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MOOSE RESEARCH CENTER REPORT

By:
Charles C. Schwartz
Albert W. Franzmann
and
David C. Johnson

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Cooperators: Charles C. Schwartz, Albert W. Franzmann, and David C. Johnson

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SUMMARY

Digestive physiology studies with moose were conducted under this job during this report period. Four complete digestion and balance trials were conducted, with rumen turnover times measured twice. Simulation experiments using a ruminant model developed by David Swift were run and comparisons of baseline data were made with various simulation runs altering input parameters. Life histories for moose at the Moose Research Center are presented and discussed.

CONTENTS

BACKGROUND

Digestive physiology studies with captive moose (*Alces alces*) were initiated last year (Franzmann and Schwartz 1979a) as part of the moose productivity and physiology project outlined by Franzmann et al. (1976). The major goal of these studies is to develop and test 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 are attempting to integrate information on the nutritional requirements of moose with that of the nutrients supplied from the vegetation. The program is two-fold: (1) vegetative biomass and nutrient quality will be determined by personnel of the U.S. Fish and Wildlife Service, and (2) moose nutrient requirements and digestive physiology will be measured cooperatively by State and U.S. Fish and Wildlife Service personnel.

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. Several preliminary runs using a ruminant model were made during this report period to help determine what inputs were most important and where data gaps existed.

OBJECTIVES

To establish baselines for 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 moose populations of the state.

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 digestability 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 formulated diet versus four major food items consumed by wild moose either singly or in combination 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

Digestive Physiology of Moose

Procedures for digestion/metabolism studies tested under this job were outlined by Schwartz and Franzmann (1981).

Rumen turnover time, (Schwartz and Franzmann 1981), was used to estimate both solid and liquid movements through the digestive tract of moose. Rumen turnover studies were done in cooperation with Drs. R. White and D. Hollaman, University of Alaska, Fairbanks. A description of the methods and underlying theory prepared by them follows:

Introduction

Nonabsorbed digestive markers have been widely used to estimate various digestive functions, especially in domestic ruminants. Digestive functions include: dry matter digestibility, rates of digesta passage, and feces output. Early studies (Balch 1950, Castle 1956) employed various colored stains as digesta markers, e.g., acid fuchsin and brilliant green. However, radioisotope-labeled nonabsorbed markers have several advantages and as a result are presently used almost exclusively. The marker most commonly used for the liquid phase of digesta is chromium-51 complex with EDTA (New England Nuclear, Inc.) (Downes and McDonald 1964). There are several particulate matter markers used in digestion studies, such as cerium-141 or cerium-144

chloride (Ellis and Huston 1968), scandium-46 chloride (Miller and Byrne 1970), ruthenium-103 chloride (Tan et al. 1971) and several others (see Ellis et al. 1979 for a review of nonabsorbed digestive markers). In the present study chromium-51 EDTA and ruthenium-103 chloride were used as the water phase and the particulate markers, respectively. These radioisotope labels have relatively short physical half-lives, as well as simple gamma spectrum which are readily distinguishable. These physical attributes are desirable for technical and radiation safety reasons. However, there is evidence that a small percentage of chromium-51 EDTA may bind to particulate material (Grovum and Williams 1973). Also, Ellis et al. (1979) found that approximately 3-7 percent of the radio-label was absorbed from the digesta and excreted via urine, whereas Tan et al. (1971) found that the absorption of ruthenium-103 marker was insignificant. The characteristics of an ideal nonabsorbed digestive marker and the extent to which the most commonly used markers meet these characteristics have been discussed (Faichney 1975).

Experimental Methods

The radioisotope-labeled markers were given as a single dose either by mixing the markers with food or by direct intraruminal administration (oral) of a gelatin capsule containing the markers. Chromium-51 EDTA and ruthenium-103 chloride were given at a dose rate of 200μCi per moose. Fresh feces samples were collected at 2 hour intervals for the first 24 hours after dosing, then 4 hour intervals for the next 24 hours and then at 6 hour intervals the following day. Subsamples were taken for radio assay and water content estimation. Samples were placed into pre-weighed counting vials, then freeze-dried to a constant weight. The samples were radio-assayed with a dual channel gamma spectrometer (Searle Analytical-Model 1195). Normal gamma stripping methods were used to calculate the marker concentrations of chromium-51 and ruthenium-103. Marker concentrations were expressed as cpm/g water (chromium-51 EDTA) and cpm/g dry matter (ruthenium-103).

The logarithm of the marker concentration was plotted as a function of time following the single dose of marker. A least-squares regression line was fit to the linear portion (terminal portion) of the marker concentraton versus time curve. The difference between marker concentration during the build up portion of the curve and the corresponding marker concentration as calculated from the above least-squares regression line was plotted against time. These data were then fit with a least-squares regression line. The first appearance time for the marker was calculated from the slopes of the two least-squares lines. Dry matter digestibility was calculated from dry matter intake and fecal output as measured by conventional methods.

Theoretical Considerations

Although the Stewart-Hamilton Principle has traditionally been applied to blood flow through organs of the body, the principle is equally applicable to digesta flow through the digestive tract (Steele 1971).

A marker dose (D) is given on the intake side (rumen) and the marker concentration (C_t) is determined as a function of time (t) on the output side (feces). Assuming a steady flow of output (feces, F), the amount of marker output in a time interval dt is equal to $C_t \cdot F \cdot dt$ and the total marker output equal to $\int C_t \cdot F \cdot dt$ or $F \int C_t \cdot dt$. If no absorption of the marker occurs then the marker dose is equal to the marker output, namely

$$D = F \int C_t \cdot dt \quad \text{.....(1)}$$

OR

$$F = \frac{D}{\int C_t \cdot dt} \quad \text{.....(2)}$$

Thus the feces output may be estimated from the marker dose divided by the area under the marker concentration versus time curve for the feces. The area under the curve may be determined mathematically or graphically. The transit time (TT) or the time of first appearance of the marker in the feces may be determined graphically from the marker concentration versus time curve for the feces or mathematically as will be discussed later. The mean time (MT) that the marker spends in the digestive tract after the first appearance of the marker in the feces may be calculated as follows (Steele 1971; Faichney 1975)

$$MT = \frac{\int C_t \cdot (t-TT) \cdot dt}{\int C_t \cdot dt} \quad \text{.....(3)}$$

where the numerator is the area under a curve obtained by multiplying the marker concentration in the feces by its respective time (t) since first appearance of the marker in feces (t-TT). MT may be obtained graphically, or mathematically if the marker concentration curve can be expressed formally.

Possibly the most meaningful rate of passage parameter in digestive studies is the total mean transit time (TMTT) or

$$TMTT = TT + MT \quad \text{.....(4)}$$

since TMTT is the total mean time that the marker was present in the digestive tract thus subject to digestion and absorption processes.

Dry matter digestibility (DMD) may be calculated from dry matter intake (DMI, g/d) as measured by conventional methods and the feces output (F, g/d), i.e.

$$DMD\ (\%) = \frac{DMI-F}{DMI}(100) \quad \ldots\ldots\ldots(5)$$

The marker concentration versus time curves for feces may be analyzed mathematically by using compartmental models. The most widely used model is a two compartment model with a time delay to account for the transit time of the marker (Blaxter et al. 1956). These authors selected this model since it was the simplest one which adequately described the kinetics observed in digestive studies using nonabsorbed markers. A rigorous analogy between this model and the digestive tract was not implied. The two compartment model adequately fits most data, however, Ellis et al. (1979) suggested that a more complex model described some data more appropriately. Further, Faichney (1975) discussed possible difficulties of applying compartmental analyses to fecal excretion curves since the models assume a continuous flow of digesta, when in fact, defecation occurs at discrete time periods.

Using the two compartment model, the transit time (TT) or the first appearance of marker in the feces may be calculated from the relationship

$$TT = \frac{\ln C_2 - \ln C_1}{K_2 - K_1} \quad \ldots\ldots\ldots(6)$$

where ln is the natural logarithm; C_1 and K_1 are the intercept and slope of the terminal component of the marker concentration curve, respectively. Likewise, C_2 and K_2 are the intercept and the slope of the least-squares line of the difference between the marker concentration as calculated from the terminal component least-squares line. The marker concentration at the transit time (CTT) as calculated from the terminal component least-squares line equals

$$C_{TT} = C_1\ e^{-K_1\ TT} \quad \ldots\ldots\ldots(7)$$

and can be used in subsequent calculations.

The predicted marker concentration in feces at a particular time following the dose (C_t) for the two compartment model is given by the relationship

$$C_t = C_{TT}\ e^{-K_1(t-TT)} - C_{TT} e^{-K_2(t-TT)} \quad \ldots\ldots\ldots(8)$$

where all parameters have been defined above. Thus, the marker concentration curve may be described as the difference between two exponential functions. For all times (t) equal to or less than the transit time (TT), the value of C_t equals zero since the marker has not appeared in the feces.

Substituting equation (8) into equation (2) and integrating yields a relationship between feces output (F), the marker dose (D) and the parameters of the two least-squares regression lines

$$F = \frac{D}{\frac{CTT}{K_1} - \frac{CTT}{K_2}} \quad \text{.....(9)}$$

Similarly, substituting equation (8) into equation (3) and integrating yields

$$MT = \frac{\frac{1}{(K_1)2} \quad \frac{1}{(K_2)^2}}{\frac{1}{K_1} - \frac{1}{K_2}} \quad \text{.....(10)}$$

again, the total mean transit time (TMTT) equals MT plus TT.

A measure of the rate of passage of the marker is of importance since it is an index of the time available for digestion and absorption as nutrients pass through the digestive tract. Several parameters have been used as indices for time available for digestion, such as the time of peak marker concentration, time of 50 percent excretion of the marker and the time between 80 and 5 percent excretion. However, these parameters may be of limited usefulness since they do not necessarily reflect the average time available for digestion and absorption (Grovum and Williams 1973). Therefore, the most important rate of passage parameter discussed is the mean time the marker spends in the digestive tract (TMTT).

Four complete digestion and balance trials were conducted during this report period. During the first two trials, the moose were fed the MRC Special with a mill by-product (Fiberlite, American Excelsior Co., Arlington, Texas) used as the source of aspen sawdust (*Populus sp.*). In the third trial the moose were fed a mixture of 40 percent aspen (*P. tremuloides*) clipped during winter and 60 percent MRC Special. During the fourth trial the moose were fed a browse diet containing equal amounts of birch (*Betula papyrifera*), aspen, and willow (*Salix* spp.) by wet weight.

Carrying Capacity Model

The goal of the moose digestion and physiology studies is to obtain input data for use in a carrying capacity model for moose on the Kenai National Wildlife Refuge (Franzmann and Schwartz 1979). The ruminant submodel used in these studies was writtern and developed by David M. Swift, National Resources Ecology Laboratory, Colorado State University, Fort Collins. A preliminary discussion of this model is available in Swift et al. (1979). A summary of the model follows:

The simulation model is a generalized model of energy and nitrogen balance for nonreproductive ruminants (Fig. 1). Energy and nitrogen costs to the animal were simulated along with the voluntary intake and metabolism of these nutrients. This permits time traces of lean body mass and fat reserves to be developed so changes in body weight and composition could be followed. The model functions as part of an ecosystem level model or, as in this case, as a stand-alone model. It was a difference-equation model, operating on a 1 day time stop.

As a stand-alone model the model was driven by input time traces of dietary nitrogen concentrations, and digestibility values, and daily maximum and minimum temperatures. The model required 47 input parameters, of which 15 were varied for moose (Table 1). A complete discription of the model will be available soon.

Simulation Experiments

The simulations with moose covered a period from 1 November to 30 April with meteorologic conditions similar to those on the Kenai Peninsula. Baseline dietary characteristics were taken from data of LeResche and Davis (1973) and from W. Regelin (pers. comm.).

Model parameters and their source, along with initial weights, are listed in Table 1. Initial conditions for the state variables representing the various body pools of energy, nitrogen, and microbial protein were selected to be consistent with the sizes of moose and their diets. Fat reserves were assumed to be 25 percent of total body weight in the fall. The value was varied in later simulation runs.

Nine baseline runs were performed altering inputs until a baseline standard was obtained which approximated what we felt was a "real" simulation of moose weight loss through winter. This baseline was then used as a base for experimental runs, where single parameters were varied to identify their importance.

All parameters and driving data were established before baseline runs were made. The only changes made subsequently were those specific to simulation runs. Experimental runs consisted of increasing and decreasing the following driving variables and parameters: daily activity, initial fat reserves, dietary nitrogen concentration, dry matter digestibility of the diet, and metabolic fecal nitrogen.

Blood Chemistry and Hematology

Procedures for collecting, handling and analyzing blood were outlined by Franzmann et al. (1976). During this period, blood was collected only from tame moose immobilized and processed at the MRC.

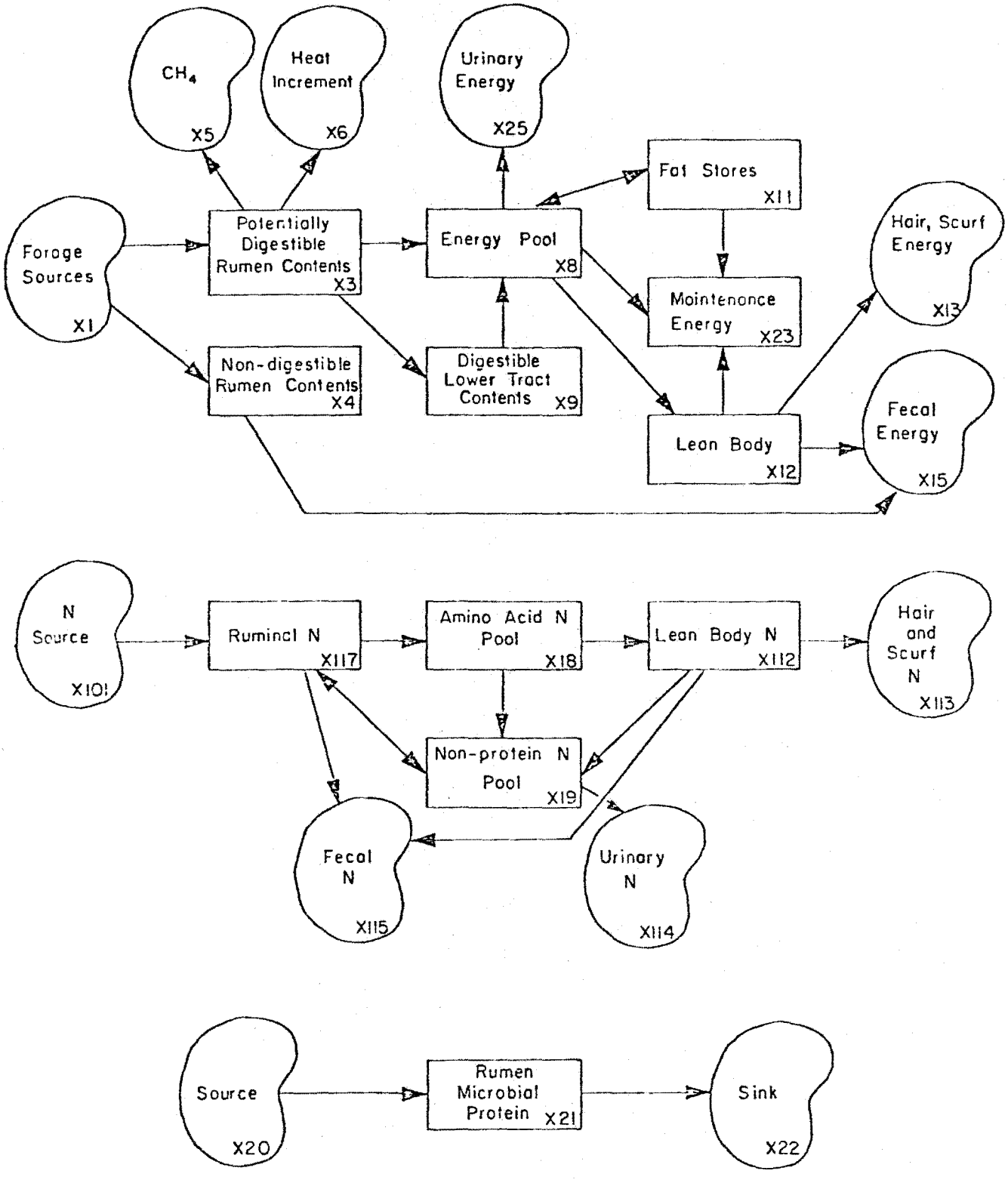

Figure 1. The structure of the ruminant submodel.

Table 1. Input data used in the baseline run for adult female moose as a standard for experimental runs.

Parameter	Input	Source of Data
Dietary crude protein (%)		
Nov.-Dec.	7.4	Oldemeyer (1974)
Jan.-Feb.	6.1	Oldemeyer et al. (1979)
March	5.0	Regelin, W. unpubl. data
April	7.5	
Dietary digestibility (%)		
Nov.-Dec.	40	Oldemeyer (1974)
Jan.-Feb.	36	Oldemeyer et al. (1979)
March	34	Regelin, W. unpubl. data
April	39	this report
Endogenous urinary nitrogen	$.115\ (wt.)^{.75}$	Robbins et al. (1974)
Metabolic fecal nitrogen	5 g Nitrogen/kg intake	Agricultural Research Council (1965)
Methane production (average)	5.0% of gross energy	Regelin, W., unpubl. data
Fasting metabolic rate (BMR)	$90\ (wt.)^{.75}$	Regelin, W., unpubl. data
Initial lean body (kg)	307.6 kg	Franzmann et al. (1978)
Initial fat weight (kg)	100 kg	Estimated: this is 24.5% of total body weight
Age at start of run (days)	2130 (5yrs, 4mo)	Assume birth date of 1 June trail runs began 1 November
Maximum life span (yrs)	11	Estimated
Wind chill (c)	5	Renecker et al. (1978)
Lower critical temp (c)	-20	Renecker et al. (1978)
Winter cost of activity	1.5 (BMR)	Moen (1976) estimated
Rate of passage (%/DAY) of digestible portion	70	This report
Fraction of undigested (%/DAY) material passing rumen	60	This report

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 one enclosure to another or released outside the enclosures in an attempt to obtain approximately the following numbers and distributions: Pen 1-2 bulls, 2 cows; Pen 2-8 moose; Pen 3-5 cows and no bulls until late in rut; and Pen 4-no moose.

Moose were moved utilizing a mixture of etorphine (M-99) and xylazine hydrochloride (Rompun) for initial immobilization of trapped animals. Each animal was routinely processed when immobilized (Franzmann et al. 1976).

FINDINGS

Digestive Physiology of Moose

We measured the intake rates of tame moose (Table 2) fed the "MRC Special" throughout the year. Intake varied seasonally with highest consumption during summer and low intake during the breeding season and again during late winter. With the exception of the breeding season and late gestation, intake rates for males and females were similar. During the rut, all three bulls in the digestation trials stopped eating for a period of 12 days (Fig. 2). Intake rates began to decline early in September until the consumption was zero by 19 September. No food was consumed until 2 October. Food consumption increased gradually from October 2 through 20 when measurements ended.

Since we were interested in having all females bred, they were not held in individual pens during the rut. Three females had access to the 7 ha calf pen and feed bunks; one male moose (Chief) roamed freely with the cows. Although food intake was not measured for individual females, they all visited the feed bunks at least twice daily. The bull would follow these females into the feeding area, but would not eat. He began consuming food early in October corresponding to the time when the two bulls in holding pens began eating.

One of the two bulls (Rodney) penned for intake measurements was put into a digestion cage for 6 days to measure urine and fecal output during the period of zero food consumption. Average daily feces production was 81.2±S.E.202 g with a mean energy content of 4.08 k cal/g. The feces was of a different consistency than "normal" fecal material in that it was coarse in texture with a large amount of a mucus-like substance that was yellow-orange in color. Although the chemical analysis is not yet available, the coarse texture was probably a result of a high wood fiber content and the yellow-orange mucus was likely nitrogenous material of endogenous origin.

Table 2. Seasonal intake of dry matter for moose fed a pelleted ration.

Animal	Date: 2-11 July	6-16 Sept.	23-28 Sept.	6-10 Oct.	11-20 Oct.	19-26 Nov.	23 Jan-2 Feb	23 Feb-4 Mar	6-19 April	3-12 May
	Animal wt. (intake $g/w^{0.75kg}$/day)									
Angel	--	368 (107)	366 (96.3)	--	--	405 (89.3)	406 (90.6)	413 (72.4)	413 (83.1)	426(80.5)
Lucy	328(107.7)	351 (113.6)	371 (75.7)	--	--	410 (90.3)	400 (65.1)	404 (67.7)	414 (62.2)	422(73.9)
Jezebel	--	319 (114.2)	320 (70.3)	--	--	343 (91.2)	374 (81.5)	379 (75.2)	384 (74.6)	405(68.6)
Chief	381 (102.0)	445 (93.9)	391 ø	--	--	426 (91.2)	417 (97.0)	418 (60.5)	438 (101.0)	450(95.4)
Chester	366 (113.1)	422 (95.9)	383 ø	381 (13.9)	382 (86.1)	403 (90.4)	391 (88.7)	389 (76.1)	397 (94.3)	397(97.5)
Rodney	373 (93.4)	425 (85.4)	393 ø	384 (50.7)	383 (78.7)	413 (95.5)	395 (91.6)	399 (73.8)	397 (94.3)	420(104.4
Mean intake ±SD	104±8.4	101±11.7	81±13.7[1/]	32±26.0[2/]	82±5.2[2/]	91±2.2	86±11.3	71±5.9	73.3±10.5[1/]	74.3±6.0[1/]
									96.3±4.1[2/]	99.1±4.7[2/]

[1/] Intake for females only.

[2/] Intake for males only.

Urine output averaged 2.7±S.E.2.3 l/day with a mean specific gravity of 1.01. Energy determinations are not complete on these urine samples. Like the fecal material, the urine was different from "normal urine" produced at other times of the year. The urine was dark brown in color and had a strong odor similar to the smell associated with a "rutting bull." The origin of the smell is unknown, but may have been from the tarsus gland. Several samples of this urine have been sent to A. B. Bubenik, Research Scientist, Ontario Ministry of Natural Resources for analysis of various pheromes.

Three female moose were fed the diet in trial one; two male moose were used in trial two. Results of these trials (Table 3) indicated higher gross energy intake levels but lower net energy retention (gross energy-fecal energy) for females when compared to males. We suspect that these differences were a result of factors other than differences of efficiency levels between sexes. The dry matter digestion (DMD) trial using the two males was conducted post-rut, during the period when the two males were increasing their intake levels back to normal (Fig. 2). We believe the higher digestion of dry matter was a result of dry matter being retained in the gut-tract while the animals refilled the digestive tract. During the rut both males stopped eating for 12 days, but continued to produce fecal material. As a result, we believe they voided most of the dry matter from the rumen and lower gastrointestinal tract during this fasting period. Since we measured intake and fecal output during the initial stages of resumed eating, much of the undigested dry matter was probably retained in the gut tract as bulk and not really digested. The digestive coefficient of 56.4±12 percent for the females probably more closely represents the true DMD of the Fiberlite by-product ration.

The standard MRC ration (Schwartz and Franzmann 1981) which contained aspen sawdust had a higher DMD (64±2.3 and 68.0±2.8) than the Fiberlite diet (56.4±1.2). This difference was probably real. Although no chemical analyses are available, we believe these differences were related to rates of digestion for the sawdust vs. the Fiberlite by-product. The aspen sawdust was milled from live aspen trees, bark included. The Fiberlite was a by-product of excelsior. This material does not contain bark but was all woody material. Aspen bark and the sap from fresh trees should be digestible.

Although the DMD from Fiberlite by-product was lower, we felt it was quite adequate as a fiber substitute in the MRC Special. It is commercially available and costs less than aspen sawdust obtained locally from mills. We plan to use this test ration in 1981-82.

The digestibility of the mixture of pelleted ration and aspen fed in Trial 3 had a total DMD of 57.3±4.4 percent. The variation in total digestibility was small. The ratio of aspen:feed consumed varied from 50 to 28 percent (Table 4). Although we attempted to

Table 3. Gross energy intake and fecal energy loss for moose fed a pelleted ration (MRC Special) containing a mill by-product (Fiberight, American Excelsior Co.) used as the source of aspen sawdust.

Trail and Animal	Body Wt. (kg)	Daily GE Intake/ $kgW^{0.15}$/day (kcal)	Fecal Energy % GE Intake
Trial 1			
Angel	366	401.8	43.3
Jezebel	320	293.5	41.8
Lucy	371	316.3	44.1
Trial 2			
Rodney	374	215.9	32.3
Chester	381	199.2	28.3

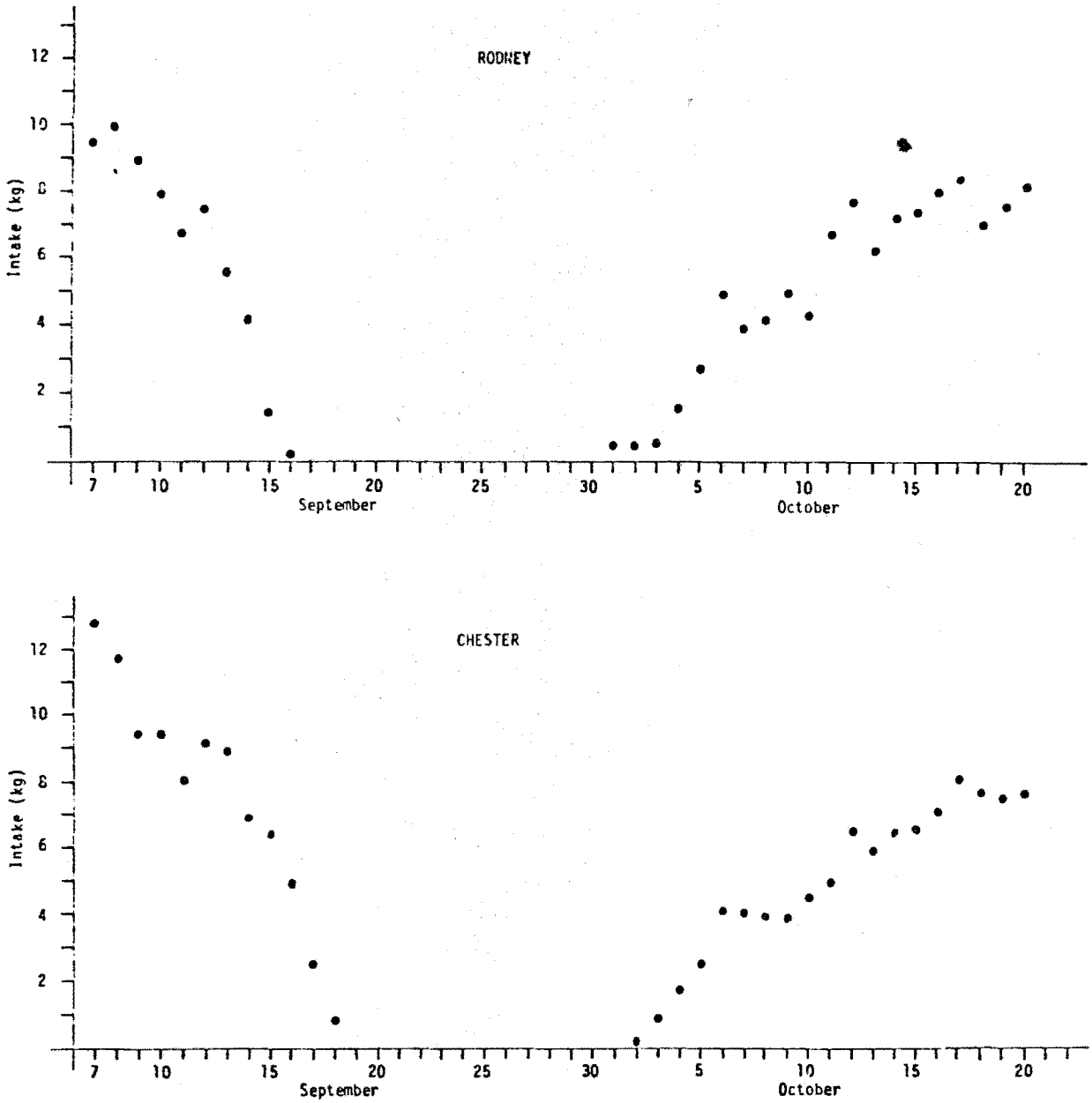

Fig. 2. Daily intake of a pelleted ration for 2 male moose from 7 September to 20 October 1981.

Table 4. Gross energy intake and fecal energy loss for moose fed a pelleted ration (MRC Special) and winter clipped aspen browse.

Animal	Body Wt. (kg)	Ratio of food Consumed Aspen: pelleted ration	Daily GE Intake/ $kgW^{0.15}$/day (kcal)	Fecal Energy % GE Intake	Calculated[1] Aspen Digestibility (%)
Chief	350	30:70	198.3	45.9	30.5
Chester	334	40:60	312.7	41.6	46.8
Rodney	341	50:50	210.8	41.2	51.4
Lucy	363	28:72	243.6	39.4	45.6

[1] The DMD of aspen was calculated by assuming a 68% DMD for the pelleted ration and calculating mathematically the digestion coefficient for the aspen (i.e., the total DMD for the mixture was 59.5%, and Chester ate 60% feed:40% aspen, then $0.68 \cdot 0.60 + \chi \cdot 0.40 = 0.595$ $\chi = 46.8\%$). The 68.0% DMD for the pelleted ration was determined from a previous digestion trial (Schwartz and Franzmann 1981).

balance the intake ratio at 40:60 aspen:feed, the ratio between animals was wide because the animals consumed variable amounts of each. Likewise this difference in consumption of aspen and feed was reflected in the total daily gross energy intake/day between animals. Chester preferred the aspen and readily consumed all that was offered. Chief and Lucy preferred the pelleted ration and ate less aspen; we therefore only offered them quantities of feed equivalent to the daily aspen intake, thus reducing total daily energy intake. We calculated the DMD of the aspen fed during this trial mathematically, assuming the DMD for the pelleted ration was 68.0 percent as previously determined in a digestion and balance trial (Schwartz and Franzmann 1981). The following calculations were made: Total DMD = 0.68 (% ration as feed) + % Aspen (X)

where X = % DMD of aspen

$$\text{then \% DMD aspen} = \frac{\text{Total DMD} - 0.68\ (\text{\% feed})}{\text{\% Aspen}}$$

With the exception of Chief, the calculated digestion coefficients for aspen were similar (Table 4). We have no explanation why Chief differed. With the exception of Lucy, another trend in the data appeared to indicate increased DMD of aspen with its increased percentage in the diet. The percentage of aspen consumed for Rodney, Chester and Chief was 50, 40, and 30 percent, respectively; the calculated DMD for aspen was 51.4, 46.8 and 30.5 percent for these animals, respectively. Since a complete chemical analysis of both the feed, aspen, and fecal material from this trial was not available for this report, we are not sure which trend is real and which is spurious.

Dry matter digestion of the mixed browse diet in Trial 4 using three moose, resulted in a mean digestibility of 39.7±4.5 percent. The dry matter ratio of birch:willow:aspen was 34.4:33.1:32.4 which was quite close to the percentage fed as wet weight. No energy determinations were available for this report.

We attempted to feed the moose a diet of browse with a birch:willow:aspen ratio of 70:20:10, but after 7 days of feeding, the moose reduced their consumption to less than 1 kg/day. The animals were immobilized (Franzmann et al. 1976) and dosed with $Ru^{103}Cl$, $Cr^{15}EDTA$, and tritium in an attempt to monitor turnover rates of rumen liquids, and solids and total body water. The animals were put into the digestion cages 30 minutes after the antagonist was administered. We attempted to collect fecal and urine samples at 2 hour intervals for the first 24 hours. The animals did not urinate or defecate at regular intervals, acted listless and refused to eat. Two of the four animals did not defecate at all during this 24 hour collection period. The other two only defecated three and two times, respectively. We released the moose after 48 hours and discontinued the trial.

We have no explanation for the apparent drop in food consumption and reduced gut mobility, but suspect it was a result of an

accumulation of phenolic resins from the birch. The birch used in this trial was cut in the 1969 burn and contained large amounts of white powder associated with glandular excretions from the bark (Bryant and Kuropat 1980).

Rumen Turnover

As outlined in the original objectives of these studies (Franzmann and Schwartz 1979), rumen turnover time was considered an important component of moose digestive physiology and a major factor leading to the success of the MRC Special as a formulated ration. Preliminary results of rumen turnover studies were discussed (Schwartz and Franzmann 1981), but due to an error in collating, the data were omitted from that report. Results of turnover studies with the MRC Special and a mixture of MRC Special and winter clipped aspen (Table 5, Figs. 3-6) indicate a mean turnover time of 22.2±3.8 hours for the particulates and 17.0±3.3 hours for the liquid portion of the rumen materials for moose fed the MRC Special. Turnover time for moose fed a mixture of MRC Special and clipped aspen (Trial 4 this report) were quite similar with a mean turnover of 20.4±1.7 and 18.8±1.4 hours for the solid and liquid materials of the rumen, respectively (Table 5, Figs. 7-9).

Carrying Capacity Model

Results of the baseline run with adult female moose (Table 6) indicated a 21.6 percent loss of total body weight, an 85.9 percent loss in total fat reserves, and less than 1 percent loss of lean body tissue. Total body weight loss was similar to losses for mule deer (*Odocoileus hemionus*) (19%) and elk (*Cervus canadensis*) (17%) for similar simulation runs (Swift et al. 1979), and was slightly higher than weight loss for adult female moose (17%) examined by Franzmann et al. 1978 at the Moose Research Center.

Percentage of fat lost was slightly lower for moose than that for deer and elk (91.2% for both) reported by Swift et al. (1979). We were unable to find any information on body composition of moose and therefore our estimate of 24.5 percent total body fat (Table 1) may have been an overestimate. Reduction of total body fat to 14.3 percent in the simulation run (Table 6), however, resulted in a 100 percent loss of total body fat over the winter.

The less than 1 percent decrease in lean body mass for moose was much lower than that for deer (-6.1%) and elk (-3.6%) (Swift et al 1979). By reducing total body fat to 14.3 percent the loss of lean body tissue increased to 17.6 percent for moose also indicating that initial fat reserve estimates of 24.5 percent were probably too high. These simulations indicate that we need to measure the total body fat for moose to improve our estimates in the simulation model.

Table 5. Rumen solid and liquid turnover rates of moose fed a pelleted ration, and a mixture of pelleted ration and winter clipped aspen in different digestion and balance trials in winter.

Animal	Ration	Body Wt. (kg)	Dry Matter Intake ($g/kg^{.075}/day$)	DMD %	First Appearance (h)		Turnover Time (h)	
					Liquid	Solids	Liquid	Solids
Chief	MRC Special	351	--	--	--	--	14.2	19.7
Chester	MRC Special	343	--	--	9	10	21.8	27.5
Rodney	MRC Special	355	--	--	17	18	16.1	22.2
Angel	MRC Special	363	--	--	14	16	16.0	19.3
$\bar{x}$±S.D.		353±8.3	--	--	13.3±4.0	14.7±4.2	17.0±3.3	22.2±3.8
Lucy	28:72 Aspen feed	363	54.3	61.7	10	17.2	10	18.5
Chester	40:60 Aspen feed	334	69.6	59.5	10	19.4	10	20.8
Rodney	50:50 Aspen feed	341	46.5	60.4	10	19.9	10	21.8
$\bar{x}$±S.D.		346±15.1	56.8±11.8	60.5±1.1	10	18.8±1.4	10	20.3±1.7

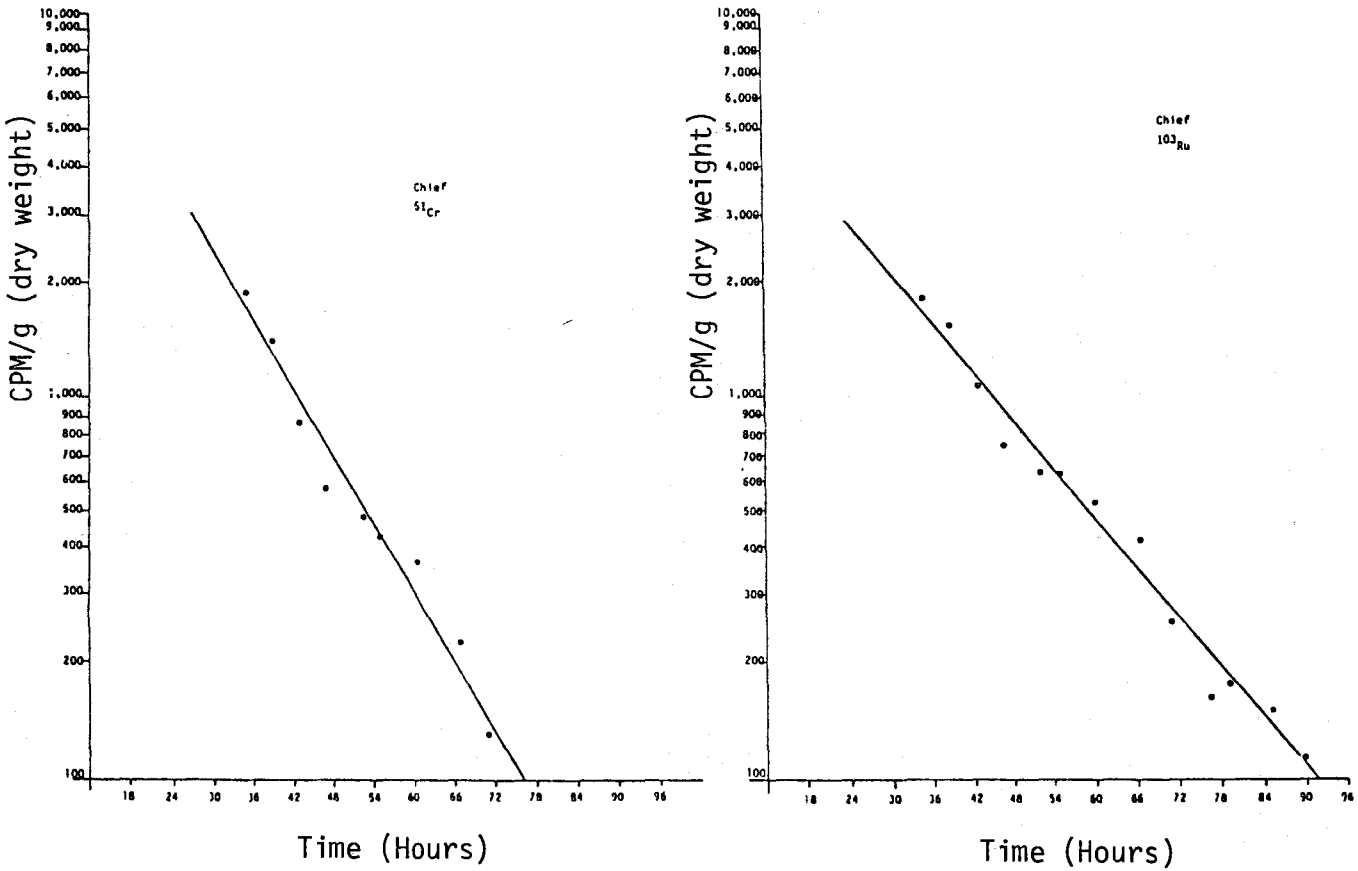

Fig. 3. Rumen solid and liquid turnover rates for Chief fed the MRC Special.

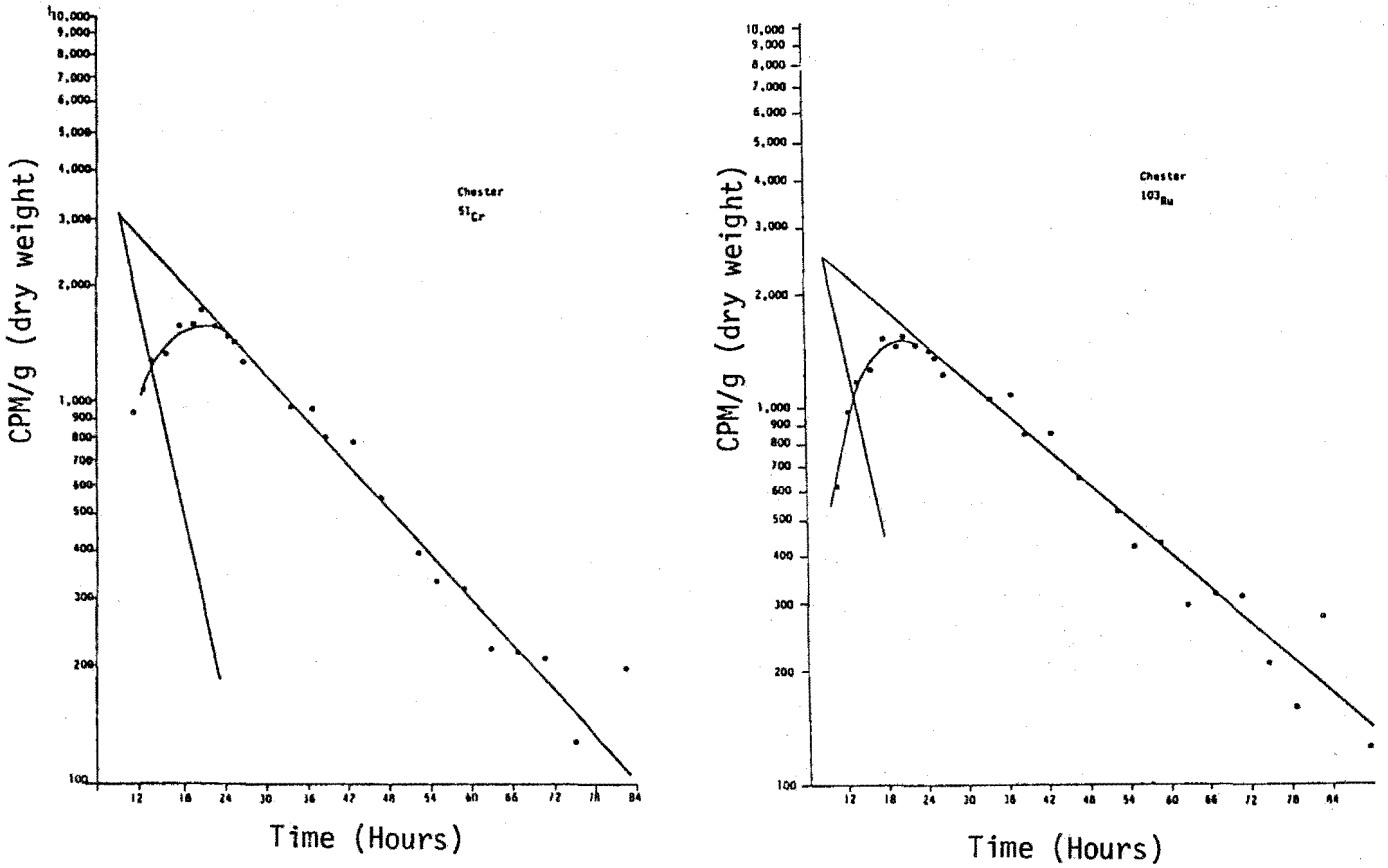

Fig. 4. Rumen solid and liquid turnover rates for Chester fed the MRC Special.

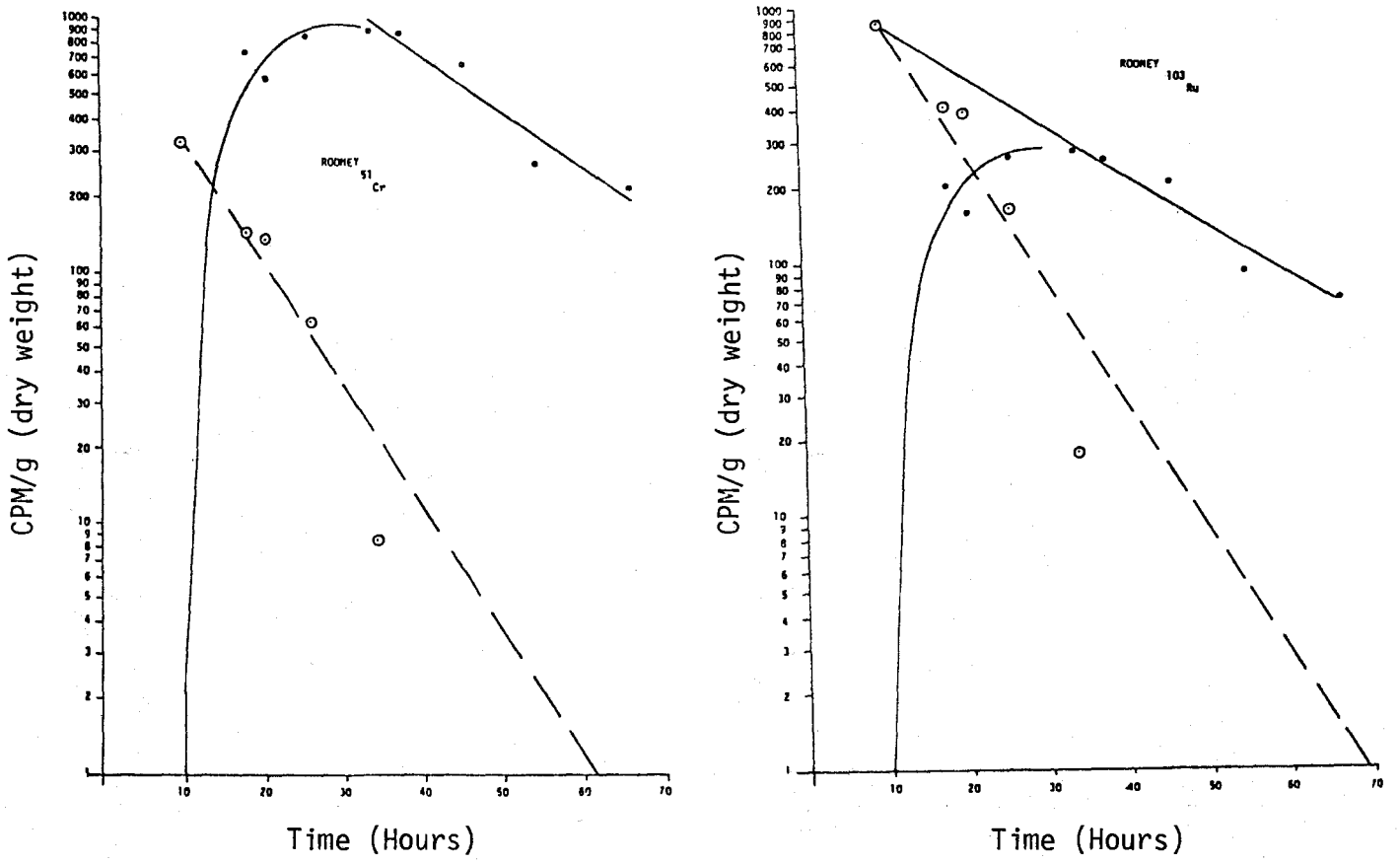

Fig. 5. Rumen solid and liquid turnover rates for Rodney fed the MRC Special.

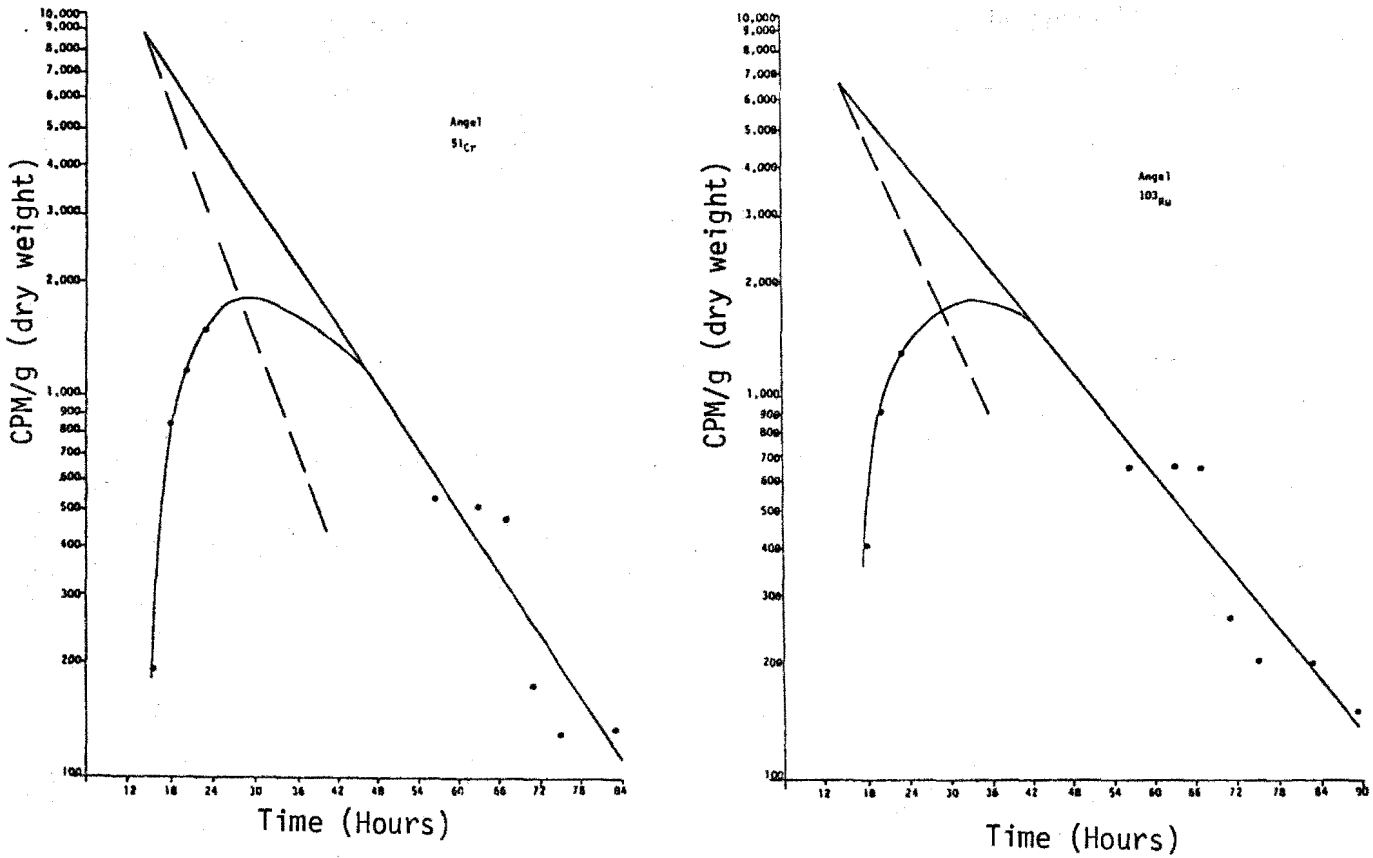

Fig. 6. Rumen solid and liquid turnover rates for Angel fed the MRC Special.

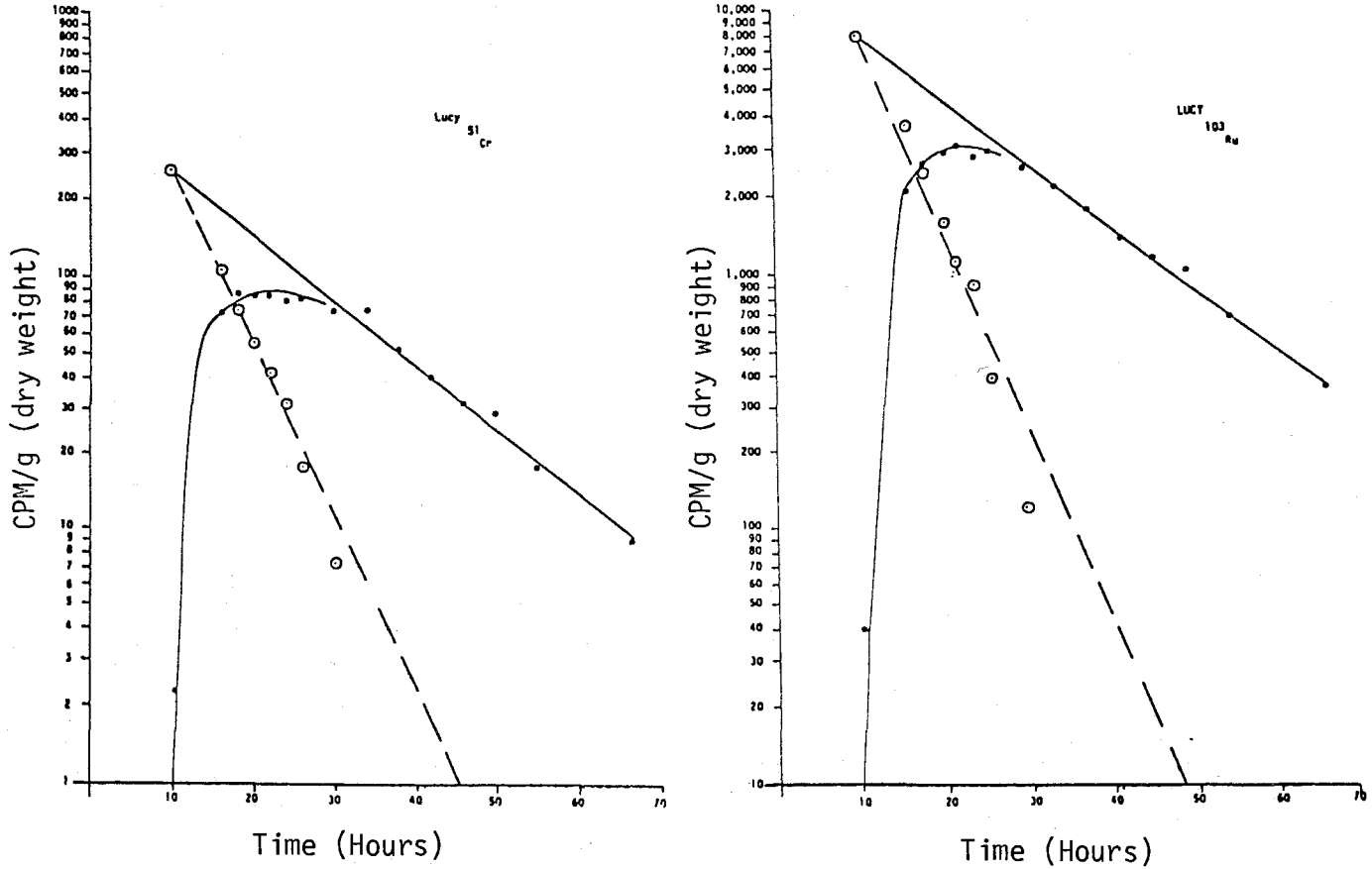

Fig. 7. Rumen solid and liquid turnover rates for Lucy fed the MRC Special and a mixture of winter clipped aspen.

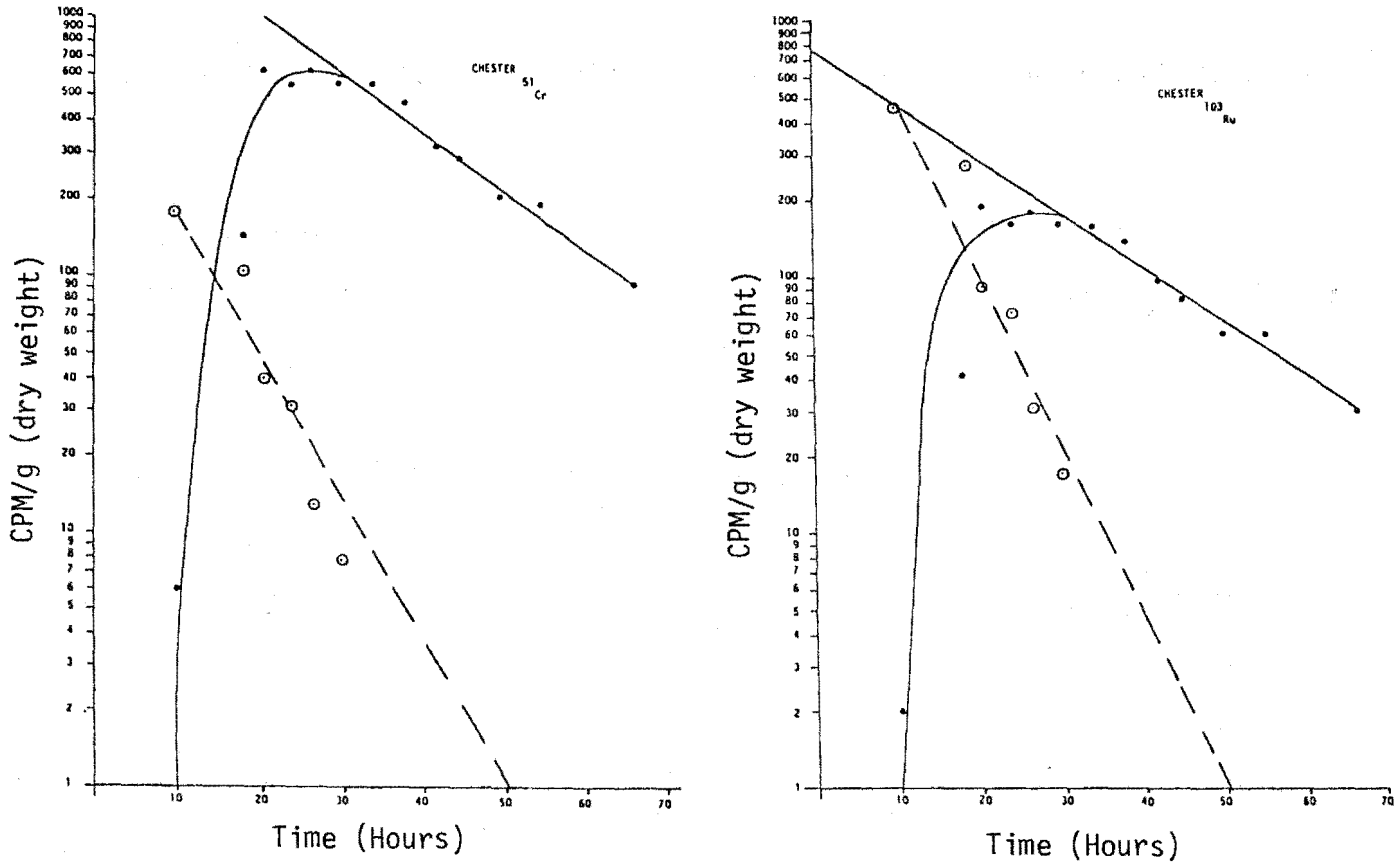

Fig. 8. Rumen solid and liquid turnover rates for Chester fed the MRC Special and a mixture of winter clipped aspen.

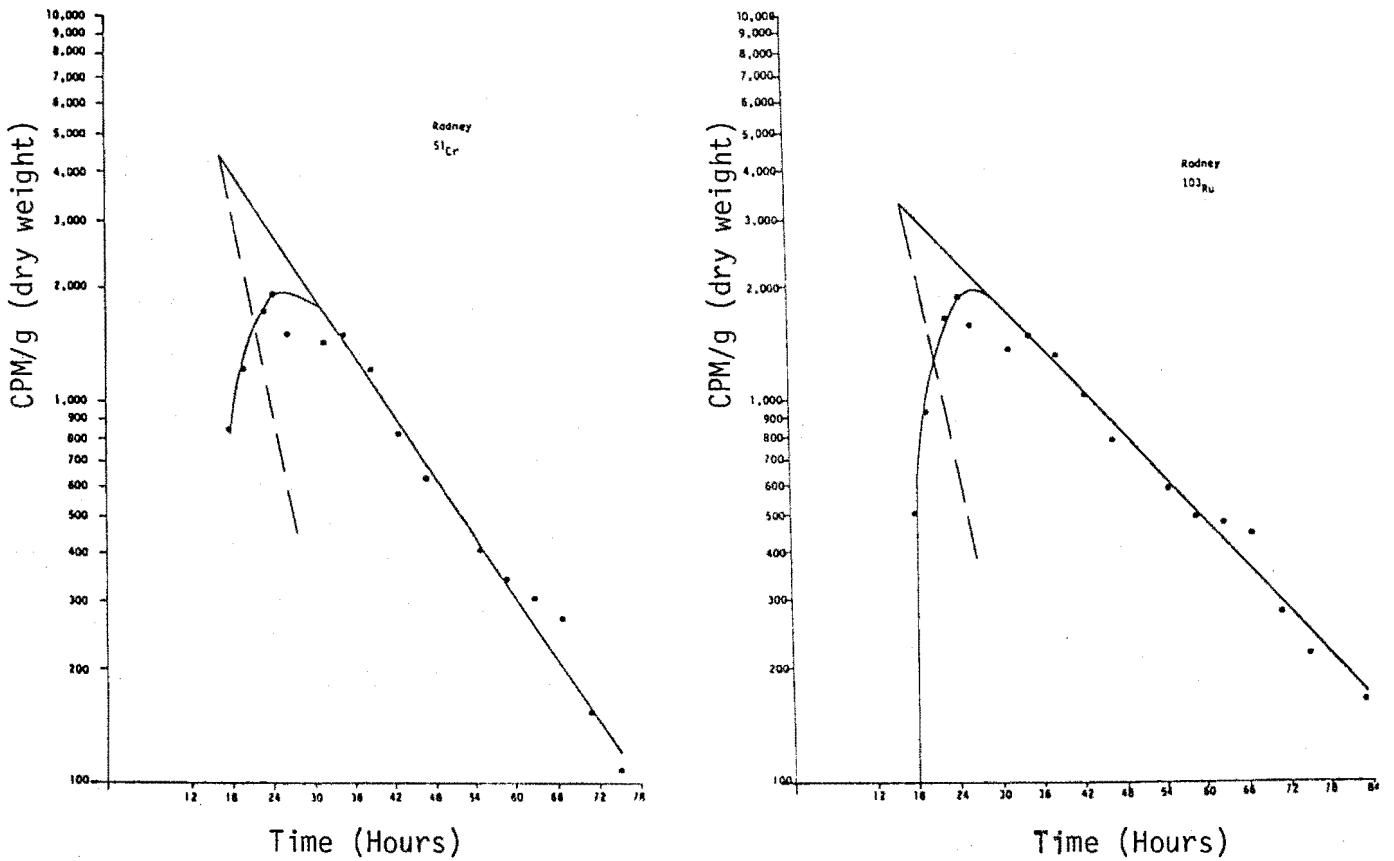

Fig. 9. Rumen solid and liquid turnover rates for Rodney fed the MRC Special and a mixture of winter clipped aspen.

Table 6. Results of simulation experiments with adult female moose in winter.

	Change in Wt. (%)	Change in Lean (%)	Change in Fat (%)
Baseline Run	-21.6	-0.16	-85.9
Activity costs increased (20%) to 1.6 BMR	-24.5	-0.18	-97.8
Activity costs decreased (20%) to 1.4 BMR	-18.3	-0.17	-72.9
Initial fat weight decreased (50%) to 51 kg (14.3% total body wt.)	-29.4	-17.6	-100
Initial fat weight increased (50%) to 153.2 kg (33.3% total body wt.)	-23.8	-0.20	-71.0
Dietary nitrogen increased by 10%	-21.9	-0.14	-87.2
Dietary nitrogen decreased by 10%	-21.3	-0.19	-85.6
Diet digestibility increased by 10%	-16.3	-0.17	-64.8
Diet digestibility decreased by 10%	-31.3	-8.4	-100
Metabolic fecal nitrogen 7.6 g/kg (Robins et al. 1974)	-28.5	-7.3	-92.0

Increasing total fat reserves to 33.3 percent of total body weight (Table 6) resulted in a similar change in total weight loss through the winter (-23.8%) when compared to baseline data (-21.6%). Total fat reserves declined 71.0 percent for the "fat" moose vs. -85.9 percent for the baseline moose. Loss of lean body tissue was similar for both runs. These changes reflect similar energy demands through the winter, resulting in near identical losses in the percentage of total weight. As discussed by Swift et al. (1979), experimental runs in which initial fat reserves were increased and decreased by 50 percent yielded the expected result that condition at the start of winter is an important determinant of overwintering success. Good estimates of winter range capacity cannot be made without taking into consideration the ability of summer and transitional ranges to provide adequate nutrition.

Changing activity costs by ±20 percent had a marked effect on moose condition change over the winter. Baseline activity costs in the baseline run were estimated as being 50 percent of basal metabolic costs. The 20 percent changes therefore resulted in activity costs of 40 percent and 60 percent of basal metabolic costs. It is unlikely that activity costs for wild ruminants can be estimated more precisely than this at present (Swift et al. 1979). Changing activity costs had little effect on lean body mass, but caused large changes in body fat and total body weight (Table 6).

Changing the dietary nitrogen content by ±10 percent resulted in almost no response in tissue weights when compared to the baseline run. These results indicate that the dietary nitrogen concentration was probably above the minimum daily requirements. The animal was thus in positive nitrogen balance.

Very large responses were observed to changes in the digestibility of the diets. An increase by 10 percent of the baseline values had the largest positive impact on fat reserves of any experimental run. Reducing digestibility by 10 percent caused a total depletion of fat reserves, an 8.4 percent loss of lean body tissue, and a 31.3 percent loss of total body weight. The changes imposed on digestion of dry matter (±10%) were not large, and well within the range expected to occur due to annual variation in forage quality, quantity and availability.

Changing the amount of nitrogen lost in the feces from 5 g/kg food intake to 7.6 g/kg intake as reported for deer by Robbins et al. (1974) had a marked effect on the loss of lean body tissue. There were also increased losses of fat and total body weight (Table 6).

We plan to run additional simulation runs in 1981 as we continue to refine the inputs.

Table 7. Weights in kilograms of five captive moose at Kenai Moose Research Center, 1980-81.

	Animal Name (Sex)						
Date	Chief (M)	Chester (M)	Rodney (M)	Lucy (F)	Angel (F)	Jezebel (F)	Comments
7/1/80	375	357	364	317	319	251	
7/8/80	383	368	380	323	331	--	
7/12/80	387	376	380	338	331	257	Chief, Chester, Rodney, Lucy released after intake trial.
7/18/80	389	377	384	334	335	262	
7/25/80	395	393	400	342	348	275	
8/1/80	401	392	385	337	340	280	
8/9/80	429	--	409	341	352	295	
8/10/80	--	410	--	--	--	--	
8/13/80	427	413	405	--	--	293	
8/14/80	--	--	--	345	355	--	
8/17/80	427	--	--	--	--	--	
8/18/80	432	414	420	357	354	299	
8/24/80	441	431	426	--	360	299	
9/2/80	448	430	433	359	364	319	
9/4/80	445	422	425	351	368	--	Bulls' antlers removed after bulls were weighed.
9/23/80	--	--	391	--	--	--	Lucy, Angel, Jezebel in crates. Rodney in crate, 23 Sept.
9/25/80	--	389	--	--	--	--	
9/26/80	394	386	--	--	--	--	
9/28/80	393	383	--	--	--	--	
9/29/80	393	--	371	371	366	320	
10/6/80	--	382	377	--	374	--	Muddy bulls.
10/9/80	--	--	--	--	--	316	
10/11/80	--	380	371	370	379	319	
10/13/80	389	--	--	--	--	--	
10/17/80	406	382	381	385	385	323	

[Continued on next page]

Table 7 (cont.). Weights in kilograms of five captive moose at Kenai Moose Research Center, 1980-81.

	Animal Name (Sex)						
Date	Chief (M)	Chester (M)	Rodney (M)	Lucy (F)	Angel (F)	Jezebel (F)	Comments
10/21/80	--	--	383	--	--	--	Rodney and Chester released from small pens.
10/24/80	410	386	385	380	380	321	
10/30/80	--	--	406	395	397	335	
11/5/80	426	402	395	398	394	332	
11/12/80	422	393	392	398	396	330	
11/19/80	418	402	410	--	393	337	
11/20/80	--	--	--	407	--	--	All on intake trial.
11/27/80	434	403	415	413	405	343	Released after trial.
12/2/80	--	--	408	--	--	--	Rodney off feed for 12hrs.
12/22/80	--	416	417	--	--	--	
12/23/80	436	415	417	425	426	359	
1/4/81	438	--	--	--	--	--	
1/7/81	427	--	--	--	--	350	
1/8/81	--	426	434	432	428	--	Start of pre-trial for Chester, Rodney, Lucy, Angel.
1/12/81	434	423	421	417	418	--	Chief locked up.
1/13/81	--	424	414	414	415	--	
1/16/81	430	410	--	--	--	--	Chief and Chester released
1/22/81	429	409	425	416	420	359	Locked up for intake trial
2/2/81	432	405	424	414	432	365	
2/5/81	--	399	410	--	--	361	
2/6/81	416	--	--	--	--	--	Chief fasted 48 hrs.
2/7/81	--	--	--	404	--	--	Lucy fasted 48 hrs.
2/11/81	420	397	410	403	418	--	Chester, Rodney, Lucy Angel began native browse trial.
2/13/81	--	391	409	396	418	--	

Table 7 (cont.). Weights in kilograms of five captive moose at Kenai Moose Research Center, 1980-81.

	Animal Name (Sex)						
Date	Chief (M)	Chester (M)	Rodney (M)	Lucy (F)	Angel (F)	Jezebel (F)	Comments
2/14/81	--	--	--	--	--	364	
2/23/81	417	391	395	400	406	374	Start intake trial.
3/5/81	419	386	403	407	420	384	End intake trial.
3/12/81	403	395	406	400	415	373	Chester, Rodney, Lucy, Angel began native browse trial.
3/15/81	407	--	--	--	--	--	Chief began fasting.
3/18/81	404	--	--	--	--	--	Chief released; ate almost nothing for 72 hrs.
3/20/81	--	--	--	400	--	--	Lucy released from stall.
3/21/81	--	--	--	--	--	380	
3/23/81	--	386	394	--	407	--	Released from digestion stalls.
3/24/81	--	385	--	--	403	--	
3/25/81	--	381	393	--	402	--	Weighed after fasting.
4/2/81	413	375	395	397	401	383	
4/6/81	433	368	395	412	409	383	Begin intake trail.
4/16/81	443	386	400	416	417	395	Rodney in chamber.
4/17/81	--	386	--	404	418	--	Lucy in chamber.
4/20/81	--	--	394	412	--	--	Angel in chamber.
4/21/81	443	376	--	--	416	--	Chester & Angel in chamber.
4/27/81	443	377	400	408	414	394	
5/3/81	446	397	412	419	425	403	
5/13/81	454	397	429	425	428	406	End of intake trail.
5/15/81	--	--	--	--	419	--	
5/18/81	460	--	425	--	380	--	Angel gave birth to female calf on 17 May.

Table 7 (cont.). Weights in kilograms of five captive moose at Kenai Moose Research Center, 1980-81.

	Animal Name (Sex)						
Date	Chief (M)	Chester (M)	Rodney (M)	Lucy (F)	Angel (F)	Jezebel (F)	Comments
5/19/81	--	413	--	--	--	--	
5/20/81	447	--	416	423	386	403	Males fasted.
5/21/81	--	393	423	--	365	--	Jezebel gave birth to male calf on 21 May.
5/25/81	--	--	--	357	372	354	Lucy gave birth to twins on 22 May 1981.
5/26/81	--	--	--	347	376	354	
5/27/81	--	400	--	345	367	344	
5/28/81	439	--	--	--	--	--	

Table 8. Weights in kilograms of captive female moose calf (Flo) at Kenai Moose Research Center, 1980-81.

Date	Weight	Date	Weight	Date	Weight
7/4/80	23.5	8/24/80	58	10/30/80	114
7/8/80	23	8/26/80	60	11/5/80	120
7/12/80	23	8/28/80	62	11/12/80	121
7/14/80	25	8/29/80	64	11/19/80	129
7/16/80	24.5	9/2/80	68.5	11/27/80	131
7/18/80	25	9/6/80	70	12/22/80	144
7/20/80	26	9/8/80	69	12/23/80	144
7/22/80	27	9/10/80	74	1/4/81	152
7/24/80	27	9/12/80	74	1/7/81	152
7/25/80	28.5	9/16/80	79	1/13/81	160
7/26/80	30.5	9/18/80	82	1/22/81	163
7/30/80	33	9/20/80	81	2/2/81	171
8/1/80	34	9/25/80	86	2/5/81	176
8/3/80	37	9/27/80	86	2/13/81	172
8/5/80	38.5	9/28/80	89	2/14/81	175
8/5/80	42	10/1/80	89	2/23/81	182
8/9/80	42.5	10/6/80	94	3/5/81	184
8/10/80	44	10/9/80	97	3/12/81	192
8/13/80	45.5	10/13/80	101	3/20/81	198
8/14/80	50	10/16/80	101	3/25/81	205
8/17/80	50	10/17/80	103	4/2/81	205
8/18/80	51	10/21/80	106	4/6/81	209
8/20/80	56	10/24/80	109	4/16/81	217
8/22/80	57.5	10/28/80	114	4/21/81	221
				4/27/81	223
				5/3/81	235
				5/8/81	234
				5/13/81	230
				5/19/81	238
				5/24/81	239
				5/27/81	251

Table 9. Moose blood protein, electrophoresis, and hematologic.

Moose	Date	Sex	Total Protein %/dl	Albumin %/dl	Globulin %/dl	Alpha 1 %/dl	Alpha 2 %/dl	Beta %/dl	Gamma %/dl	A/G Ratio	Hb %/dl	PCV %
Angel	10/08/79	F	4.3	2.9	1.4	0.6	0.4	0.3	0.3	2.00	16.4	46
Chester	10/08/79	M	7.3	4.8	2.5	0.5	0.4	0.6	1.0	2.00	18.5	47
Rodney	10/08/79	M	8.1	4.9	3.2	0.5	0.6	0.8	1.4	1.50	16.5	45
Chief	10/08/79	M	5.9	4.1	1.8	0.3	0.4	0.5	0.7	2.40	14.0	42
Chief	3/25/80	M	7.2	5.0	2.2	0.4	0.4	0.6	0.9	2.20	16.2	37
Angel	3/25/80	F	8.1	5.0	3.1	0.5	0.6	0.5	1.4	1.60	14.5	35
Chester	3/25/80	M	7.9	5.1	2.8	0.4	0.4	0.6	1.3	1.90	18.6	38
Lucille	3/25/80	F	7.8	5.4	2.4	0.4	0.4	0.6	1.1	2.20	16.4	36
Rodney	3/25/80	M	7.3	5.1	2.2	0.4	0.4	0.5	0.9	2.40	18.3	39
Jezebel	4/13/80	F	7.9	5.1	2.8	0.4	0.4	0.6	1.4	1.80	16.1	45

Table 10. Moose blood chemical data.

Moose	Date	Sex	Glucose mg/dl	Chol. mg/dl	Triglyceride mg/dl	LDH U/L	SGOT U/L	SGPT U/L	Alk. Phos. U/L	Phos. mg/dl	Ca mg/dl	Ca/P Ratio	Na mEq/L	K MEq/L	Cl mEq/L	Co_2 mEq/L	BUN mg/dl	Creat. mg/dl	Bili. mg/dl	Uric Acid mg/dl
Angel	10/08/79	F	65	51	33	185	28	17	43	4.9	6.6	1.32	85	4	49	12	10	1.5	0.1	0.3
Chester	10/08/79	M	129	85	11	46	71	43	73	8.1	10.8	1.33	144	6	95	21	19	3.1	0.3	0.1
Rodney	10/08/79	M	118	81	7	37	54	31	96	8.1	10.7	1.32	148	6	97	20	23	4.5	0.7	0.3
Chief	10/08/79	M	85	63	2	270	68	19	31	4.5	8.2	1.82	119	4	80	20	14	3.2	0.4	0.2
Chief	03/25/80	M	80	71	16	322	73	49	22	7.7	11.0	1.43	142	6	96	26	25	2.4	0.2	0.1
Angel	03/25/80	F	98	65	1	384	82	25	22	6.4	11.1	1.73	142	7	95	26	17	1.5	0.1	0.0
Chester	03/25/80	M	106	22	14	353	60	32	28	8.0	10.9	1.36	143	7	96	27	22	2.5	0.1	0.0
Lucille	03/25/80	F	89	59	12	330	69	31	25	5.9	10.8	1.83	142	6	99	23	23	2.8	0.3	0.0
Rodney	03/25/80	M	103	65	20	284	49	34	106	11.5	9.8	0.85	145	6	98	21	21	2.7	0.1	0.1
Jezebel	04/13/80	F	133	76	10	548	116	50	142	8.3	10.7	1.28	142	7	95	29	14	1.6	0.1	0.0

Table 11. Histories of Pen I moose at Kenai Moose Research Center.

Moose Number	Sex	Year of Birth	Significant Observations			No. Times Observed	No. Times Captured
			Date	Event	Remarks		
58	M	1970	2 June 1981	Observed	Most recent sighting	8	0
8	M	1978	4 June 1981	Observed	Most recent sighting	12	0
R-70-8	F	1968	15 June 1981	Helicopter survey	Seen with calf		14
125	F	1966	22 Apr. 1981	Observed	Most recent sighting	4	0
UC	F	?	25 May 1981	Carcass visited	Probably died during winter. Cause unknown	6	0
UC[1/]	F	1980	18 June 1981	Yearling	Most recent sighting	1	0
UC	F	?	21 June 1981	observed	Only sighting	1	0

[1/] Assumed to be 1980 calf of R70-8. Latest sighting of them together was on 25 Mar. 1981.

Table 12. Histories of Pen 2 moose at Kenai Moose Research Center,

Moose Number	Sex	Year of Birth	Significant Observations			No. Times Observed	No. Times Captured
			Date	Event	Remarks		
670	F	1970	Not observed this year		Assumed dead		
129	F	1976	5 Apr. 1981	Released outside pens	With UC yearling male	12	0
31	F	?	18 June 1981	Observed	Most recent sighting	8	0
UC	F	?	9 Aug. 1980	Released outside pens	Small moose	?	0
UC	M	1979	5 Apr. 1981	Released outside pens	With No. 129 female	12	0
UC	M	1979	6 June 1981	Observed	Most recent sighting	3	0
UC[1/]	F	?	21 June 1981	Observed	Most recent sighting	?	0

[1/] There have been several sightings of an UC female. There may be two or more UC females.

Table 13. Histories of Pen 3 moose at Kenai Moose Research Center.

Moose Number	Sex	Year of Birth	Significant Observations			No. Times Observed	No. Times Captured
			Date	Event	Remarks		
2870(14)	F	1970	Not observed this year		Assumed dead		
13	F	1970-72	15 June 1981	Helicopter survey	Seen with calf	5	0
17	F	?	14 June 1980	Helicopter survey	Most recent sighting	1	0
20	F	?	20 June 1981	Latest sighting	Trapped in 3N, 6/15/81 Radio collar changed	7	2
5	M	?	15 June 1981	trapped in 3S	Moved into Pen 4	6	3
UC[1/]	F	?	15 June 1981	Helicopter survey	Cow with light blue ear flag in right ear seen with twin calves	4	0
75(15)[1/]	F	1969	Not identified if seen this year				
UC	F	?	10 June 1981	Trapped in 4NE	Cow broke into Pen 3 from trap. Calf caught and also put into Pen 3	1	1

[1/] Uncollared cow with light blue ear flag may be No. 75(15).

Table 14. Histories of Pen 4 moose at Kenai Moose Research Center.

Moose Number	Sex	Year of Birth	Significant Observations			No. Times Observed	No. Times Captured
			Date	Event	Remarks		
71[1]	F	1969	15 June 1981	Seen from helicopter	Previously assumed dead	2	0
5	M	?	15 June 1981	Trapped in 3S	Moved into Pen 4	6	3
UC	F	?	15 June 1981	Helicopter survey	Seen with calf	?	0
UC	F	?	15 June 1981	Helicopter survey	Seen with calf	?	0
UC	F	?	15 June 1981	Helicopter survey	Seen with calf	?	0
UC	F	?	15 June 1981	Helicopter survey	Seen without calf	?	0
UC[2]	M	1979(?)	15 June 1981	Helicopter survey	Small bull	1	0
UC	M	?	15 June 1981	Helicopter survey	Mature bull	1	0
UC	F	?	10 June 1981	Trapped in survey	Cow broke into Pen 3 from trap. Calf caught and also put into Pen 3	1	1

[1] No. 71 had not been positively identified since 3 June 1978. A moose with the same collar and ear tag was seen on 8 June and 1 July 1980.

[2] An UC yearling bull was seen several times during the fall of 1980. A small bull thought to be a yearling was seen on 15 June 1981. If this was a small 2-year-old, perhaps there is only one small bull.

Table 15. Mortality within enclosures at Kenai Moose Research Center from 1 July 1980, through 30 June 1981.

Pen No.	Moose No.	Sex	Year of Birth	Date	Remarks
1	UC	F	?	25 May 1981	Carcass located from ground. Previously seen from air. Cause of death unknown.
2	670[1/]	F	1970	9 May 1978	Last time positively identified. It was thought that a moose with metal ear tags sighted more recently might be No. 670. This moose now assumed dead.
3	2870(14)[1/]	F	1970	27 Sep. 1979	Last sighting. Assumed dead.

[1/] May have died before 1 July 1980, but not previously reported dead.

Moose Weights

We are continuing to weigh the tame moose bi-weekly (Table 7 and 8). Since these animals will not attain maximum body size until 3-4 years of age, no mathematical equations to describe their growth have been calculated at this time.

Blood Chemistry and Hematology

Blood samples were collected during the report period from captive tame moose (Tables 9 and 10). Because of inadequate programming capabilities these data were not analyzed for this report.

Productivity and Mortality of MRC Moose

Histories of individual moose through 31 May 1981 are listed in Tables (11-15).

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PREPARED BY:

Charles C. Schwartz
Game Biologist

APPROVED BY:

Donald J. Somerville
Director, Division of Game

SUBMITTED BY:

Karl B. Schneider
Regional Research Coordinator

Gregory N. Bos
Acting Research Chief,
Division of Game