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MOOSE RESEARCH CENTER REPORT

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Progress Report
Federal Aid in Wildlife Restoration
Project W-22-4, Job 1.28R and 1.31R

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PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: Mike Hubbert, Institute of Arctic Biology, Univ. of Alaska, Fairbanks

Project No: W-22-4 Project Title: Big Game Investigations

Job No.: 1.28R Job Title: Moose Nutrition and Physiology Studies

Period Covered: 1 July 1984-30 June 1985

SUMMARY

Major studies conducted during this period at the Moose Research Center (MRC) centered around refining the carrying-capacity model. Nine moose were put into 3 treatments and fed a pelleted diet *ad libitum*. These treatment diets were balanced to contain 2.7, 2.3, and 1.9 Kcal metabolizable energy (ME) per kg of feed. Changes in weight, body fat, rumen turnover, and metabolic rate were monitored. Animals on all treatments had similar weight dynamics and body fat reserves. Animals on 2.3 and 1.9 ME intake levels consumed more feed to compensate for lower digestibility. Samples for radioassay were prepared and analyzed for water. Rumen turnover studies were conducted and data from those studies are presented in this report. Weight data from the captive moose herd are presented. Data on life histories of moose from the MRC enclosures are presented.

Key Words: moose, nutrition, physiology, productivity.

CONTENTS

BACKGROUND

Digestive physiology studies with captive moose (Alces alces) were initiated in 1979 (Franzmann and Schwartz 1979) as part of the moose productivity and physiology project outlined by Franzmann et al. (1976). The major goal of these studies was to develop a carrying-capacity model for moose on the Kenai Peninsula. Background pertaining to this subject has been discussed (Franzmann and Schwartz 1979). In general, we were attempting to integrate information on the nutritional requirements of moose, with information on the nutrients supplied from the vegetation.

The program is two-fold: (1) vegetative biomass and nutrient quality will be determined, and (2) moose nutrient requirements and digestive physiology will be measured. This report describes ongoing research into the nutrient requirements of moose. The overall objective of these digestive physiology studies is to obtain input data for use in a carrying-capacity model. Major emphasis this year centered around testing a previously developed (Swift 1983) simulation model.

Part of the long-range objectives for research at the Moose Research Center (MRC) involves the development and testing of a carrying-capacity model for moose (Franzmann and Schwartz, 1979). This carrying-capacity model consists of 2 components, a submodel which simulates nutrient flows within the moose, and a submodel which allocates available vegetation biomass and associated nutrients from a range or habitat to the moose.

The moose submodel was originally developed for elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) in Colorado (Swift, 1983) and has been adapted to moose. The model basically simulates the flow of energy and protein through the ruminant system and predicts changes in lean body weight and fat weight based on energy and protein intake.

This ruminant submodel is an integral component of the overall carrying-capacity model, and refinement and testing is a major objective of ongoing research at the MRC.

Body condition is central to the current concept of carrying capacity, and changes in total, lean, and fat weight are integral components of the ruminant submodel. Weight change has been used as the indicator of energy or protein status; changes in weight reflect diet quality. Body composition of moose has received no attention to date. Since metabolic differences exist between moose and other domestic and wild ruminants, use of these data is questionable. Body composition is generally assumed to be the chemical composition of an animal's body, or the percentage of fat, water, protein, and ash. Absolute and relative magnitude of these components is indicative of an animal's nutritional state.

The relationship between fat and water content within the body, and their negative correlation, was first discovered by Pace et al. (1947). This relationship is quite useful in predicting the total fat content of an animal's body. Pace et al. (1947) developed a mathematical relationship which shows that average water content of the fat-free mass is 72.6% and percent fat may be calculated by: $\% \text{ fat} = \frac{100 - \% \text{ TBW}}{0.726}$ where TBW is total body water. This relationship has led to the present conceptual model of body composition.

This generalized formulation has been used for a variety of domestic species. Robbins (1973) developed specific relationships between body composition components of white-tailed deer (*Odoceileus virginianus*): the relationship is between the concentrations of water (x) and fat (y) in the ingestion-free body: $y = 79.98 - 1.0757x$.

Both relationships hold promise in predicting total fat reserves in moose based upon quantification of total body water. Torbit (1981) compared body composition estimates of mule deer, based on total body water calculated chemically, with estimates based on tritiated water (TOH). Estimates from TOH for total body water were consistently lower than chemical estimates for this component; however, differences were small and strong statistical relationships existed. Current research at the MRC centers around estimates of body composition based on body water relationships. Additionally, studies to estimate minimum maintenance energy requirements, seasonal metabolic rates, changes in rumen flow, and dry matter digestion are components of this study.

OBJECTIVES

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

To apply the above criteria to various Alaskan moose populations.

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

To determine nutritional value and digestibility of the common moose forage species and to relate hair element monitoring to moose mineral metabolism.

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

To develop and test a formulated diet capable of meeting the essential nutrient requirements of captive moose.

To determine crude protein and gross energy requirements for various sex and age classes of captive moose on a seasonal basis.

To determine the effects of various levels of nutrient quality on blood parameters in captive moose.

To compare the ability of captive moose to digest and assimilate a formulative diet, versus 4 major food items consumed either singly or in combination by wild moose during winter.

The goal is to obtain a 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 physiology, is an integral part of this goal.

PROCEDURES

Experimental Methods

Nine moose composed of 6 adult females and 3 males (1 yearling, 2 adults), originating from a wild population in Alaska, were used as experimental animals. Animals were hand-reared as described by Regelin et al. (1979) and maintained on a special moose ration (Schwartz et al., 1980, 1985).

Research trials began 27 November and ended on 22 April, a period of time equivalent to winter in Alaska. Animals were assigned at random to 3 treatment groups defined by 3 different levels of feed energy. These treatments (Table 1) were assigned as 2.7, 2.3, and 1.9 Kcal of metabolizable energy (ME) per kg feed. Animals were given the diets *ad libitum*. It was our intention to simulate wintering animals on 3 types of winter range, with good- to poor-quality range available. We expect these ME levels to cause minimal, moderate, and severe loss of body weight, or for animals on low ME diets to adjust dry matter intake to compensate for poor diet quality.

Moose were randomly assigned to each treatment except that 1 male was included in each group. Animals were held in individual isolation pens (2.5 x 13.0 m) and fed once daily at 1000 hours; water and trace mineral salt were available *ad libitum*. Animals were weighed once a week. At 4-week intervals, animals were injected with tritium and placed in digestion cages for estimation of total body water. Body composition was estimated for all moose every month. Because of a limited number of digestion cages, 3 animals were tested weekly. The sampling design used was to estimate, in a single week, total body water in all animals from the high energy treatment. The 2nd treatment (medium energy) was sampled the 2nd week, and the 3rd treatment (70% energy) was sampled the 3rd week. When body water was estimated, each animal was given a deep muscle injection of 2 ml of a physiological saline solution containing 1 microcurie of tritiated water per gram. Injections were administered to undrugged animals while they stood on the scale for weighing. After injection, animals were moved to the digestion cages, but they were not locked in until 4-6 hours post-injection time. Urine samples were collected at approximately 12-hour intervals for 4 days. Collection trays were cleaned with water prior to each trial. At the conclusion of a trial, animals were returned to their individual isolation pens.

Urine samples were analyzed for tritium according to the methods described by Holleman et al. (1982).

Rumen solid and liquid turnover rates were estimated at monthly intervals using the elements cobalt and ytterbium as described by Hart and Tolan (1984). Moose were given a single oral dosage on a feed sample. The moose were given access to eat the sample for 15 minutes, after which it was removed. Fecal samples were collected at each defecation the 1st day and at 6-hour intervals for the following 2 days.

Resting metabolic rates and methane production were estimated over a 12-hour period using a metabolic chamber and methane analyzer previously described by Regelin et al. (1981).

Digestion of dry matter was estimated using conventional digestion and balance trails (Church 1969, Schneider and Flah 1975, Ensminger and Olentine 1978).

Productivity and Mortality of MRC Moose

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

Moose within the MRC enclosures were moved from 1 enclosure to another or released outside the enclosures in an attempt to obtain approximately the following numbers and distributions: Pen 1 (2.5 moose); Pen 2 (3 moose); Pen 3 (2 moose); and Pen 4 (1 moose). One moose from Pen 1 was to be removed on 25 March 1985. Moose were moved utilizing an etorphine (M99, Lemmon Company, Sellersville, Pa.) and xylazine hydrochloride (Rompun, Haver-Lockhart, Shawnee, Kans.) mixture for initial immobilization of trapped animals. Each animal was routinely processed when immobilized (Franzmann et al. 1976). Numbers of moose were set to utilize approximately 34%, 77%, 59%, and 100% of the current annual growth of birch in Pens 1-4, respectively.

RESULTS AND DISCUSSION

Trials were initiated on 9 December 1984 and continued through 25 April 1985, followed by 3 weeks of metabolic trials. Intake varied in all treatments throughout the trial (Table 2-4), but generally followed the intake pattern established in previous studies (Schwartz et al., in press). Animals consuming the medium and low ME diets tended to compensate for the lower caloric value of the feed by eating more (Tables 2-4); data analysis on this subject was not complete enough to make statistical tests for this report.

Samples collected for both rumen and water turnover are currently being analyzed, so estimates of rumen turnover time and total body fat were not available for this report. Estimates of digestion of dry matter and individual nutrients will be made in the final report.

Productivity and Mortality of MRC Moose

Histories of individual moose through 30 June 1985 are listed in Tables 5-8. Mortalities are listed in Table 9. Moose numbers approximated those established for carrying-capacity estimates established last year.

Moose Weights

We continue to collect routine weight date from the tame moose (Tables 10-12). Weight data collected in the past were analyzed and presented in a manuscript at the 2nd International Moose Symposium, in Uppsala, Sweden. An abstract of this manuscript is presented in Appendix A.

Testing Carrying-Capacity Model

The carrying-capacity model was tested at the MRC facility. Results were reported in a separate report and have been included in Appendix B.

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Table 1. Percent composition of pelleted ration fed to moose during winter at the Moose Research Center (MRC), 1984-85.

	Diets[a]	
Ingredients	MRC special (high energy)	Rice hull (low energy)
Corn	28.7	26.4
Sawdust	25.9	23.6
Oats, rolled	17.2	0
Soybean meal	6.3	5.5
Cane molasses	5.7	7.5
Barley	5.7	0
Beet pulp	5.7	0
Rice hulls	0	34.1
Vitamin premix	0.3	0.1
Dical	1.3	1.1
Pelaid	1.4	1.3
Mycoban	T	0.1
Crude protein	9.5	6.8
Metabolizable energy	2.2	1.54
Crude fiber	24.7	34.9

[a] Medium energy treatment was a 50:50 ratio of the high and low energy ration and contained 8.4 crude protein, 2.3% ME, and 29.5% crude fiber.

Table 2. Weekly weight and intake of dry matter for 3 moose fed a pelleted diet containing 2.7 Kcal/g of metabolizable energy.

Date	Oly		Angel		Bando	
	Wt (kg)	g/BW$^{0.75}$	Wt (kg)	g/BW$^{0.75}$	Wt (kg)	g/BW$^{0.75}$
12/9/84	418	21.89	469	45.48	395	68.34
12/16/84	418	52.68	471	47.88	404	65.46
12/23/84	419	56.92	461	45.84	400	61.57
12/30/84	419	51.96	458	45.63	398	68.38
1/6/85	415	47.95	465	42.95	410	65.37
1/13/85	418	58.35	459	45.01	418	58.91
1/20/85	420	55.31	463	44.85	417	55.74
1/27/85	419	66.10	456	45.50	412	73.12
2/3/85	422	56.91	461	47.53	416	73.26
2/9/85	422	56.98	459	51.40	414	76.27
2/18/85	420	24.64	460	40.51	403	56.16
2/25/85	414	47.02	458	49.07	410	63.50
3/4/85	409	49.89	457	49.46	403	75.78
3/11/85	413	48.50	467	52.74	414	62.72
3/18/85	417	52.58	471	41.34	416	63.73
3/25/85	411	57.18	467	42.08	414	61.26
4/1/85	419	46.94	473	52.22	418	70.59

Table 3. Weekly weight and intake of dry matter for 3 moose fed a pelleted diet containing 2.3 Kcal/g of metabolizable energy.

	Trixie		Lucy		Charlie	
Date	Wt (kg)	$g/BW^{0.75}$	Wt (kg)	$g/BW^{0.75}$	Wt (kg)	$g/BW^{0.75}$
12/9/84	478	61.53	413	59.74	396	27.22
12/16/84	482	63.12	406	73.13	403	58.06
12/23/84	479	62.65	410	72.07	398	70.57
12/30/84	488	43.91	416	66.89	396	61.25
1/6/85	470	52.19	418	63.05	401	62.07
1/13/85	477	58.19	414	59.28	402	63.30
1/20/85	473	66.14	418	69.42	402	67.35
1/27/85	481	61.76	413	77.54	401	66.76
2/3/85	484	58.82	405	65.42	397	65.25
2/10/85	476	49.71	407	59.68	397	46.74
2/17/85	474	47.42	405	70.45	398	47.01
2/24/85	477	52.02	409	72.05	390	74.75
3/3/85	473	48.19	410	68.78	379	72.82
3/10/85	468	42.58	413	67.14	381	70.33
3/18/85	471	49.54	411	73.34	389	57.95
3/25/85	471	50.83	415	64.77	384	63.22
4/1/85	474	55.25	417	68.64	387	65.36

Table 4. Weekly weight and intake of dry matter for 3 moose fed a pelleted diet containing 1.9 Kcal/g of metabolizable energy.

	Deneki		Jezebel		Joker	
Date	Wt (kg)	$g/BW^{0.75}$	Wt (kg)	$g/BW^{0.75}$	Wt (kg)	$g/BW^{0.75}$
12/9/84	468	84.31	435	85.73	421	82.27
12/16/84	478	84.82	425	68.04	428	98.79
12/23/84	481	77.71	432	88.88	434	74.00
12/30/84	477	69.57	431	84.64	431	74.81
1/6/85	475	62.09	424	78.40	428	81.76
1/13/85	467	73.89	426	90.56	431	86.56
1/20/85	473	79.81	433	92.11	431	84.97
1/27/85	474	64.97	439	95.74	433	77.84
2/3/85	456	50.52	441	74.02	428	76.18
2/10/85	445	66.84	439	81.04	427	85.78
2/17/85	441	42.15	426	77.04	420	89.86
2/24/85	433	35.66	431	67.86	422	82.43
3/3/85	434	63.65	415	67.98	421	82.69
3/11/85	426	13.71	428	92.95	427	94.87
3/18/85	--	--	430	88.30	432	96.08
3/24/85	--	--	431	88.05	433	82.03

Table 5. Histories of Pen 1 moose at Kenai Moose Research Center (1 July 1984-30 June 1985).

Moose No.	Sex	Year of birth	Significant observations: Date	Event	Remarks	No. of times observed	No. of times captured
23-83[a]	F	?	27 Sep 1984	Trapped.	Drugged and moved to Pen 4 with trailer.	4	1
Uncollared calf of 26-83[a]	F	1984	25 Mar 1985	Terminated.	Rumen liquor	Many[b]	0
26-83	F	?	30 Jun 1985	Still in pen.	Cow observed after this date.	Many[b]	1

[a] Moose no longer living in this pen.
[b] Moose No. 26-83 was radio-tracked several times throughout the winter. Her calf was usually observed with her.

Table 6. Histories of Pen 2 moose at Kenai Moose Research Center (1 July 1984-30 June 1985).

Moose No.	Sex	Year of birth	Significant observations Date	Event	Remarks	No. of times observed	No. of times captured
1-84[a]	M	?	9 Oct 1984	Trapped.	Previously uncollared, released outside of pens. Probably broke into pen during previous winter.	1	1
28-85	F	?	30 Jun 1985	Still in pen.	Caught and initially collared on 24 Feb 1985. Previously seen several times while uncollared.	Many[b]	1
Uncollared calf of 28-85	?	1984	8 Jun 1984	Last seen.	Only seen once. Mother often seen later along. Assumed to have died before 30 Jun 1984.	1	0
27-83	F	?	30 Jun 1985	Still in pen with calf.	Seen with calf after 30 Jun 1985.	Many[b]	2
4-83[a]	M	?	1 Oct 1984	Trapped.	Released outside of pens. Radio collar removed.	3	1

[a] Moose no longer living in this pen.
[b] Cows No. 27-83 and 28-85 were both radio-tracked several times during the winter.

Table 7. Histories of Pen 3 moose at Kenai Moose Research Center (1 July 1984-30 June 1985).

Moose No.	Sex	Year of birth	Significant observations Date	Event	Remarks	No. of times observed	No. of times captured
23-83	F	?	30 Jun 1985	Still in pen.	Radio signal heard on normal mode after 30 Jun 1985.	Many[a]	1
Uncollared	F	?	1 Feb 1984	Last seen.	Not certain that this cow is still alive. Not seen during reporting period.	0	0

[a] Cow No. 21-83 was radio-tracked several times during the winter.

Table 8. Histories of Pen 4 moose at Kenai Moose Research Center (1 July 1984-30 June 1985).

Moose No.	Sex	Year of birth	Significant observations			No. of times observed	No. of times captured
			Date	Event	Remarks		
23-83	F	?	30 Jun 1985	Still in pen.	Cow observed after this date. Captured in Pen 1 and moved to Pen 4 on 27 Sep 1984.	Many[a]	1

[a] Cow No. 23-83 was radio-tracked several times during the winter.

Table 9. Mortality within enclosures at Kenai Moose Research Center from (1 July 1984-30 June 1985).

Pen No.	Moose No.	Sex	Year of birth	Date	Remarks
1	Uncollared (Calf of 26-83)	F	1984	25 Mar 1985	Calf terminated. Rumen liquor collected.
2	Uncollared	?	1984	8 Jun 1984	Calf probably died prior to this reporting period. Calf was seen only once (8 Jun 1984) and was not seen on 30 Jun 1984 or on other later occasions when the mother was observed.

Table 10. Weights in kilograms of 9 adult moose at Kenai Moose Research Center (9 July 1984-30 June 1985).

1984	Chief	Lucy	Angel	Jezebel	Trixie	Oly	Deneki	Joker	Charlie	Comments
Jul 9	514	390	421	404	413		344			
10							339			
11	525						347			
13				398						
14			424		418		344			
15	517									Chief put back into 15-acre pen.
18		381							406	Charlie put back into 15-acre pen.
19	528									
20						345		400		Joker put back into 15-acre pen.
25	542						366			
27			426	410	426	346		417	430	
30		392								
31				414						
Aug 3	562	389	431	421	428	359	375	412	393	Charlie very lame in left hind leg.
4	554	394	428		433					
5	557	402	429	417		373				
12	565	406	442	415	440	356	400		384	Charlie still very lame.
16	576									
20	586		446	427	450	365	407	467	392	Charlie putting some weight on bad leg.
28	567	407	449		459	379	416	470		Charlie beginning to shed velvet.
29				406					413	Charlie shedding velvet.
Sep 3				421						
5			435		461		418	459		
6	545	388				365			423	
12	526						434	440	399	
13	518							435	397	Bulls' antlers removed.
14		366	432	396	428	359	439			
17				402			446			
21	485	375	443		417		435			
23				405		358				

Table 10. Continued.

1984	Chief	Lucy	Angel	Jezebel	Trixie	Oly	Deneki	Joker	Charlie	Comments
Sep 24									364	
28			429		412		419			Angel, Trixie, Deneki returned to 15-acre pen.
30		368								
Oct 4	456					360				
5			413	379						
6				392			409	367	346	Chief escaped; Deneki in estrus.
7		359								Lucy in estrus.
12		357					415	371	346	Charlie has infection near left eye.
25	444	378	435	380	431	385	428	384	364	
Nov 8			450	408	446	411	443		378	
9	480	390						409		
15		390					452			
16	485	392	460	416	458	423		419	384	
26	498	410	463			423	465	420	387	
27				429	468					
Dec 3	506	413	469	435	478	418	468	421	396	
10	526	406	471	425	482	418	478	428	403	
17	523	410	461	432	479	419	481	434	398	
22							477			Deneki in chamber.
24		416	458	431	488	419	477	431	396	Deneki in chamber.
25	526			429						Jezebel in chamber.
26								427		Joker in chamber.
27					483					Trixie in chamber.
28		419								Lucy in chamber.
29									401	Charlie in chamber.
30						424				Oly in chamber.
31	523	418	465	424	470	415	475	428	401	Angel in chamber; TOH[a]-Deneki, Jez, Joker.

Table 10. Continued.

1984	Chief	Lucy	Angel	Jezebel	Trixie	Oly	Deneki	Joker	Charlie	Comments
Jan 7	526	414	459	426	477	418	467	431	402	TOH-Trixie, Lucy, Charlie.
14	520	418	463	433	473	420	473	431	402	TOH-Oly, Angel, Bando.
21	524	413	456	439	481	419	474	433	401	
28		405	461	441	484	422	456	428	397	TOH-Deneki, Jez, Joker.
29	526									Chief has lost both antler bases.
Feb. 4	535	407	459	439	476	422	445	427	397	TOH-Trixie, Lucy, Charlie.
11	533	405	460	426	474	420	441	420	398	TOH-Oly, Angel, Bando.
16							439			Deneki in chamber.
18	531	409	458	431	477	414	433	420	390	Jez in chamber.
19								422		Joker in chamber.
20					477					Trixie in chamber.
21		414								Lucy in chamber.
22						406				Oly in chamber.
23			460							Angel in chamber.
25	528	410	457	415	473	409	434	421	379	TOH-Deneki, Jez, Joker.
Mar 4	528		467	428		413	426	427		
5		413			468				381	TOH-Trixie, Lucy, Charlie.
11	531	411	471	430	471	417	396	432	389	TOH-Oly, Angle, Bando.
18		415	467	431	471	411	403	433	384	
19	542									
25		417	473	434	474	419	415	435	387	TOH-Deneki, Jez, Joker.
Apr 1	530	415	472	417	473	419	414	425	380	TOH-Trixie, Lucy, Charlie.
8	532	417	479	425	477	417	417	428	379	TOH-Oly, Angel, Bando.
15		425	475	424	475	411	422	416	373	
16							417			
23		420	464	413	474		418		382	Oly released on 19 Apr; Joker, 20 Apr.
24	543									
30	527	414			470			417	369	Lucy, Trixie, Charlie released on 25 Apr.

Table 10. Continued.

1984	Chief	Lucy	Angel	Jezebel	Trixie	Oly	Deneki	Joker	Charlie	Comments
May 1			468	410			415			Angel, Deneki released 1 May; Jez, 2 May.
12		406	461	412	473	400	397			
13	533								387	
19	532	405	457	431		393	399	418	396	
21					428					
22					436					Chief injected with Fluorexon.
23	536		453							
25			387							Angel calved on 23 May.
26	535	415		426	432	397	390	435	397	
27					387					Trixie calved late 26 May or early 27 May.
29			377		371					
Jun 1				425						Jez had calf in 15 acre pen.
2	544				370	376			394	Oly calves in 15 acre pen; Lucy in small pen.
3		376					402			
4			359							
6		351		354			409			First postpartum wt. for Jez.
10,		350	364	362		345	396	404		First postpartum wt. for Oly.
11	560							402		Joker is confined due to broken antler.
12	550						390			Joker given 3rd injection of Combiotic.
15							383		415	
17	545	355	376	374	383	366		396	410	
22		353	378	369	398	365				Lucy, Angel, Jez, Oly put into Pen 2.
23	573									Trixie put into Pen 2.
24							406		418	Joker put into Pen 2.

[a] TOH = tritiated water.

Table 11. Weights in kilograms of 4 yearlings and 1 calf moose at Kenai Moose Research Center (9 July 1984-30 June 1985).

1984-85	Hugo	Bertha	Janie	Bando	Molly	Comments
Jul 9			309	357		
15		264				Bertha put back into 15-acre pen.
16				366		Bando put back into 15-acre pen.
17			313			Janie put back into 15-acre pen.
20	313					Hugo put back into 15-acre pen.
25	323		305	342		
27		278				
31			315	360		
Aug 3	321	280	314	355		
4	328	280				
11	345		329	377		
12		280				
20	359	297	339	393		
28	356	292	350	401		Hugo beginning to shed velvet.
Sep 3				410		
5	372	284	357			
7				413		
12	380		364	413		
13	376			409		Antlers removed from Hugo and Bando.
14		271	358			
21	355	288	373	388		
28	331			366		Bando and Hugo released into 15-acre pen.
30		293	365			
Oct 7	318					
12		296	369			
25	346	306	381	382		
Nov 8	365	321	400	399		
16	369	326	411	408		
26	377	330	411	411		
Dec 3	381			395		
4		333	411			
10	383	340	411	404		

Table 11. Continued.

1984-85	Hugo	Bertha	Janie	Bando	Molly	Comments
Dec 17	383	343		400		
24	393	345	422	398		
31	388	338		410		
Jan 1				420		Bando in chamber.
2			422			
7	394	354	423	418		
14	394	346	418	417		
21	395	354	422	412		
28	394			416		
29		354	414			
Feb 4	395	353	416	414		
11	397	360	419	403		
18	398	359	425	410		
24				415		Bando in chamber.
25	403	365	422	403		
Mar 4	406	367	431	414		
11	404			416		
14		376	423			
18				414		
19	406	370	433			
25	414	372	433	418		
Apr 1	414	381	436	415		
8	419	383	441	419	200	Molly (calf) arrived in early Apr.
15	414	382	445	420		
24					202	Bando released into 15-acre pen, 19 Apr.
28				412		
30	409	380			203	
May 1			446	415		
12		378	432			
13	420			415		
17					215	
19	418	382	427	417	211	
26	409	392		419	225	
Jun 2	409		374	413	217	Janie calved 22/23 May (15-acre pen).
3		387				
6					225	

Table 11. Continued.

1984-85	Hugo	Bertha	Janie	Bando	Molly	Comments
Jun 10					225	
11				422		
12		330	389			Bertha calved late 5 Jun, or early 6 Jun.
15	422					
17	415	333	384	415	220	
24	432	348	404	444	233	Molly and Hugo put into Pen 2.

Table 12. Weight, in kilograms, and histories of 9 moose calves born at Kenai Moose Research Center in 1984 (23 May-9 November).

1984	Trixie's M	Trixie's F (Dos)	Oly's F (Dolly)	Jez's M (Max)	Jez's F (Minnie)	Lucy's F (Bo)	Lucy's M (Sephus)	Deneki	Angel's M	Comments
May 23	13.0	12.5								Trixie's calves born at 2122 and 2136 hrs.
25			14.0							Oly's calf approx. 2-5 hrs. old at 0745 hrs.
26	12.0 (dead)	12.0								Trixie's male died between 2300 and 0600 hrs.
29				14.5	11.5					Jez's twins born between 1430 and 2200 hrs.
30		14.0		15.0	12.0					Weighed on platform scale.
Jun 3		18.0								Dos and Trixie released into 15-acre pen.
4				16.0	15.0					Jez and twins released into 15-acre pen.
7						14.5	13.5			Lucy's calves 1-3 hrs. old at 0600 hrs.
8						14.5	13.5			Weighed on platform scale.
12		Dead								Dos necropsied.
14						16.5	18.5			
15				23.5	22.5					Jez's calves weighed wet.
20								12.0 (dead)		Deneki's calf born dead (90900-1200 hrs.).
21									16.5	Angel's calf 1-4 hrs. old at 0800.
22						17.5	24.0		15.0 (dead)	Angel's calf died before 0800.
24						19.5	25.5			Bo's infected navel better.
27						21.5	27.5			

Table 12. Continued.

1984	Dolly	Max	Minnie	Bo	Sephus	Comments
Jul 7		36.5		27.0	34.5	Bo's navel dirty again.
9					36.0	
13		41.0	44.0			
18				34	44	
20			51(?)			Minnie at feeder with Oly (not her mother).
27	57(?)	54	59(?)			Minnie (?) very wild on scale. Dolly (?) calm. Possible that these calves switched mothers.
28	--	--	--	--	Dead	Dead calf found. Assumed to be Sephus. Probable black bear kill.
30	60			42		Calf with Oly assumed to be Dolly.
Jul 31	58	63				Female calf with Jezebel assumed to be her own (Minnie).
Aug 3	67	63		44		
5				46		
12	75	71	80	49		
20	87	80	89			
28	97					
29		91	101			

Table 12. Continued.

1984	Dolly	Max	Minnie	Bo	Comments
Sep 3	97	108			
5		101			
6	107		111	75	
14	92			75	Bo scouring, Dolly not well.
17		93	102		Calves scouring.
21		93		78	
22	83				Dolly has liquid scours and raw area around tail.
26		96	97		Max and Minnie both still scouring.
30	81	97		82	Dolly and Max still scouring; Bo is not.
Oct 4	77	90	87	84	All calves except Bo still scouring.
12				88	
25				86	Dolly died on 21 or 22 Oct. Bo scouring again. Max and Minnie not seen.
Nov 9				60	Bo in very bad shape, scouring.

Appendix A. Abstract of M. S. presented at 2nd International Moose Conf., Uppsala, Sweden. August 1984.

SEASONAL WEIGHT DYNAMICS OF MOOSE

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Abstract: Total body weight data for moose are presented and discussed. Information from 6 animals (3 males and 3 females) over a 5-year period was analyzed and fitted to standard growth equations. Changes in weight were dynamic seasonally with periods of weight loss and gain different for males and females. Males obtained maximum weights in late August just prior to the rut. They lost between 11-19% of their body weight during the breeding season, which represented the greatest weight loss at any season. Weight loss from pre-rut maximums to post-winter lows ranged from 7-23% and were dependent upon the combined weight loss during the rut and subsequent winter losses. Weight gains from winter lows to pre-rut maximums ranged from 33-41%. Females reached maximum weight in mid-winter, much later than males, while mimimum weights occurred shortly after parturition. Average weight loss ranged from 15-19%. Weight gains from lows to highs ranged from 25-43%. Females giving birth to single or twin calves lost an average of 34.8 and 63.0 kg, respectively. Mathematical fits of maximum weights for males and females using a Brody equation are presented. Data would not fit sinusoidal equations and reasons for the lack of fit are presented. Comparisons with other published weight data for moose are made.

Appendix B. Field Validation of a Moose Carrying-capacity Model

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Introduction

"Carrying capacity," the number of individuals a unit of land can support for a unit of time, is a term commonly used by the wildlife biologist. However, quantification of carrying capacity has been elusive, and meaningful application of the concept is generally nebulous. Early attempts to measure ungulate carrying capacity were based on range or browse transects, indicator plants, or browse utilization methods. Using these techniques, the biologist obtained a better understanding of the relationships between the animal population and its forage base. But, because he could not relate these measurements to the nutritional requirements of the animal, he has seldom been able to quantify numbers of animals that the range could support.

A more recent approach to the problem of quantifying carrying capacity has been to integrate the nutritional needs of the animal with those supplied by the range. This concept of biological carrying capacity requires an understanding of ungulate nutrition, the nutrients the animal must obtain from the range, and the ability of the range to meet those nutritional needs.

This approach to quantifying carrying capacity has been developed and refined through work at the Moose Research Center (MRC) since 1978. A computer simulation model (moose submodel) has been developed that predicts daily forage intake based upon nutritional physiology of moose, their nutrient requirements, and the quality of available forage. The 2nd part of the carrying capacity equation requires quantification of the amount of biomass available for each forage species. A 2nd computer model (vegetation submodel) estimates the amount of available forage and nutrients available with different diet mixes and levels of utilization. When the 2 submodels are integrated, the output is a quantification of the potential carrying capacity of the range being evaluated. The term "potential carrying capacity" is used rather than the actual or realized population level because the two may be quite different. Any moose population has a number of decimating factors (predation, hunting, starvation, etc.) operating upon it at any time.

The purpose of this study is to test the accuracy of these models in a field situation. Four 260-ha exclosures at the MRC provide an ideal "laboratory" to test the concepts without the complicating factors of seasonal movements, shifting home ranges, and unknown losses due to predation.

Objectives

The goal is to determine the accuracy and precision of a model to predict moose carrying capacity within the exclosures (pens) at the MRC.

Specific objectives are to:

1. Measure forage biomass in each pen within 20% of the mean at the 80% confidence level.

2. Use the simulation models to predict the number of moose days during winter required to utilize the current annual growth (CAG) of paper birch (Betula papyrifera) at various levels during winter.

3. Stock each pen with the appropriate number of moose to utilize birch CAG at 35, 50, 75, and 100% levels.

4. Measure the utilization of birch CAG in each pen and compare the predicted and measured utilization levels.

Methods

Moose Submodel

The generalized ruminant submodel developed by Swift (1983) was modified to be specific for moose. The report by Swift (1983) describes the physiological constraints and requirements of ruminants in mathematical terms. Changes made in this model to make it specific for moose include: seasonal energy requirements (Regelin et al. 1985a), diet mix (LeResche and Davis 1973, data in files), digestibility and nitrogen (N) content of forage (Regelin et al. 1985b), rate of passage and rumen turnover time (Schwartz et al. 1985a), rumen volume (Gasaway and Coady 1974), N requirements (data in files), seasonal food intake (Schwartz et al. 1985b), and seasonal fluctuations in body weight and body composition (Schwartz et al. 1985c).

This model partitions the gross energy intake into specific components and predicts forage intake and changes in body weight on a daily basis. The assumptions inherent in the model are that fat content on 15 October is 15% of total body weight and that gross energy of forage is 4.45 kcal/g.

Vegetation Submodel

The key to the vegetation submodel is accurate and precise data on available biomass of forage species and accurate information on food habits. Information on food habits collected within the pens by LeResche and Davis (1973) and by Regelin et al. (1985b) in 1979 and 1980 was used to predict the seasonal diet mix of moose in the pens.

Estimation of Forage Biomass

A random sampling design was used to estimate forage biomass in each pen. All biomass measurements were made between 18 July and 10 August. Each pen was subdivided into 4 equal-sized and shaped (800 m square) quadrants. Transects were located in each quadrant by drawing random numbers between 1 and 800 that equated to distances in meters from a pen corner. Each 1 m distance had an equal chance of being selected. Along each transect line, 8 random points (between 1 and 800) were selected for location of a 1 x 5 m plot. The 1 x 5 m plots were established using a 5 m cable stretched between 2 pins and a meter stick. A 20 x 50 cm subplot was nested within the lower righthand corner of each plot. Distances to transects and plots were determined by pacing and direction maintained using a compass.

The number of stems of paper birch, aspen (Populus tremuloides), and willow (Salix spp.) rooted within each plot were counted for density estimates. Stems exceeding a diameter of 5 cm at 10 cm above the ground or less than 40 cm in height were ignored. The stem of each hardwood species within the plot and nearest the lower righthand corner was measured for height, diameter at 10 cm above the ground, and clipped. Shrubs were divided into 3 height strata for clipping, 0-40, 41-80, and 81-400 cm. Plant material above 400 cm was discarded. Leaves and CAG from each strata were sacked and weighed separately. All mountain cranberry (Vaccinium vitis-idaea), rose (Rosa acicularis), and fireweed (Epilobium angustifolium) located in or overhanging the 20 x 50 cm subplot were clipped to ground level and each species sacked separately. All clipped material was dried at 100°C for 48 hours and weighed to the nearest 0.1 g.

Epson HX 20 computers were used as field data recorders. All data on plant density, height, and basal diameter collected in the field as well as weight data measured in the laboratory were entered into the field computer. These data were electronically transferred to a Fujitsu Micro 16 personal computer each evening. After 6 transects had been completed in each quadrant, data were analyzed and variance estimates used to predict the number of transects required to estimate CAG biomass within 20% of the mean at the 80% confidence level. Once the estimated number of transects had been completed another analysis was conducted to ensure the biomass estimates were within the desired level of precision. Additional transects were measured if necessary.

The shrub biomass and density measurements were combined at the plot level to provide an estimate of the biomass on each 1 x 5 m plot. The means and variances of biomass estimates in each quadrant were combined for each pen by the following formulas:

$$\bar{\bar{x}} = \frac{1}{4}(\bar{x}_1 + \bar{x}_2 + \bar{x}_3 + \bar{x}_4)$$

$$S^2_{\bar{\bar{x}}} = \frac{1}{16}\left(\frac{\left(S_{x_1}\right)^2}{n_1} + \frac{\left(S_{x_2}\right)^2}{n_2} + \frac{\left(S_{x_3}\right)^2}{n_3} + \frac{\left(S_{x_4}\right)^2}{n_4}\right)$$

Degrees of freedom for the estimators were approximated by the formula:

$$d_{f_{\bar{\bar{x}}}} = \frac{\left(16 \times S^2_{\bar{\bar{x}}}\right)^2}{\frac{\left(\frac{\left(S_{x_1}\right)^2}{n_1}\right)^2}{n_1-1} + \frac{\left(\frac{\left(S_{x_2}\right)^2}{n_2}\right)^2}{n_2-1} + \frac{\left(\frac{\left(S_{x_3}\right)^2}{n_3}\right)^2}{n_3-1} + \frac{\left(\frac{\left(S_{x_4}\right)^2}{n_4}\right)^2}{n_4-1}}$$

Stocking of Pens

Pens were stocked on 15 October with the proper number of moose to remove 35, 50, 75, and 100% of the birch CAG by 30 April. Predicted utilization levels were calculated based on forage intake rates and availability of birch CAG. Two major assumptions were required to make these calculations:

1. Intake of birch stems cannot exceed 70% of the daily food intake, based on LeResche and Davis (1973).

2. Moose utilize birch old growth material and the amount of old growth eaten varies with the utilization level of CAG stems. The relationship between utilization level of CAG and percentage of old growth material in the diet is:

% CAG utilization	% birch that is old growth twigs
25	20
35	25
50	30
75	40
100	50

This relationship is based on reanalysis of data collected by Oldemeyer (1981).

Birch Utilization

Individual plants of paper birch were randomly selected and permanently marked for measurement of utilization of CAG during winter. Within each of the 4 quadrants in each pen, 12 transects were randomly established in the same manner as the biomass transects. Along each transect a random starting point between 1 and 800 m was selected. Ten sampling points were established on each transect at 20 m intervals beginning at the random starting point. If the random starting point was 601 m or greater, there was not adequate distance to establish 10 plots before reaching the end of the quadrant. In these cases, all possible points were established on the original transect and the remainder placed on a parallel transect 5 m to the right running in the opposite direction. This procedure ensured that plants near the ends of the transect had an equal probability of being selected as all other plants.

The birch stem over 400 cm tall but less than 5 cm in diameter, nearest each point, was selected for sampling. The distance from the point to the chosen birch was measured so utilization could be weighted for plant density. Shrub density could influence the probability of a plant being browsed, with shrubs in locally high density areas having a reduced probability of being selected. The weighting factor used to equalize the probability was $\frac{1}{d^2}$ where d was the distance from the pin to the nearest birch. If no birch occurred within a 5 m radius of the point, no plant was measured. This resulted in unequal numbers of birch stems sampled in each quadrant.

The selected birch plant was marked with a metal tag, its height and basal diameter measured, the number of CAG twigs counted, and the diameter of each CAG twig measured to the nearest 0.1 mm just anterior to the bud scale scar. CAG counts and measurements were recorded separately for 3 height strata, 0-40, 41-80, and 81-400 cm above ground level.

Concurrently, unbrowsed CAG twigs of adjacent birch plants were clipped at the bud scale scar. Two hundred CAG twigs were collected in each quadrant and dried at 100°C for 48 hours. Each CAG twig was weighed and its diameter at the bud scale scar measured. Regression equations for each pen were calculated to relate diameter to weight. The weight of CAG twigs on each permanently tagged shrub was estimated using these regression equations.

The next spring just prior to leaf burst, each permanently tagged birch was examined for utilization by moose and snowshoe hare. If the plan had been browsed, the number of unbrowsed CAG was counted and their diameter measured. The browsed CAG twigs had their diameter measured at the point of browsing and the bud scale scar. The proportion of CAG weight removed from each shrub was calculated and the average utilization in each pen determined. The level of utilization predicted by the carrying capacity model was compared with the utilization levels measured in each pen.

Results

Forage Intake

The moose submodel predicted that an adult female moose weighing 395 kg would consume 1,643 kg of oven-dry forage from 15 October to 30 April. The daily intake of forage varied over the winter period with highest daily intake of 9.5 kg/day from October to December and lowest intake (6.6 kg/day) in late March (Fig. 1). These intake rates are similar to estimates for free-ranging moose in Alberta (Reneker et al., 1985).

The diet mix of moose within the pens was dominated throughout the winter by paper birch (Table 1). Mountain cranberry is an important component of the diet in late winter. Digestibility of this diet varied seasonally with the lowest levels from January to March (Fig. 2). N content of this diet followed a seasonal pattern similar to that of digestibility (Fig. 3).

Biomass Estimates

The number of plots used in each pen to estimate biomass varied (Table 2) depending on variability in plant density and biomass. The number of 1 x 5 meter plots per pen varied from 344 to 576. Total biomass in each pen varied from 422 to 606 kg/ha and was measured within at least 10.7% of the mean at the 80% confidence level in all pens (Table 3). The amount of birch CAG varied greatly between pens (4.4 to 14.4 kg/ha) due to past browsing history and habitat manipulation in Pen 1. Birch CAG was measured within 16 to 19% of the mean at the 80% confidence level.

The proportion of birch CAG in each height strata was variable between pens; the 81-400 cm strata had the greatest amount of CAG in all but Pen 4 (Table 4). Birch CAG compose a small amount of the total biomass varying from 0.7 to 3.4%; however, 91-98% of the shrub CAG was composed of birch. Mountain cranberry was a surprisingly large component of the total biomass, varying from 61 to 93% of the total (Table 4).

Stocking Rates

Desired utilization rates of birch CAG were 35% in Pen 1, 100% in Pen 2, 50% in Pen 3, and 75% in Pen 4. The number of moose-days of use required to achieve these utilization rates was calculated and each pen stocked at the proper level by early November. The desired utilization levels were not achieved due to delays in removing some moose, moose breaking into the pens, and moose dying during the winter. The number of moose, moose-days of use, and total intake of birch CAG over the winter is shown in Table 5.

Utilization of Birch CAG

The model predicted utilization rates of paper birch CAG of 49% in Pen 1, 91% in Pen 2, 67% in Pen 3, and 60% in Pen 4. The number of birch plants examined to determine utilization in each pen varied from 196 to 279 plants (Table 6). The measured utilization is compared with predicted utilization levels in Table 7. The predicted utilization levels in Pens 1 and 4 were not significantly different ($P > 0.20$) from measured values. The measured utilization levels in Pens 2 and 3 were significantly lower than the predicted values.

Discussion

The moose submodel appears to accurately predict daily intake levels. The model accurately predicted changes in body weight of tame moose fed the pelleted ration and also accurately predicted daily intake rates of the tame moose over an annual cycle. The validity of the moose submodel has been demonstrated by these tests with the tame moose. The intake values predicted for the free-ranging moose in the pens were similar to those measured by Reneker and Hudson (1985) in Alberta. I have confidence that our estimates of daily forage intake are accurate.

Forage biomass was measured within the desired precision levels for all species and plant parts except for rose and fireweed in some pens (Table 3). Utilization was estimated within 25% of the mean at the 80% confidence level in all but Pen 3 (Table 7). Sample sizes for utilization estimates will be increased for the 1984-85 estimates.

There are 2 likely reasons for the poor agreement between predicted and measured utilization in Pens 2 and 3. The first is that the diet was not accurately predicted. Pens 2 and 3 contain large amounts of mature forest where mountain cranberry was abundant and readily available due to interception of snow by the mature trees. It is possible that moose in these pens ate more mountain cranberry and less birch than estimated. The food habits of moose in each pen will be verified in winter 1984-85 by microhistological analysis of fresh fecal samples in each pen at monthly intervals.

The 2nd complicating factor was birch utilization by snowshoe hares. The hare density was extremely high in the pens and they used the birch plants heavily. It was impossible to separate utilization by hares or moose based on the angle of the bite because the hare often consumed old growth material after the moose had browsed the CAG. The utilization levels reported in the Results section are combined utilization levels for moose and hare. Nearly all plants that were browsed by moose were also browsed by hares. Hares prefer old growth to CAG because the CAG has higher amounts of phenolic resins. Options to correct the problem of browsing by hares are being evaluated.

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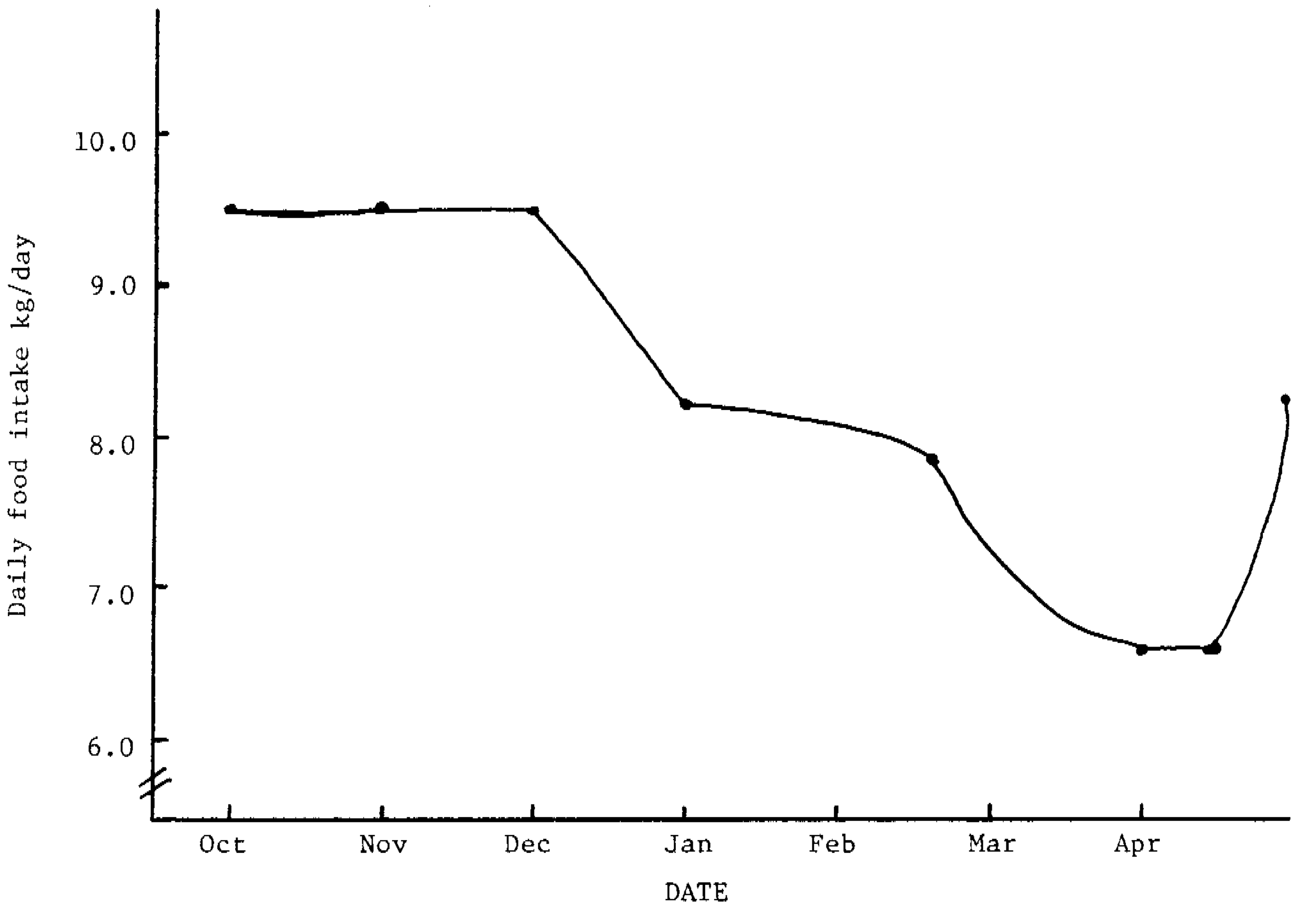

Fig. 1. Daily food intake of moose as predicted by the moose submodel.

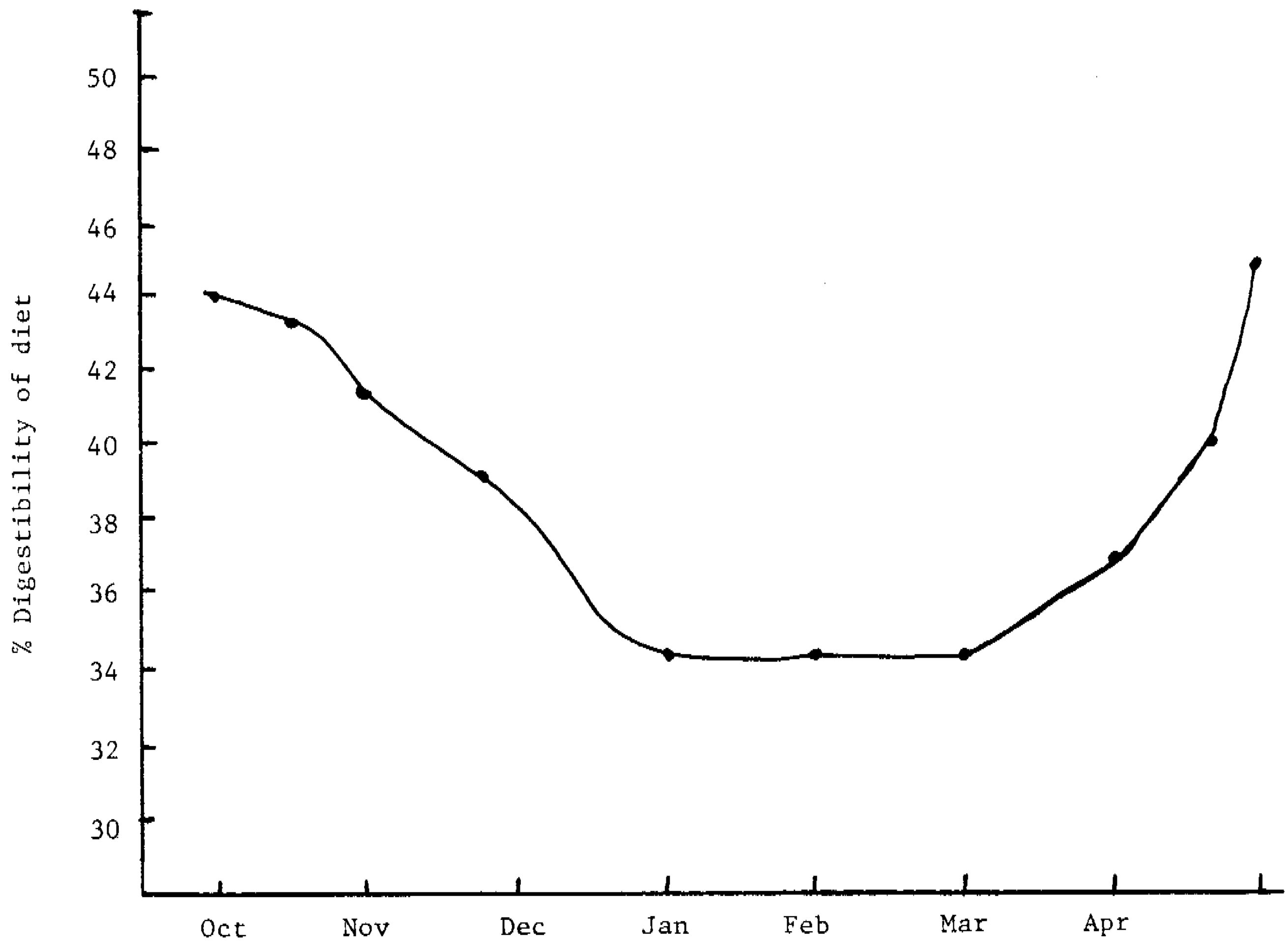

Fig. 2. Digestibility of the diet of moose during winter at the Moose Research Center, Alaska.

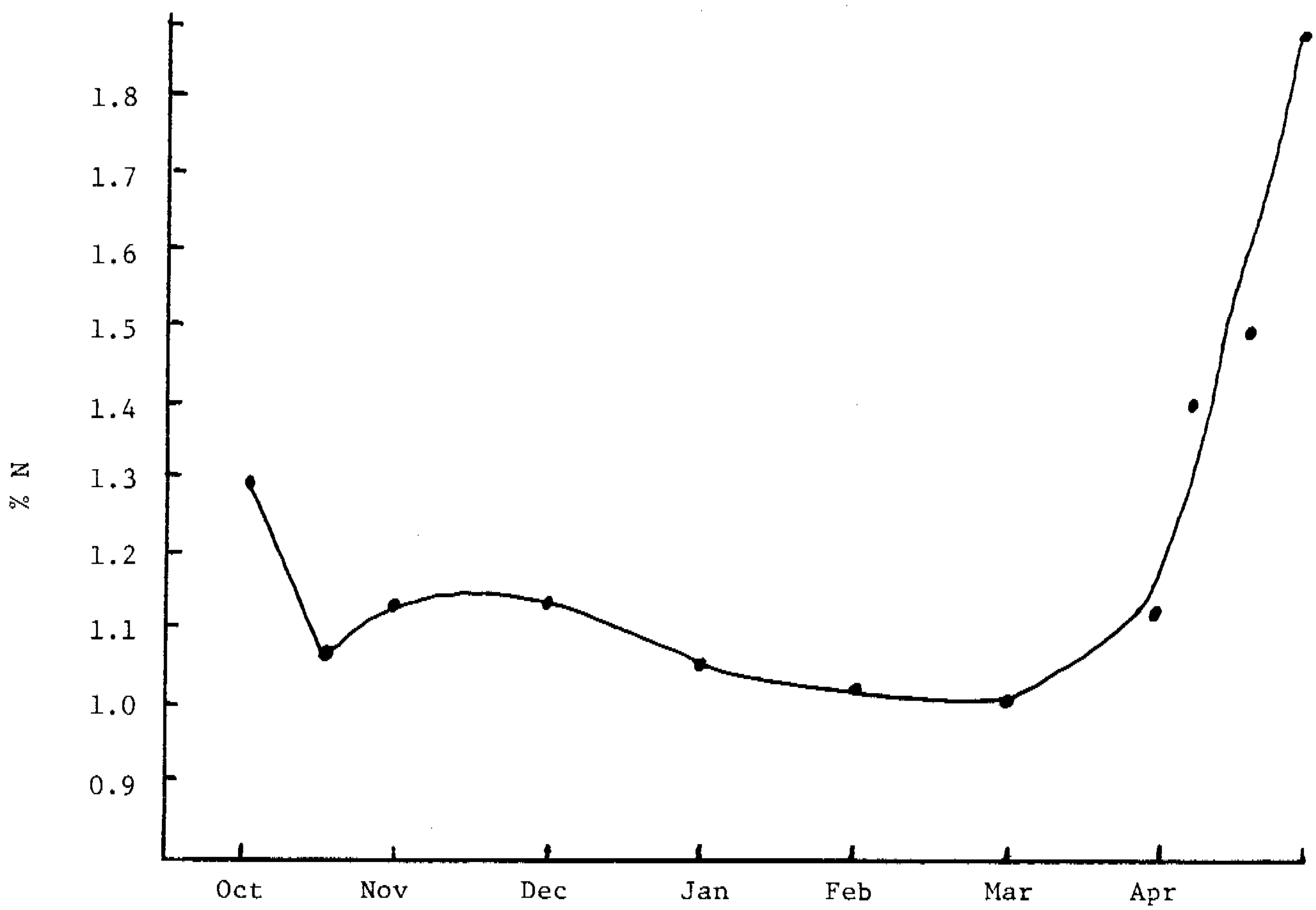

Fig. 3. Nitrogen content of the diet of moose during winter at the Moose Research Center, Alaska.

Table 1. Diet mix of moose from October through April used in the simulation model.

Species	% of diet Oct	Nov	Dec	Jan	Feb	Mar	Apr
Paper birch	50	60	60	60	70	70	60
Willow	20	20	20	20	5	5	15
Aspen	15	10	10	5	--	--	10
Mountain cranberry	5	10	10	15	25	25	10
Rose	5	--	--	--	--	--	5

Table 2. Number of transects in each quadrant used to estimate forage biomass in the pens at the Moose Research Center in 1983. Eight plots were located along each transect.

Quadrant	Pen 1	2	3	4
A	6	6	16	18
B	20	12	12	10
C	33	14	18	6
D	10	11	26	18
Total	69	43	72	52

Table 3. Total forage biomass and biomass of individual species and plant parts in kg/ha ±80% confidence interval in each pen at the Moose Research Center in late August 1983.

	1	2	3	4
Total biomass on 8/24/83	422 ± 36	506 ± 47	523 ± 51	606 ± 65
Birch CAG, 0-400 cm	14.4 ± 2.6	7.7 ± 1.5	11.8 ± 2.3	4.4 ± 0.7
All shrub CAG, 0-400 cm	14.6 ± 2.6	7.8 ± 1.6	12.2 ± 2.3	4.7 ± 0.7
Birch leaves	90.5 ± 15.9	58.2 ± 12.5	90.1 ± 19.9	17.9 ± 4.8
All shrub leaves	91.2 ± 16.0	58.4 ± 12.5	91.0 ± 19.9	18.8 ± 4.9
Mountain cranberry	311.5 ± 34.7	394.8 ± 48.0	384.1 ± 43.3	562.5 ± 65.2
Rose	25.4 ± 4.9	37.6 ± 22.8	31.8 ± 14.9	15.5 ± 4.4
Fireweed	30.9 ± 7.2	7.2 ± 2.1	3.7 ± 0.8	4.8 ± 1.3

Table 4. Proportion of birch in each height strata and proportion of total biomass comprising various species and plant parts in the pens at the Moose Research Center in 1983.

	Pen			
	1	2	3	4
% birch CAG in 0-40 cm strata	22.1	9.3	6.8	28.4
% birch CAG in 41-80 cm strata	23.9	5.1	12.6	36.5
% birch CAG in 81-400 cm strata	54.0	85.6	80.6	35.0
% birch leaves in 0-40 cm strata	10.2	2.4	2.2	14.3
% birch leaves in 41-80 cm strata	15.6	3.3	5.6	26.3
% birch leaves in 81-400 cm strata	74.2	94.3	92.2	59.4
% birch CAG of total shrub CAG	96.4	98.2	96.9	91.1
% birch leaves of total shrub leaves	99.2	99.6	98.9	95.4
% birch leaves of total biomass	21.4	11.5	17.2	3.0
% birch CAG of total biomass	3.4	1.5	2.3	0.7
% mountain cranberry of total biomass	61.6	78.0	73.5	93.0
% rose of total biomass	6.1	7.4	6.1	2.5
% fireweed of total biomass	7.4	1.4	0.7	0.8

Table 5. Predicted intake of birch CAG by moose in each pen at the Moose Research Center from October 15 to April 30.

Dates	No. moose	Moose days	Mean intake kg/day	Total intake kg	Total birch eaten (kg)	Birch CAG eaten (kg)
Pen 1 (desired utilization 35%)						
10/15-4/30	2	396	8.3	3287	2038	1528
10/15-11/9	2	50	9.5	475	238	178
		446		3762	2276	1706
Pen 2 (desired utilization 100%)						
10/15-4/30	3	594	8.3	4930	3056	1528
10/15-10/25	4	40	9.5	380	190	80
12/10-1/20	1	41	7.8	320	192	81
2/5-3/31	1	54	7.0	378	265	132
		729		6008	3703	1821
Pen 3 (desired utilization 50%)						
10/15-4/30	2	396	8.3	3287	2038	1427
10/15-11/1	2	34	9.5	323	161	113
10/15-1/15	1	92	9.2	846	491	344
		522		4456	2690	1884
Pen 4 (desired utilization 75%)						
10/15-12/19	1	66	9.5	627	357	214
10/15-12/1	1	47	9.5	446	245	147
11/9-2/23	1	106	8.8	933	583	350
		219		2006	1185	711

Table 6. Number of birch plants marked in each quadrant and used to measure utilization in the pens at the Moose Research Center in 1983.

Quadrant	Pen 1	Pen 2	Pen 3	Pen 4
A	36	67	74	78
B	58	53	64	74
C	48	72	75	75
D	54	76	54	52
Total	196	268	267	279

Table 7. Pen size, biomass of birch CAG available in each pen on October 15, 1983, and predicted utilization rates by moose through April 30, 1984.

Pen	ha	kg/ha	Total kg	Predicted winter intake of birch CAG	Desired % utilization	Predicted % utilization	Measured % utilization		80% CI
1	240	14.4	3456	1706	35	49.4	40.6	±	10.8
2	260	7.7	2002	1821	100	90.9	41.8	±	9.8
3	239	11.8	2820	1884	50	66.8	34.4	±	13.7
4	268	4.4	1179	711	75	60.3	67.6	±	10.0

PROGRESS REPORT

State: Alaska

Cooperators: None

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

Job No.: 1.31R Job Title: Evaluating and Testing of Techniques for Moose Management

Period Covered: 1 July 1984-30 June 1985

SUMMARY

Controlled studies were designed to evaluate the use of Ruthenium chloride 103 (Ru^{103}) as an inert solid particulate matter. Results indicate that Ru^{103} was not satisfactory because unknown quantities washed out into the liquid portion of the feed. Liquid and solid turnover of material in the rumen was tested using the elements cobalt (Co) and ytterbium (Yb). Results indicated that these elements meet the criteria for measuring rumen digesta turnover in moose. Results are discussed.

CONTENTS

BACKGROUND

The Moose Research Center (MRC), with known numbers of confined moose (*Alces alces*), provides unique conditions for developing and testing techniques applicable to moose management. Initiation and completion of studies under this job were predicated upon developments in related fields, with new drugs, equipment, and procedures potentially applicable to moose management. A final report covering activities under this project from July 1974 through June 1981 was completed by Franzmann and Schwartz in 1982; a progress report on the renewal of this job, covering the period from 1 July 1982 through 30 June 1983, was submitted and published by Franzmann et al. in 1984.

The MRC facility was used this past year for controlled testing of a moose carrying capacity simulation model. Part of these studies required determination of the rate of passage of food through moose. During this report period, we evaluated 2 different methods employed by animal scientists.

OBJECTIVE

To test and evaluate techniques that are potentially useful for determining factors necessary for management of moose.

METHODS

Ruthenium Chloride 103 (Ru^{103}), as well as the elements cobalt (Co) and ytterbium (Yb), were tested and results are presented in the following 2 sections. The test with Ru^{103} was conducted at the Institute of Arctic Biology under the direction and design of Drs. R. W. White and D. F. Holleman, upon our request.

We thank them for their cooperation. Samples of cobalt and ytterbium were analyzed at New Mexico State University, Animal Science Laboratory; that assistance is greatly appreciated.

Ruthenium 103 Testing

"Markers" have been widely used to estimated passage of digesta through the gastro-intestinal tract. Many types of markers have been utilized, such as colored particulate matter, rare earth markers and radioactive isotopes. The requirements for an ideal marker have been outlined by Faichney (1975) and are briefly stated as follows:

1) Should be inert, with no toxic physiological effects on the animal or microflora.

2) Should not be absorbed or metabolized within the gasto-intestinal tract.

3) Should be physically similar to or intimately associated with the material it is to mark.

4) Should not be influenced by gastrointestinal secretion, digestion, absorption, or motility.

5) Should have physiological properties which allow for precise, quantitative analyses, and it must not interfere with other analyses.

Unfortunately, none of the current markers satisfy these criteria. However, the ability to mark the material of interest is of critical importance. Allen (1982) discusses the importance of the binding ability of a marker to target material, and and the consequences of errors incurred if binding capacities of markers are not understood.

Ru^{103} has been used for estimating particulate passage in muskox, caribou, reindeer and moose, without testing binding capacity. If the binding between the marker and target material is incomplete, then the marker would flow with the liquid phase and mask actual particulate passage. An *in vitro* trial was conducted to determine binding capacity at different time intervals after marking.

Procedure:

A 10-gram sample of the pelleted diet (MRC) was placed in a large test tube with 100 μl of Ru^{103} and 34 ml of McDougall's buffer (McDougall 1948). Tubes were incubated at 37 C while being continuously shaken. Samples were removed at various times and centrifuged at 3,000 RPM for 30 minutes; 5 ml of the supernatent was removed and counted for activity (P1). The remaining supernatant was filtered and counted for activity (P1F). The % dose recovered from the supernatant was calculated as:

$$\% \text{ Dose} = \frac{\text{Sample activity x } (35/5) * 100}{\text{Standard activity}}$$

Results:

Ru^{103} did not bind well with the target particulate matter (Table 1) with 26.2 to 65.1 percent of the activity associated with the liquid. Time of incubation seemed to have little effect on the amount of binding taking place, so correction of data for nonbinding was not possible. This would cause severe masking of the particulate flow rate and probably cause underestimation of particulate passage rates. Additional techniques for enhancing marker binding to targets have been examined by Uden et al. (1982) and should be incorporated into preparation techniques for Ru^{103}, or a substitute marker should be tested and used.

Cobalt and Ytterbium Testing

Forage intake, digestion, and rate of passage are all critical to energy utilization of moose. Different foraging strategies and rumen structure occur among various grazing ungulates (Hoffman, in press). Uden et al. (in press) documented different rates of digestibility and gastro-intestinal rates of passage between sheep, cattle, ponies, and rabbits. These differences may be extenuated when working with animals that have extreme fluctuations in seasonal intake and diet quality like the moose. Moose have been classified by Hoffman (in press) and by Kay et al. (1980) as "concentrate selectors," which indicates a rapid particulate passage rate through the digestive tract. This relationship between passage rate and intake has been investigated by several authors (Adams and Kartchner 1984, Ulyatt et al. 1967, Hartnell and Satter 1979), with conflicting results as to the effect of intake upon passage rate. Recent work by Krysl et al. (1985) regarding particulate passage rates, has shown that ytterbium-labeled forage has been effective for predicting total fecal output from grazing animals. This technique could become very useful for prediction of total intake under field conditions. Likewise, ytterbium appears useful as a solid particle marker useful for estimating solid particulate kg units within the rumen. For these reasons ytterbium was tested in moose.

Procedure:

Six adult moose (age 2-5 years) were used to determine particulate and liquid passage rate. Three moose were alloted to 2 treatments. Animals were individually housed in 3 x 10 m open pens, with free access to water and trace mineralized salt. The trial was conducted in late April. Dietary treatment consisted of a high (HQ) and low quality (LQ) diet fed *ad libitum* (Table 2). The treatment diet was fed for 150 days preceding the trial.

Particulate passage rate was estimated using ytterbium-labeled "HQ" or "LQ" feed as outlined by Varga and Prigge (1982). Liquid passage rate was estimated using LiCoEDTA.3H_2O crystals (cobalt, Van Waters and Rogers, Anchorage, AK) (Uden et al., in press). A 10 g sample of cobalt crystals was mixed with 190 g ytterbium-labeled diet and offered to treatment animals for 30 minutes. Consumption of the markers took place within 20 minutes and dose time was considered the mean between offering and total consumption.

Fecal samples for analysis of marker concentrations were intensively collected 24 hours after the 1st dosing, followed by 2 collections per 24 hours thereafter, until 120 hours, when sampling was stopped. Fecal samples were collected in plastic bags and frozen until analysis. Samples were thawed at room temperature, dried in a forced-air oven at 50 C for 48 hours, and ground through a 2 mm screen.

Analysis of cobalt and ytterbium in the fecal material was done as described by Hart and Tolan (1984). Co and Yb concentrations were calculated on a dry-matter basis, and liquid and particulate passage rates were calculated according to Grovum and Williams (1973).

Data were analyzed using Student's *t* test (Steel and Torrie 1960).

Results:

Intake of dry matter differed significantly ($P < 0.05$) between the HQ ($\bar{x} = 35.5$) and LQ ($\bar{x} = 74.1$) diets (Table 3). There was no significant difference between particulate and liquid passage rates either within or between treatments. Varga and Prigge (1982) reported differences between liquid and solid dilution rates with different levels of dry matter and with different qualities of diet for cattle fed long-stem legumes and grasses. Data presented by Galyean et al. (1979) and Adams and Kartchner (1984) also showed an increase in liquid passage with increasing intake. Care must be taken in comparing across species, especially between grazers and browsers. Cattle are grazers while moose are browsers; each has a very different rumen structure. Though general comparisons and trends may be valid, caution is required. Whether differences between the rumen structures of moose and cattle are responsible for the differences between these data and those reported in the literature is not known at this time. A 2nd possibility for the observed differences could center around particle size of the pelleted feed used in these studies compared with long hay and forage tested in cited studies with cattle.

If solid and liquid passage rates are similar between moose and cattle, passage may be based on the rate of digestion of dietary particulate matter. Grass and browse are quite different, structurally, as to the site of digestible nutrients within the plant. Nutrient content of grasses is more uniformly dispersed throughout the stem, whereas nutrient content of the browse is concentrated in the outer layer of bark and buds. No benefits of increased digestion are obtained by retaining browse in the rumen for a long period of time. Further benefits of rapid turnover of both liquids and solids may center around detoxification of plant secondary compounds which are very evident in moose dietary constituents. Further investigations into rate of digestion of specific dietary constituents would be beneficial to understanding dietary constraints and selection of moose.

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Table 1. Binding capacity of ruthenium chloride 103 to a pelleted ration developed for moose at the Moose Research Center.

Time after dosage	% of dosage		
	Supernate	Filterate	Total of all liquids
1.5	27.7	25.5	53.2
3.0	14.2	12.0	26.2
4.5	20.3	19.3	39.6
9.0	35.0	27.2	62.2
22.0	12.6	15.3	27.9
29.0	20.9	25.9	46.8
46.0	30.7	31.5	62.2
70.0	34.2	30.9	65.1

Table 2. Percent composition of pelleted ration fed to moose during winter at the Moose Research Center (MRC).

MRC SPECIAL (HQ)		RICE HULL (LQ)	
Corn	28.7	Corn	26.4
Sawdust	25.9	Sawdust	23.6
Oats, rolled	17.2	Oats, rolled	0
Soybean meal	6.3	Soybean meal	5.5
Cane molasses	5.7	Cane molasses	7.5
Barley	5.7	Barley	0
Beet Pulp	5.7	Beet pulp	0
Rice hulls	0	Rice hulls	34.1
Vitamin premix	0.3	Vitamin premix	0.1
Dical	1.3	Dical	1.1
Pelaid	1.4	Pelaid	1.3
Mycoban	T	Mycoban	0.1
Crude protein	9.5%	Crude protein	6.8%
Metabolizable energy	2.22	Metabolizable energy	1.54%
Crude Fiber	24.7%	Crude Fiber	34.9%

Table 3. Dry matter intake, and particulate and liquid passage rates for moose fed a high (HQ) and low quality (LQ) diet at the Moose Research Center (MRC), 1984-85.

Animal	Treatment	Intake ($g/BW^{0.75}$)	Rumen turnover time	
			Ytterbium	Cobalt
Angel	HQ	35.2	30.2	31.0
Bando	HQ	38.5	33.3	29.5
Oly	HQ	30.5	31.3	30.9
Jezebel	LQ	78.1	31.4	29.5
Deneki	LQ	69.6	25.3	30.4
Mean	HQ	35.5	30.3	32.5
Mean	LQ	74.1	28.4	30.0