of the stand, and vocalized three different times. After five minutes, she moved on to another hillside. The calf walked back and forth past the cow's trail through the hardwoods, at one point moving back 100 m in the direction she had come, as if to go around the stand. She finally moved past the cow's trail and entered the hardwoods further north, 20 minutes after the cow had moved on. The calf laid down in the hardwoods, as the cow continued travelling and browsing birch 300 meters away.

The calf was not seen again. A well-scavenged carcass found on the shore of Coyote Lake on February 2 was identified as this calf, since the last sighting of her was on the other shore of the lake and Cow #138 was still in the vicinity of the carcass.

The carcass of Calf #119 was found following a ten-day cold snap with temperatures between -35- -40°F. Likewise, the death of Calf #117 and the presumed date of death of #670's calf followed a period of below-zero temperatures. Snow cover was early, deep, and presistent.

Some observations of cows with calves were made at the KNMR Moose Habitat Rehabilitation Area. The build-up of moose concentrations in this area occured synchronously with the MRC calf mortality aerial sightings of lone calf groupings. It is possible that some cows may have left weak calves behind in moving to the area. One group of two, and sometimes three, lone calves was sighted repeatedly in the rehabilitation area. Of those collared moose outside the MRC enclosures which were known to have calves in the fall, two cows, MRC #178 and MRC #287 still had them in late March. MRC #141 (C-8) had lost twin calves by mid-February, MRC#287 lost a calf between late December and mid-March, and MRC #220 apparently lost hers in early March. In addition, seven calf carcasses were found in the area, along with frequent signs of wolf activity.

Cow-calf pairs were seen in aggregation with other moose frequently. However, they tended to flee immediately in the case of disturbance by the observer or by aerial counts. The cow and calf fled together, unless they were widely separated at the time of disturbance, and they often fled with other cow-calf pairs. On the other hand, the lone calves stayed in a small area, even if all other moose fled. On several occasions, the observer approached an area where no moose were visible and walked to within 30 meters of lone calves, who fled only if the observer made noise repeatedly. In comparison, approaches made to penned calves never resulted in flight. The typical response of a calf with a cow to disturbance was to freeze with its rear to the observer.

Nursing attempts were observed both in the Pens and in the rehabilitation area. These attempts followed a disturbance of some kind and were immediately refused by the cow who moved away several steps in each case. On January 24, #670's calf made such an attempt. Another attempt was seen in the rehabilitation area on March 4. The last example was fairly dramatic. On March 21, a cow and calf were browsing one-eighth mile apart on a hillside above Willow Lake. The calf saw the observer first and ran three quarters of the way across the lake, then she stopped. The cow did not start moving until she saw the observer five minutes later. She then ran across the lake to the calf. When the two met, after several minutes in which the calf appeared disturbed, the calf made its unsuccessful nursing attempt. Winter nursing attempts were also observed by Johnson (Johnson et al. 1973).

Feeding Interactions

January 16 - Outside Cow #138 and calf approach Rastus, on other side of Pen 2 fence. Rastus stops briefly, looks at pair, continues down fenceline. #138 hesitate for 30 minutes, with many looks into Pen 2 and into woods across road. Calf freezes, cow finally moves into woods, calf following. (30 min.)

January 20 - Moose #79 beds down near downed aspen, along north fenceline of Pen 2. Ten minutes later, Rastus (tame moose) approaches area; #79 got up. Both feed briefly. Rastus approaches #79 closely, vocalizes three times. #79 moves quickly and changes feeding place. Rastus repeats his approach twice more. #79 moves the first time, remains in place the second. Rastus vocalizes twice; she moves. Finally, Rastus uses antler on #79's rear. She moves off several hundred meters to another aspen site. (10 min.)

This time, Raquel (tame moose) approaches the new feeding site. #79 moves before Raquel reaches the site. Raquel approaches, #79 moves to another part of the tree. She feeds briefly, then returns to her first feeding site. (10 min.)

Unfortunately, both Rastus and Wally, Jr. are already there. Wally, a castrated young bull, vocalizes and chases her when she approaches. He repreats this twice more as she approaches again. She moves away 100 meters, then approaches Rastus slowly (submissively?) with a low vocalization. Rastus allows her to feed, meanwhile scraping his antlers on a spruce tree directly behind her. Rastus approaches and vocalizes. Wally, Jr. charges, while Rastus thrashes his antlers behind her. #79 moves off into the woods. (15 min.)

January 24 Moose #670 and calf feed on down aspen. Moose #36(MM) approaches, then charges #670, who moves a few feet. Cow and calf approach observer, calf in lead, to 5 meters. Both move to another aspen tree. #36 approaches, chases cow and calf, who move to feed on another part of the same tree. (13 min.) Two minutes later, #36 lays down.

January 28 Following the chasing away of her calf (described under Cow-calf Bond, Results section) #79 moves to an aspen feeding site. Moose #120 is feeding there; #79 chases her. #120 moves to another part of the same tree. #79 approaches, chases again. #120 moves to another tree. (5 min.)

March 7	Moose #79, #36, #120 feed on birch, 30 meters away from one another. No approaches or interactions seen. (60 min.)
March 7	Moose #120 moves into an area where Moose #79 is lying down next to a down aspen. #79 gets up and feeds on the aspen.
March 16	Moose #670 is feeding on aspen behind the MRC cabins, where Raquel and Rastus usually hang out. Raquel and Rastus enter the clearing and begin to feed. #670 approaches Rastus, who yields his feeding site. Rastus moves to where Raquel is feeding; Raquel chases him off. Rastus approaches #670 slowly and very close. She vocalizes and moves off, yielding her site. Rastus repeats the maneuver twice more.

Time/Activity Records

All observations, with a break-down into relative components of various activities, are presented in Table 3 and summarized in Table 4. The values for Moose #79 are presented separately in the summary, since observation of her made up 53 percent of all observation time. Eight other moose were subjected to behavioral observation; 11 additonal moose, including the three tame moose, were sighted or observed incidental to long-term observations of the nine. Table 5 presents complete bouts of activity and rest.

The various categories of behavior are defined through observation of repeated patterns. Feeding on birch (*Betula papyrifera*) consisted of moving through regrowth areas while stripping birch twigs and small to medium branches off with movements of the head and bending over medium site saplings to strip upper branches. Feeding on aspen (*Populus tremuloides*) involved gnawing bark and cambium from the large number of mature aspen trees felled in a wind storm on October 30, 1974. Individual moose sometimes spent several days in an area where many trees were available. Cratering has been a subject of study on other winters at the MRC. It involves pawing through the snow to eat ground vegetation, notably low-bush cranberry (*Vaccinium vitis-ideae*). Travelling and browsing involved movements of about 100 to 300 meters, including feeding briefly on different food types such as ground vegetation, small birch plants, and aspen brances. Traveling was continuous movement to a feeding site or bed. Standing and lying are fairly obvious categories. Other activities observed included eating snow, attending to various stimuli, and comfort activities of snorting, stretching, shaking, scratching on branches and yawning.

The observed cratering activities of individual moose does not reflect the number of snow craters seen at the MRC. Few craters, however, were seen after March 10, when snow depth readings (Table 5 - Productivity and Physiology section of this report) peaked in all the habitat types. When snow depths are compared to chronological sightings of each type of activity, one possible correlation does occur. A concentration of aspen-feeding activity can be seen between January 24

Table 3. Chronological observations of penned moose, Moose Research Center, by activity.

* - Disturbed by observer ** - Disturbed by another moose _ - Includes eating *Vaccinium*

Date	Animal #	Feed Birch (min.)	%	Feed Aspen (min.)	%	Crater (min.)	%	Travel & Browse (min.)	%	Travel (min.)	%	Stand (min.)	%	Lay (min.)	%	Total Time (min.)
1/11/75	168									X				X		-
1/15/75	670	60														60
	Calf	30				20								10		60
1/16/75	40	70														70
	138			30	33			30	33	30	33					90
	Calf			30	33			30	33	30	33					90
1/17/75	138	X*								35						35
	Calf	X*								35						35
1/20/75	79	10		20				25						30*,**		85
1/22/75	168	75								X						75
1/23/75	79	53												32*		85
1/24/75	670			126**	51			25	10					96	39	247
	Calf (36MM)			140**	54			25	10					95	36	260
1/25/75	670			55										X		55
				125										X		125
	Calf			41						X						41
				95	76			35	24							130
1/27/75	Unmarked Calf	X		X				95								95
1/28/75	79			134	90			15	10							149
	117 (120)							15								15
1/30/75	79			30*,**	55	25	45							X		55

Date	Animal #	Feed Birch (min.)	%	Feed Aspen (min.)	%	Crater (min.)	%	Travel & Browse (min.)	%	Travel (min.)	%	Stand (min.)	%	Lay (min.)	%	Total Time (min.)
2/4/75	670	73	27											192	73	265
2/5/75	79			25	32	20	26	32	42					X		77
2/6/75	79			60	60	12	10	30	30							102
2/7/75	40	120								X						120
	79	65	68			30	32									95
2/10/75	R-70-8	X														
	670	40	29			30	21			70	49					140
2/16/75	73	X		X		X										
	1	X														
2/19/75	79	91	25	20	6	5	1	65	18					195	50	376
2/20/75	40	74	26					15	5	X				196	69	285
	79	X														
2/21/75	79	X		X												
2/25/75	79			120	28			10	2					295	69	425
2/26/75	40	X														
2/27/75	40	X														
	79			X												
2/28/75	79			X												
3/7/75	79	88	27											242	73	330
	(120)	X														
3/9/75	79	130	25	55	11					30	6			300	58	515
	(120)	X														
	(3)	X														

Date	Animal #	Feed Birch (min.)	%	Feed Aspen (min.)	%	Crater (min.)	%	Travel & Browse (min.)	%	Travel (min.)	%	Stand (min.)	%	Lay (min.)	%	Total Time (min.)
3/15/75	120	X														
	36(MM)	X														
	79	X														
3/16/75	670 (Rastus, Raquel)			X**												
3/17/75	79	45	10	72	16			10	2	14	3	4	1	300	67	445
	670			X												
	(1)	X														
3/23/75	79	172	34	12	2					2	1	5	1	314	62	505
3/29/75	79			377	20									158	30	535
4/10/75	36(FF)			35	19			41	22	4	2	3	2	107	56	190
	57			X												
	79			X												
4/11/75	36(FF)			20	10					5	2			177	88	202
	79			X												
4/12/75	36(FF)			90	19			100—	21					290	60	480
	79			X												
4/13/75	79	77	16	62	13			34—	7					302	63	475
4/18/75	36(FF)			X				X								
4/19/75	79 (Rastus)	X		52				37						51**		140

Table 4. Summary of time spent by moose in different categories of behavior.

Activity	Feed Birch	Feed Aspen	Crater	Travel & Browse	Travel	Stand	Lay Down	Total Time (min.)
All Moose								
Total Time/ Activity (min.)	1273	1876	142	669	255	12	3382	7609
% of Total Time	17	25	02	09	03	-	44	
#79								
Total Time/ Activity (min.)	731	1089	62	233	16	9	1919	4059
% of Total Time	18	27	02	06	-	-	47	

Table 5. Complete Bouts of Rest and Activity Observed.

Date	Moose #	Type of Activity	Active (min.)	Lying (min.)
Jan. 24	670	Feed Aspen	75	97
	Calf	Feed Aspen	65	95
Feb. 2	670	Feed Birch	73	182
Feb. 19	79	Feed Aspen, Feed Birch	75	195
		Feed Birch	91	
Feb. 20	40	Feed Birch	36	165
Feb. 25	79	Feed Aspen	75	75
		Crater, Feed Aspen	50	140
March 7	79	Feed Birch	73	167
March 9	79	Feed Aspen	50	270
				30 (Disturbed)
March 17	79	Feed Birch, Feed Aspen	86	91 (Disturbed)
		Feed Aspen	24 (Disturbed)	70 (Disturbed)
March 23	79	Feed Birch, Feed Aspen	141	173
March 29	79	Feed Aspen	70	145
		Feed Aspen	73	100
				132
April 10	36( )	Feed Aspen	83	107
April 11	36( )	Feed Aspen	25(Disturbed)	
April 12	36( )	Feed Aspen	77	95
		Feed Aspen, Feed Cranberry	113	
April 13	79	Feed Aspen, Feed Cranberry	36(Disturbed)	122(Disturbed)
		Feed Birch, Feed Cranberry	100	90(Disturbed)
Number of undisturbed bouts			18	16
Mean length of bout (min.)			78	142

and February 7; January 22 and February 5 snow depth readings reveal conditions of snow melt. The following period, February 7 to February 17 is one of birch-feeding activity; snow depth readings of February 5 and February 20 document a series of snow falls. Moose were never observed pawing to remove snow from the top of down trees, thus the pattern of snow cover can be seen to affect the availability of this food source, which was made available only through a wind storm on September 30, 1974. In addition, when individual movement patterns are compared to weather patterns, a certain restriction to small areas of dense regrowth seems to occur in severe snow storms.

Little information was gained on the cow-calf bond. The singular interaction of Cow #79 and her calf, which resulted in the calf being chased away from food and dying soon after does indicate that break-up of the bond can, indeed, be actively caused by the cow, rather than a passive process of leaving behind a calf too weak to follow. It also demonstrates that a calf may actively seek to remain with a cow. Finally, it gives some credence to the theory that cows on the Kenai may practice a strategy that results in loss of the calf; #79 has lost her calf in two previous winters. The survival of an orphan calf until approximately the same time as calves with cows is worth noting.

Of greatest interest in results from observation of various feeding activities is the large percentage of time (25 percent) spent feeding on downed aspen, an activity that was not observed in quantity in previous winters. While the amount of aspen eating may have reduced the amount of cratering by moose, the low percentage of time (2 percent) spent cratering was probably an underestimation of the amount of such activity. Much of this activity took place in early winter when observation periods were few. However, signs of such activity ceased around March 10, when snow depths were maximum. The overall contribution of ground vegetation to the winter diet was difficult to determine. However, in the winter of 1972-73, Johnson spent 40 percent of observation time observing cratering (Johnson et al. 1975). LeResche and Davis (1971) reported that diet in the winter of 1970-71 was 2 percent birch twigs, 21 percent low-bush cranberry, and 67 percent willow (*Salix* spp.) and alder (*Alnus* spp.) Low-bush cranberry was emergent during the study. This winter, low-bush cranberry became available with snow melt on April 10. Concurrently the amount of time spent travelling and browsing began increasing. The comparison with past studies underscores the unusually large contribution of aspen bark to diet this winter, while observation probably underestimates the amount of cratering activity, and thus, the contribution of ground vegetation to the winter diet.

Moose activities of cratering and eating downed aspen indicate a flexibility in food habits. These activities seem to occur in response to depletion of a major forage source (e.g. willow) and to the sudden availability of supplementary food types (e.g. aspen bark). The capacity for opportunistic exploitation of food sources in areas that moose already occupy may be an example of the over-all opportunistic character of moose behavioral patterns, which ultimately allow them to successfully occupy habitat that fluctuates in quantity and quality.

Interactions of Raquel, Wally Jr. and Rastus, tame and semi-tame Moose.

Raquel, a female moose raised in captivity since a calf, was brought to the MRC as a yearling in 1970. Since that time she has calved twice: a male in 1971 named Wally, Jr. who was castrated as a yearling and a male in 1973 named Rastus. We classified Raquel "tame," being approachable and able to be hand-fed. The two males were only "semi-tame," being somewhat afraid of man and approachable only when feeding on supplemental calf starter. These moose have afforded excellent opportunity to observe various cow-calf yearling interactions, but being "tame" the validity of this behavior is suspect. It is reported here only for its possible utility in comparisons with observations of behavioral interactions of wild moose.

In spring 1972 the cow/yearling bond was not broken, perhaps since Raquel did not calve that year. The castration of Wally in April 1972 may have affected this situation. The two moose were also enclosed in the 10-acre calf pen at that time. The two moose fed and travelled together until Raquel was released into Pen 2 in October 1972. When Raquel was again put back into the calf pen in April 1973, she was not aggressive toward Wally. On May 12, 1973 a "game" was observed in the lowland of the calf pen. Raquel chased Wally throughout the swamp area holding her head low. The chase lasted for one and one half minutes in the lowland when it moved to the upland regrowth. There it continued for another minute at a rapid pace over windfalls. When they came back to the swamp Wally soon stopped. Raquel stood a few yards away and stamped a front hoof three times in the water. With that the chase ended. The whole episode appeared to the observer (a non-ethologist) as more of a game than an aggressive act of breaking a mother-offspring bond.

However, on June 6, 1973 the chasing took on new meaning. Raquel came first to the feed trough on that day. As Wally approached she charged him; ears back, striking at him several times. Wally vocalized very submissively at each charge. The actual aggressive actions may have begun the day before since Wally was reluctant to enter the feeding area. Prior to that they were still feeding together.

On June 11, 1973 Raquel calved for the second time. When we approached the newborn calf, Raquel was not upset by our presence. The calf (Rastus) vocalized when we tried to weigh it and Raquel approached us but at no time acted aggressively. A short time later Wally approached along the fence approximately 50 meters away. Raquel charged him quite aggressively until he left the vicinity.

On June 14, 15 and 17 Raquel left her calf on the far side of the calf pen when she came for her supplemental feed. The calf accompanied her to the feed trough for the first time on June 18. The cow and calf were released into Pen 2 on July 13 and Wally on July 24. From this period until August - September 1974 no significant observations were recorded. In general, Wally was not tolerated near Rastus during the calf's first summer and possibly fall. As time progressed Wally was accepted near the cow/calf pair. The two males associated more together than Raquel with Wally.

Raquel did not calve again in 1974 and Rastus remained with her until the rut of that year. Their bond seemed like a loose association in August as Rastus began displaying rutting behavior. They were last seen together on September 2. Rastus was seen alone or with other Pen 2 moose in all parts of Pen 2 during the rut.

On November 15, 1974 both males came in to the feed trough and fed amicably together. When Raquel came up both males departed. As Raquel ate both males approached her to eat also. With ears back Raquel chased after her antlered yearling. Rastus stood his ground, lowering his head and ears. Not be be intimidated Raquel reared back raising her front legs approximately seven feet and half-heartedly struck at him. He backed off slightly while Raquel stood her ground with ears back. In a possible show of displacement behavior, Rastus began rattling the Pen 2 fence with his antlers. Raquel then went back to feeding. Then as Wally approached her she chased him. He too, stood his ground but vocalized very submissively. She stamped her feet several times, yet Wally remained where he was. She then returned to feeding. The two bulls approached one another through the calf pen fence as Raquel fed and Rastus tried to spar with Wally. He only vocalized submissively. Rastus then approached the feed trough with little interference from Raquel except a lowering of her ears. As he approached he sniffed urine in the snow and promptly gave a lip-curl. Wally also approached and Raquel chased him out of the area. Rastus followed Raquel in this chase, sniffed her vulva and gave another 5-10 second lip curl.

Raquel appeared to be dominant of the three but respected antlered Rastus. Wally is lowest on the "peck order." Raquel chased Wally more than Rastus and seemingly more than necessary.

On December 1, 1974 it appeared that Rastus became slightly more dominant than Raquel, using his antlers to intimidate her. She vocalized submissively but was allowed to feed beside him. During December and most of January Raquel would normally come to the feed trough first and as the two males (who travelled together) approached, she allowed Rastus to feed, vocalizing as he neared. She invariably chased Wally but he became so persistent he was allowed to feed. All three moose ate together with Rastus in the middle and the other two eating under his antlers at each side.

On January 26, 1975 Raquel again was first to the feed trough. During the previous 24 hours Rastus had shed his right antler and as he approached Raquel his antlerless side was toward her. With no vocalizing she charged him with ears back. Eventually be was allowed to feed with his antlerless side toward Raquel. The remaining antler was grasped while he fed and as he backed up, the antler came off. It startled him, so he momentarily backed off several meters. As he approached the feed trough again - only antlerless this time - Raqual chased him, (aggressively ?) ears back, out of the vicinity.

Wally approached about that time and was chased by Raquel but made it past her into the calf pen with Rastus. Calf starter was put into the lower feed trough for the males. Wally came up first and began eating. When Rastus came up to eat Wally kept on eating without looking up, flinching, or vocalizing. Rastus ate briefly and backed off a short distance. When be approached again, Wally vocalized but both ate together. For a second time Rastus left and this time when he returned to feed Wally looked up and the observer presumed that Wally for this first time noticed that Rastus was antlerless. Wally promptly laid his ears back and Rastus retreated. It appeared that Rastus quickly recognized his loss of dominance although he once did lay his ears back to both Raquel and Wally at this time but both ignored him.

Wally finished the remaining feed in the lower trough and moved toward Raquel at the upper trough. She aggressively charged him but he persisted through several charges until he was allowed to feed with Raquel. However when Rastus tried to approach he was promptly and vehemently chased away by Raquel.

Wally was given 200 mg testosterone on January 21 and this may have affected his behavior toward Rastus.

On January 28 Wally was first to come in to feed. When Raquel arrived she lowered her ears but Wally vocalized, raised his head very high and remained where he was. When he lowered his head, he was allowed to eat with Raquel. She only responded by frequently flicking the ear nearest Wally. When Rastus came up she chased him and he got stranded between Raquel and Wally. They aggressively chased him back and forth between them a couple of times before he escaped back out into Pen 2. Raquel then persistently chased him out into the brush and remained on guard for about two minutes preventing his return. Raquel then returned to feed peaceably with Wally. Rastus came back and sneaked by both moose, approaching the feed trough along the fence to the left of Wally. Wally allowed Rastus to feed beside him but was for an unknown reason chased out of area by Raquel who then kept Wally away and allowed Rastus to feed.

On about February 17, 1975 Wally died of malnutrition. Apparently by being low in this moose heirarchy most of the time, he was unable to get sufficient quantities of this supplemental feed and he relied too heavily on the calf starter for sustenance.

Raquel remained dominant over Rastus and chased him when he approached the feed trough yet allowed him to eat with her when he insisted on remaining. During May 1975 the two moose travelled together and again formed a moose bond.

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JOB PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: Albert W. Franzmann and Paul D. Arneson

Project Nos.: W-17-7 Project Title: Big Game Investigations

Job No.: 1.14R Job Title: Development and Testing of New Techniques

Period Covered: July 1, 1974 to June 30, 1975

SUMMARY

Succinylcholine chloride (Anectine) with Hyaluronidase (Wydase) continued to be the drugs of choice for routine immobilization of adult moose at the Kenai Moose Research Center (MRC) and for helicopter tagging operations. All calves at the MRC were immobilized with etorphine hydrochloride (M99) and reversed with diprenorphine hydrochloride (M50-50). Immobilization cost using M-99 and M50-50 increased to $18.00 per calf and up to $60.00 for adult moose. No new drugs were tested during this report period.

Pellet count census evaluation studies continued and an additional year of data from Pen 1 was obtained. Pellet groups/moose/day were obtained by back-tracking moose in snow for 24-hour periods. Twenty-five 24-hour trackings were made of four different adult female and four different adult male moose. Mean daily defecation rates were 19.6 for adult male and 14.6 for adult female moose. These rates were significantly different (a=0.01). Beds/day/female moose were 5.4 and for male moose 5.5 beds. Moose-days for each of the MRC enclosures were calculated on a monthly basis from 1967 to present to facilitate pellet group census evaluation.

A proposal for biotelemetry studies at the MRC entitled "Telemetric application to physiologic, metabolic and behavioral studies of Alaskan Moose" was prepared and submitted.

Rumen liquor may be collected from moose by surgical rumenotomy under special conditions.

BACKGROUND

Moose *(Alces alces)* research and management require methods of estimating numbers and of handling, marking and following animals. These techniques necessarily vary with location of the management/research problem. The Kenai Moose Research Center (MRC), with known numbers of confined animals, provides a unique test-ground for numbers-related techniques and for methods and equipment whose effectiveness can only be estimated by relocation of the animal. Developments in many fields that provide drugs, equipment and procedures potentially applicable to moose management determined the thrust of activity under this job objective. A final report covering activities under this project from June 1969 through June 1974 was completed (Franzmann et al. 1974). The project has been renewed and will be continued corresponding to activity at the MRC.

Immobilizing, reversing and adjunct drugs applicable to handling moose at the MRC were reviewed and evaluated (Franzmann et al. 1974). The criteria for an ideal immobilizing drug for moose as outlined by LeResche and Davis (1971) remain valid, and testing of new drugs as they become available against these criteria should continue.

A pellet count census evaluation for moose was initiated at the MRC and preliminary findings were reported (Franzmann et al. 1974). A recommendation from this report was that daily winter defecation rates for moose at the MRC were required since published data from other areas may not be applicable.

The problems and promise in application of biotelemetry to MRC projects were reviewed (Franzmann et al. 1974). As a result of these investigations, a proposal was prepared, during this report period, entitled "Telemetric application to physiologic, metabolic, and behavioral studies of Alaskan moose".

Van Dyne (1968) reviewed techniques for measuring dietary preferences and digestibilities of foods selected by large herbivores. Previous studies at the MRC have utilized techniques involving observation of free-ranging animals (LeResche and Davis 1973), estimating food intake by observing browsed plants (LeResche and Davis 1971 and Oldemeyer 1974), rumen contents analyses of shot animals (LeResche and Davis 1971), fecal analysis (LeResche et al. 1973) and in vitro digestibility trials (Oldemeyer 1974, Franzmann et al. 1974). In vitro digestibility trials required obtaining moose rumen liquor. Rumen sampling from elk *(Cervis canadensis)* and deer *(Odocoileus* sp.) utilizing a rumen trocar technique was reported by Follis and Spillett (1972). Rumen sampling utilizing a stomach tube and pump is a procedure regularly utilized in the practice of veterinary medicine. A method to obtain rumen liquor for in vitro digestion trials in an efficient and effective manner without sacrifice of the individual was required. Franzmann et al. (1974) discussed and reviewed the difficulties associated with rumen liquor sampling from free-ranging moose. Despite the collection problems, the MRC has provided rumen liquor for in vitro digestion trials (Oldemeyer 1974, Oldemeyer et al. 1975). Surgical entry into the rumen (rumenotomy) (Frank 1953) may be considered an additional rumen liquor collection method.

PROCEDURES

Immobilizing Drugs

No new drugs were tested during this report period, however, complete records were maintained of all drugs routinely used to capture moose at the MRC and for tagging operations.

Pellet Count Census Evaluation

The sampling and counting procedure for evaluating pellet count census techniques at the MRC was described previously (Franzmann et al. 1974). Plots in Pen 1 were counted and cleared one additional time in May 1975 for a total of five consecutive winter samples.

Moose were back-tracked on fresh snow during winter 1974-75 to determine daily defecation rates. The initial sighting of each moose was recorded and marked and the following day the moose was tracked until relocated. Time, pellet groups, beds and urinations were recorded. If tracks of moose intermingled and positive identification of a track could not be made, the data were discarded. Observations did not generally coincide with 24-hour periods, however, rates were adjusted accordingly.

In conjunction with the pellet count census evaluation it was necessary to determine winter moose-days in Pen 1. Moose-days were calculated from individual moose records maintained at the MRC for each pen as these data would also be useful for other studies.

Biotelemetry

A proposal was prepared and submitted to an outside foundation for consideration based upon previous investigations into biotelemetry feasibility (Franzmann et al. 1974).

Rumen Sampling

Surgical entry into the rumen (rumenotomy) was used as a method to obtain rumen liquor in addition to methods previously reported (Franzmann et al. 1974). The procedure used was adapted to moose from the technique described by Frank (1953).

FINDINGS

Immobilizing, Reversing and Adjunct Drugs

Succinylcholine chloride (Anectine-Burrough Wellcome and Co., Research Triangle Park, N.C.) with hyaluronidase (Wydase-Wyeth Laboratories Inc., Philadelphia, Pa.) continued to be the drug of choice for routine immobilization of adult moose at the MRC and for helicopter tagging operations (Franzmann and Arneson 1974). All calves were immobilized with etorphine (M99-D-M Pharmaceuticals, Inc., Rockville Md.) utilizing 3 mg of the drug. Reversal was accomplished by intraveneous injection of 6mg diprenorphine (M50-50-D-M Pharmaceuticals, Inc., Rockville, Md.). Of 22 calves immobilized 3 had a poor immobilization response, nevertheless, all were handled and sampled.

Both etorphine and diprenorphine are now commercially available but they still remain under the restrictions of the Bureau of Narcotics and Dangerous Drugs. It now costs approximately $18.00 to immobilize and reverse a calf and up to $60.00 for an adult moose provided there are no misses and lost charges.

No new drugs were tested during this report period. The use of xylazine (Rompun-Chemagro, Kansas City, Mo.) for long-term immobilization is described under the Rumen Sampling section of this report.

Pellet Count Census Evaluation

Twenty-five 24-hour trackings were made of four different adult male and four different adult female moose within the MRC enclosures from February 19 to March 21, 1975 (Table 1). Mean daily defecation rates were 19.6 for adult male and 14.6 for adult female moose. Rates were significantly different (a=0.01) between males and females. Information on defecation rates and this year's pellet-plot counts will be incorporated into the manuscript previously prepared (Franzmann et al. 1974) and submitted for publication.

Numbers of beds/day were also recorded and the mean beds/day was 5.5 (range-4 to 7) for adult male and 5.4 (range-4 to 7) for adult female moose. Urinations per day were recorded initially, but it was soon discontinued due to difficulty in accurately determining and locating urination tracks.

Historical moose-days figures for each of the MRC enclosures were calculated from individual moose records maintained since initial closure of each pen. Tables 2 and 3 summarize moose-days for each enclosure on a monthly basis since 1967. This information was utilized for the pellet-group census evaluation calculation for Pen I. Moose-days data for all the enclosures were required for browse production and utilization studies.

Rumen Sampling

On August 15, 1974, the semi-tame castrated male moose (Wally Jr.) was trapped and immobilized to collect rumen liquor. Xylazine (Rompun-Chemagro, Kansas City, Mo.) was utilized as the immobilizing drug and 10 ml (100 mg/ml.) was the initial dose. After several periods of lying down and getting up, we pulled him down and injected an additional 3 ml xylazine intravenously, 11 minutes after the initial dose.

The stomach tube and pump method of obtaining rumen liquor was attempted; however, after several unsuccessful attempts we prepared the animal for a rumenotomy. Due to previous difficulties with the rumen pump method (Franzmann et al. 1974) we were prepared to attempt the rumenotomy.

Table 1. Pellet-groups/day/adult male and adult female moose during February and March 1975 at the MRC

	Males	Females	Combined
Number of individuals observed	4	4	8
Number of days observed	15.93	8.81	24.73
Mean pellet groups per day	19.61[1]	14.58[1]	17.64
Std. deviation	3.32	3.86	4.27
Range	14-25	10-22	10-25

1 - A t-test indicated significant differences between male and female daily defecation rates (a=0.01)

Table 2. Summary of moose days for Pens 1 and 2 by month from 1967 thru 1974 at the Kenai Moose Research Center.

PEN I

	1967	1968	1969	1970	1971	1972	1973	1974	
Jan	217	292	279	248	465	465	391	248	2605
Feb	196	232	252	224	410	435	326	224	2299
Mar	217	248	279	248	403	403	341	232	2371
Apr	210	240	265	240	390	360	330	210	2245
May	241	288	248	280	459	380	367	225	2488
June	300	414	240	360	600	390	396	240	2940
July	310	434	248	372	620	403	403	248	3038
Aug	310	434	248	372	599	403	403	224	2993
Sep	300	290	240	360	572	360	390	198	2710
Oct	310	279	248	425	623	373	260	186	2704
Nov	300	270	240	450	657	344	240	180	2681
Dec	310	279	248	465	682	410	248	186	2828
Total	3221	3700	3035	4044	6480	4726	4095	2601	31902

PEN 2

	1967	1968	1969	1970	1971	1972	1973	1974	
Jan	310	465	496	434	589	503	469	465	3731
Feb	280	421	448	379	532	511	358	417	3346
Mar	310	403	496	403	589	586	320	417	3524
Apr	300	390	480	390	570	467	265	360	3222
May	350	403	528	437	645	466	194	404	3427
June	450	390	536	510	780	510	210	480	3866
July	465	372	501	527	789	505	260	482	3901
Aug	465	372	465	527	723	465	310	426	3753
Sep	450	490	450	510	690	480	264	408	3742
Oct	465	527	465	527	713	556	441	434	4128
Nov	450	510	450	510	690	523	450	420	4003
Dec	465	527	465	589	713	465	465	434	4123
Total	4760	5270	5780	5743	8023	6037	4006	5147	44766

Table 3. Summary of moose days for Pens 3 and 4 by month from 1967 thru 1974 at the Kenai Moose Research Center.

PEN 3

	1969	1970	1971	1972	1973	1974	Total
Jan		310	341	372	217	279	1519
Feb		280	308	307	196	252	1343
Mar		310	341	279	217	247	1394
Apr		300	330	255	210	210	1305
May		314	373	248	233	233	1401
June		330	450	210	270	270	1530
July		341	465	217	279	279	1581
Aug	310	341	446	217	279	255	1848
Sep	360	330	390	210	270	240	1800
Oct	364	341	419	217	279	248	1868
Nov	330	330	420	210	270	240	1800
Dec	341	341	434	217	279	248	1860
Total	1705	3868	4717	2959	2999	3001	19249

PEN 4

	1969	1970	1971	1972	1973	1974	Total
Jan		541	527	830	728	620	3246
Feb		434	481	739	510	560	2724
Mar		434	558	604	527	538	2661
Apr		374	540	431	439	480	2264
May		412	606	440	315	489	2262
June		510	720	410	323	553	2516
July		527	744	434	413	589	2707
Aug	651	527	737	434	474	589	3412
Sep	570	510	711	446	480	510	3227
Oct	589	527	893	508	548	527	3592
Nov	570	510	1105	638	544	510	3877
Dec	558	527	1249	734	620	527	4215
Total	2938	5833	8871	6648	5921	6492	36703

A tarpaulin cover was placed over the area in the trap to shade the animal. The animal was placed in lateral recumbency with his head uphill and the left side up. The legs and head were tied to prevent premature standing.

Following preparation of the surgical site, the incision area was infiltrated with procaine. Surgical procedure followed the description by Frank (1953). The only modification was that we simply removed and strained the rumen contents into a preheated thermos bottle and then the closure was made.

It was necessary to supplement the initial immobilizing dose 57 minutes later with 2 ml of xylazine. The surgical procedure from initial incision to closure required 59 minutes and the animal was down 86 minutes. The moose was kept in the trap for several hours until he completely recovered from effects of xylazine. He was then released and retained in the "calf pen" for observation and medication. The following day penicillin was adminstered via Cap-Chur equipment and he was released back into Pen 2 on September 12. Twenty-eight days later he was again trapped and the skin closure was incomplete; however, sub-skin healing was complete. The skin closure required an additional 30 days for complete healing.

This procedure has many obvious disadvantages such as time, equipment and personnel required. It may, however, be considered a method of choice when large quantities of rumen liquor are required, when an animal cannot be salvaged, and when other methods fail.

Rumen liquor collected was utilized for in vitro digestion trials. The following is an account by Ellie Groden, a work-study assistant to John Oldemeyer, outlining the general procedure:

The digestion trial follows the two-stage method described by Tilley and Terry (1963) as modified by Pearson (1970).

Materials

The predominant moose browse species of each site was selected for the analysis. Samples of only the current annual growth of leaves and twigs were taken from various plants in each plot. At sites where black or white spruce (*Picea mariana* or *P. glauca*) dominated the vegetation, willow was selected as the predominant moose browse species; where paper birch (*Betula papyrifera*) was predominant, it was collected; and from all mature timber stands aspen (*Poplus tremuloides*) saplings represented the predominant browse species and was collected. Lowbush cranberry (*Vaccinium vitis-idaea*) which was present in all plots, and is an important winter food source for moose, was collected from two plots in each of the areas, along with the predominant browse species from that plot.

Methods

Mechanical Digestion: The dried plant material from each plot was ground first in an Osterizer blender, then in a hand grinder until fine enough to pass through a 30-mesh sieve. Ground plant material was again put in the oven and dried at 90°C overnight.

Duplicate 0.5-gram samples of the oven-dried forage were weighed into 100-ml test tubes. These plus six blank tubes and six tubes containing 0.5-gram samples of ground commercial calf ration were randomly placed in a water bath at 38°C until needed.

A rumen sample was taken by rumenotomy on a semi-tame moose at the Kenai Moose Research Center on the Kenai Moose Range. The moose had been trapped the previous night. Forage material and juices were extracted from the open rumen of the live moose and the juices were strained through several layers of cheesecloth into a prewarmed thermos. The rumen liquor and a buffer were added to the plant material within three hours of removal from the moose.

Micro-organismal Digestion: Once obtained, one part rumen liquor was mixed with four parts buffer solution. Fifty ml of the mixture was added to each tube, and each was gassed with CO_2 before stoppering to assure anerobic conditions. During incubation in the water bath, the tubes were sealed with a Bunsen gas release valve. The 4mm-slit in the rubber tube on the valve normally remains closed, opening only to release gas from inside the tube, not allowing any to move into the tube from outside (Tilley and Terry 1963). The tubes were shook and gas release valves checked at 3, 6, 9, 18, 23, and 26 hours from the start of incubation.

Pepsin Digestion: After 48 hours of micro-organismal digestion, bacterial activity was checked and pepsin digestion begun by the addition of 2.2 ml of acid solution to each tube, followed by 5 ml of pepsin solution. The tubes were incubated for 48 hours at 38°C, and were shook and their gas release valves checked at 0, 4, 8, 16, 22, and 27 hours.

After the 48 hours of incubation, digestion was stopped by the addition of 12 ml $NaCO_3$ solution, raising the pH to near 7.0.

Filtration: Vacuum filtering of the material in each tube was begun immediately following completion of digestion stages. Once most of the moisture was suctioned out of the material, the residue on the filter paper was put in the oven at 90°C and left to completely dry overnight.

After two days of drying, the samples were weighed. The percent material digested was calculated using the average weight of the material in the blank tubes as a base point, according to the following equation:
% digestibility =
1.0 - (wgt. filtered plant material-ave. wgt. blanks) /0.5g

Biotelemetry: A proposal for biotelemetry studies at the MRC entitled "Telemetric application to physiologic, metabolic and behavioral studies of Alaskan moose" was submitted to an outside agency for funding.

RECOMMENDATIONS

Efforts should continue in testing and evaluating new immobilizing drugs for moose as they become available.

The rumenotomy procedure for collecting moose rumen liquor may be considered an additional method warranted under special conditions.

New techniques developed in other areas of research should be continually evaluated for their potential application to moose management.

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