ALASKA DEPARTMENT OF FISH AND GAME
JUNEAU, ALASKA

STATE OF ALASKA
Jay S. Hammond, Governor

DEPARTMENT OF FISH AND GAME
Ronald O. Skoog, Commissioner

DIVISION OF GAME
Ronald J. Somerville, Director
Donald McKnight, Research Chief

MOOSE RESEARCH CENTER REPORT

By:

Albert W. Franzmann and Charles C. Schwartz

Volume X
Project Progress Report
Federal Aid in Wildlife Restoration
Project W-17-11, Jobs 1.14 R and 1.21 R

(Printed October 1979)

JOB PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: Albert W. Franzmann, Charles C. Schwartz, and Wayne L. Regelin

Project No.: W-17-11 Project Title: Big Game Investigations

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

Period Covered: July 1, 1978 through June 30, 1979

SUMMARY

Several studies continued under this job during this report period. No new drugs were tested and the combination of Etorphine and xylazine hydrochloride remains the drug combination of choice for immobilizing moose. Diprenorphine was the antagonist used with this immobilization combination. Pellet group plots were not cleared or counted during this report period, but a manuscript is in preparation on previous pellet group analyses. Preliminary data analysis indicated that shrub density and plant height were not greatly influenced by the application of fertilizers to the rehabilitated areas in Pen 1. Five moose calves were successfully raised to provide animals for digestive physiology and energy studies.

CONTENTS

BACKGROUND

The Kenai Moose Research Center (MRC), with known numbers of confined animals, provides unique conditions for developing and testing techniques applicable to moose (*Alces alces*) management. Initiation and completion of programmed studies under this job were not always possible because developments in related fields providing drugs, equipment and procedures potentially applicable to moose management determined the thrust of our activity. A final report covering activities under this project from July 1969 through June 1974 was completed (Franzmann et al. 1974). The 1976, 1977 and 1978 progress reports (Franzmann and Arneson 1976, Franzmann and Bailey 1977, and Franzmann and Schwartz 1978) covering this job were primarily devoted to pellet count census evaluations, the use of immobilizing drugs, biotelemetry, fertilization of moose forage in rehabilitated areas, moose calf mortality assessment, raising moose calves and electronic tissue measurement. Studies which continued through this report period were; the use of immobilizing drugs, fertilization of moose forage in rehabilitated areas, pellet count census and raising moose calves. The moose calf mortality study was continued as a separate study and job (Franzmann and Schwartz 1978, and Franzmann and Schwartz 1979). Background for these continuing studies was outlined in previous reports (Franzmann and Arneson 1976, Franzmann and Bailey 1977, and Franzmann and Schwartz 1978).

OBJECTIVES

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

PROCEDURES

Immobilizing, Reversing and Adjunct Drugs

No new drugs were tested during this report period. Etorphine (M-99, D-M Pharmaceutical, Inc. Rockville, MD) and xylazine hydrochloride (Rompun, Haver Lockhart Laboratories, Shawnee, KS) were used for immobilizing moose during this report period and diprenorphine (M50-50, D-M Pharmaceuticals, Inc. Rockville, MD) was used as the antagonist drug.

Pellet Group Plots

Pellet group plots in Pen 1 were not cleared or counted during this report period.

Effects of Nitrogen Fertilizer Upon Production of Moose Forage

Fourteen experimental plots (each 30 m^2) were established in April, 1977. Twelve plots were treated with fertilizer and two served as control plots. All plots were located within Pen 1, a one-square mile exclosure at the M.R.C. (Fig. 1). This area was burned by wildfire in 1947 and the regrowth vegetation was disturbed by LeTourneau tree crushers in December, 1976. Seven plots (sites 1 and 2) were located in a birch-spruce regrowth vegetation type (Fig. 2) and seven (sites 3 and 4) in a spruce regrowth type (Fig. 3). Ammonium sulfate fertilizer (28% nitrogen) was applied to sites 2 and 3 on April 12, 1977. Application rates were 67 or 133 kg of actual N per ha. On October 3, 1977, eight plots were treated: four with ammonium sulfate and four with urea (56% N). Rates were the same as the spring application. All fertilizer was applied using a whirly-bird, backpack fertilizer spreader. Spring application was made during a period of rapid snowmelt with a snow cover of about 8 cm. The soil was moist from fall rains during the autumn application.

Vegetation measurements within each plot were made during late August, 1978. Shrub and tree density was determined by counting the number of stems of each species rooted within 1 x 5m sampling plots. The height, number of current annual growth (CAG) leaders and length of CAG was measured on all birch, aspen and willow plants within each sample plot. Five sample plots were examined in each treatment plot.

Estimates of plant biomass were obtained by clipping 10,0.5m^2 sampling plots in each treatment plot. All vegetation within or overhanging each plot was clipped at ground level. Birch, aspen, willow and rose plants were sacked separately. All graminoids were sacked together as were all forb species and other shrubs. The clipped material was dried at 100 c for 24 hours and weighed to the nearest 0.1 gram.

Raising Moose Calves at the MRC

Digestive physiology and energy metabolism studies were initiated during 1978 which depended upon raising moose calves (Franzmann and Schwartz 1978). Five of eight captive, hand-reared moose calves survived through one year of age. Two calves died prior to weaning, but they lacked vigor and were generally unhealthy from the start. The third calf was killed by a timber wolf that entered the MRC enclosure. The remaining five calves are healthy and responding well to training.

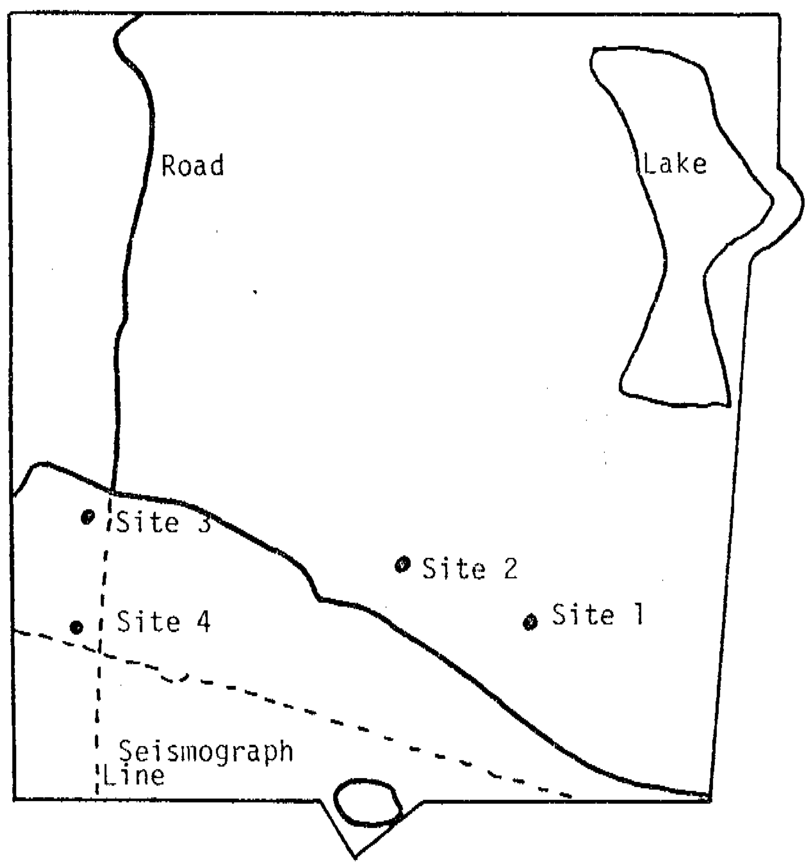

Fig. 1. Location of fertilizer sites in Pen 1 at the Moose Research Center

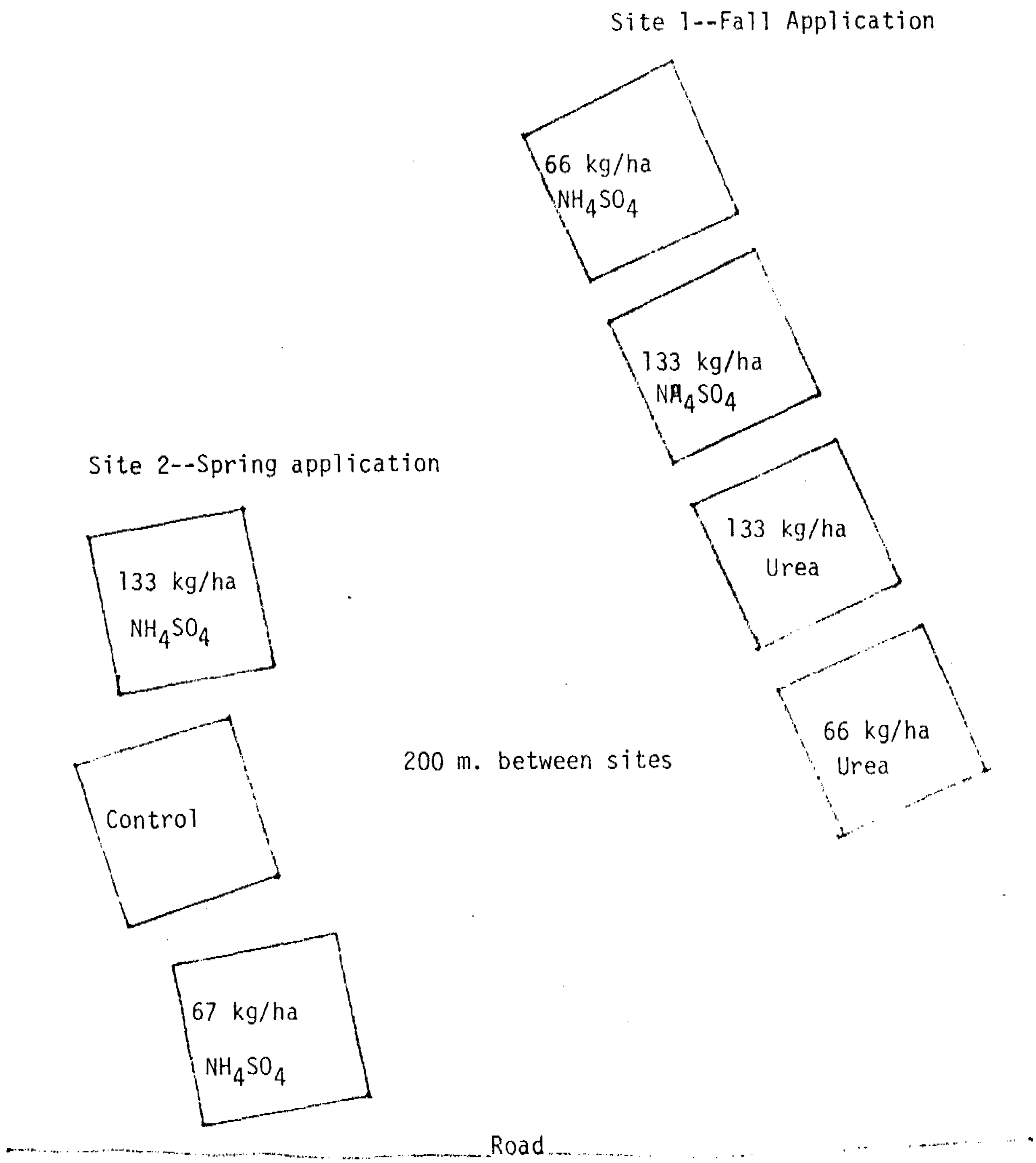

Fig. 2. Layout of fertilizer plots in Pen 1, Moose Research center.

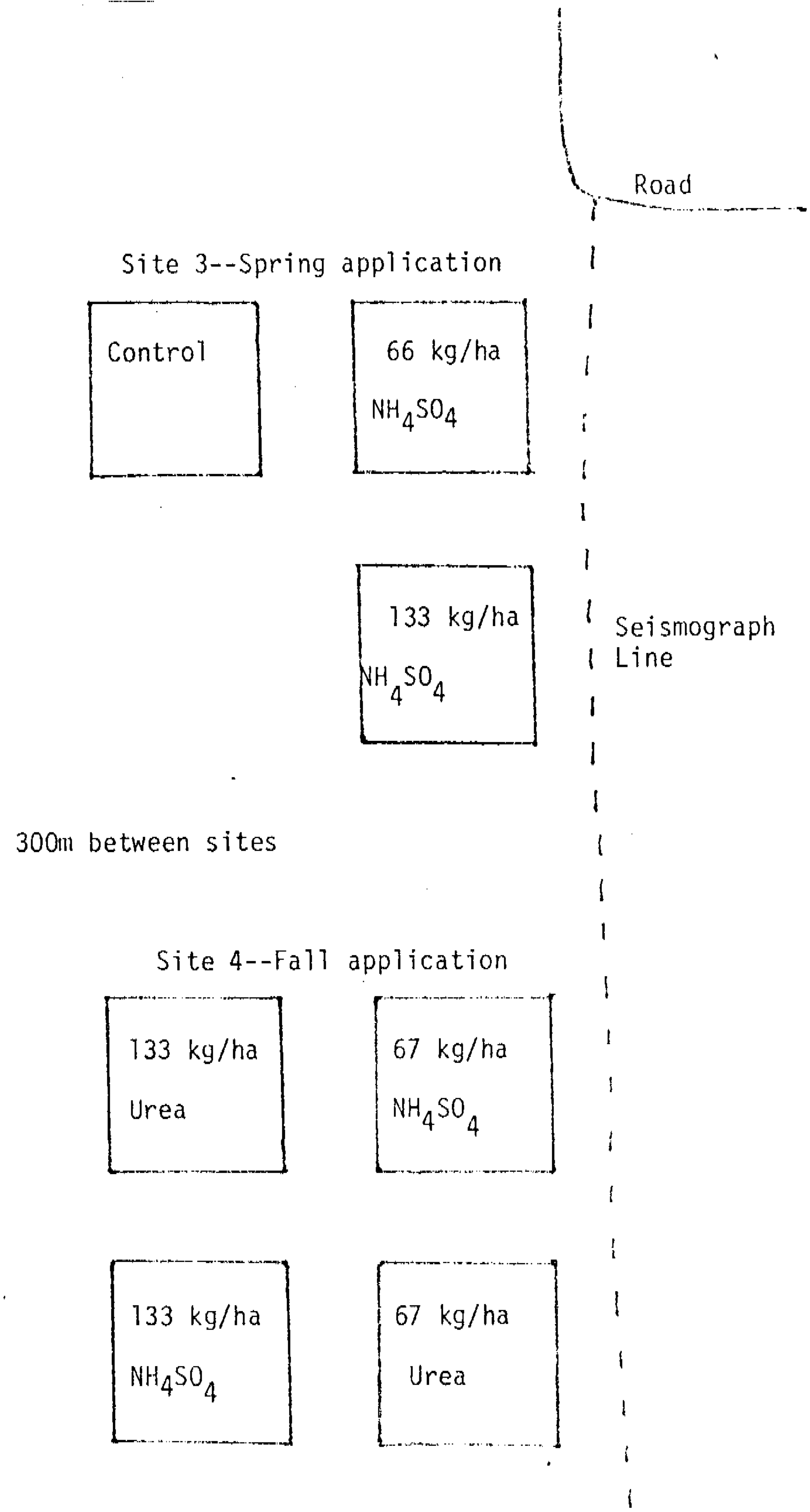

Fig.3. Layout of fertilizer plots in Pen 1, Moose Research Center.

FINDINGS

Immobilizing, Reversing and Adjunct Drugs

No new drugs were tested during this report period.

Pellet Group Plots

A paper is in preparation utilizing findings from the 1976-77 and 1977-78 seasons of pellet group analyses on censusing and habitat use by Alaskan moose.

Effect of Nitrogen Fertilization Upon Moose Forage

Preliminary data analysis indicated that shrub density and plant height were not greatly influenced by the fertilizer treatments (Tables 1 and 2). The spruce regrowth vegetation type had a shrub density much less than the birch-spruce vegetation type. The number of current annual growth leaders and length of CAG on birch plants were not changed due to application of N fertilizer (Table 3).

The standing crop biomass of all vegetation on the experimental plots varied from 294 to 733 kg/ha. These differences do not appear to be related to the fertilizer treatments (Table 4). Shrub biomass was reduced on several plots compared to control areas. Grass production appeared to be greatly increased on fertilizer plots compared to control areas. Further data analysis must be completed before conclusions can be drawn from these data. No great differences were detected between spring and fall application dates nor between ammonium sulfate and urea fertilizer.

Raising Moose Calves at the MRC

The five calves raised at the MRC to yearlings provided the tame moose needed to initiate the physiology and energy metabolism studies under the Moose Productivity and Physiology job (see Moose Productivity and Physiology this report). In addition to hand-rearing the calves, considerable time was spent developing and constructing facilities for both digestion and balance trials and energy metabolism studies. A 5 x 6 m log building was constructed to house instruments for energetic studies, feed storage and general laboratory use. A 2.2 x 2.2 m log building was constructed to house an electric generator and for general storage. In addition, five moose digestion crates for total fecal and urine separation and a metabolic chamber were constructed. Holding facilities for the tame moose were expanded and individual pens for feeding tame moose were built.

Table 1. Shrub density (plants per 25 m^2) and average plant height (m) on Sites 2 and 3. Sites were fertilized with ammonium sulfate on April 12, 1977.

	Site 2, Birch-spruce regrowth						Site 3, Spruce regrowth					
	Control		66 kg/ha		133 kg/ha		Control		66 kg/ha		133/kg/ha	
Species	No.	Ht.	No.	Ht.	No.	Ht.	No.	Ht.	No.	Ht.	No.	Ht.
Betula papyrifera	11	35	7	29	7	26	22	11	0	-	0	-
Salix spp.	0	-	3	42	0	-	0	-	0	-	0	-
Rosa acicularia	35	16	44	23	4	30	0	-	0	-	0	-
Rubus species	0	-	3	17	1	8	0	-	0	-	0	-
Pinus glauca	0	-	0	-	0		0	-	1	-	0	-
Total	44		57		12		22		1		0	

Table 2. Shrub density (plants per 25 m^2) and average plant height (cm) on Sites 1 and 4. Sites were fertilized with urea or ammonium sulfate on October 3, 1977.

Species	66 Urea No.	66 Urea Ht.	66NHySO4 No.	66NHySO4 Ht.	133 Urea No.	133 Urea Ht.	133NHySO4 No.	133NHySO4 Ht.
	Site 1 - Birch-spruce regrowth							
Betula papyrifera	18	42	11	29	22	35	13	39
Salix sp.	0	-	1	22	0	0	1	38
Populus termuloides	0	-	1	24	0	0	0	-
Rosa acicularis	31	32	32	21	42	26	3	16
Pinus glauca	0	-	0	-	2	26	1	40
Rubus sp.	0	-	0	-	0	0	0	0
Total	49		45		66		18	
	Site 4 - Spruce regrowth							
Populus tremuloides	0	-	1	31	0	-	0	-
Rosa acicularis	2	25	1	13	0	-	0	-
Rubus species	0	-	2	7	0	-	0	-
Total	2		4		0		0	

Table 3. Average number of current annual growth leaders per birch plant and average length of each CAG leader and standard error of each measurement.

Site	Treatment	Number CAG/plant	$S_{\bar{x}}$	Average length Cag	$S_{\bar{x}}$
1	66 urea	3.5	0.78	17.6	2.90
1	133 urea	5.5	1.53	15.2	1.90
1	66 NH_4SO_4	9.5	2.46	12.1	0.35
1	133 NH_4SO_4	3.2	0.71	20.9	4.21
2	66 NH_4SO_4	7.1	1.47	13.0	1.34
2	133 NH_4SO_4	6.4	1.27	10.6	2.22
2	Control	8.0	2.01	16.0	5.74

Sites 3 and 4 had no birch plants within sample plots.

Table 4. Standing crop biomass of vegetation on fertilizer plots at the MRC in August, 1978. Numbers are average grams per 0.5 m^2 plot and standard error.*

		Forb		Shrub		Grass		Rosa acicularis		Betula papyrifera		Pinus glauca		Salix spp.		Total	
Site	Treatment	gm	$S_{\bar{x}}$	gm	$S_{\bar{x}}$	gm	$S_{\bar{x}}$	gm	$S_{\bar{x}}$	gm	$S_{\bar{x}}$	gm	$S_{\bar{x}}$	gm	$S_{\bar{x}}$	gm	$S_{\bar{x}}$
1	66NH_4	2.88	0.61	8.75	4.31	1.66	0.98	0.36	0.24	0.17	0.17	0.88	0.64	0		14.72	4.54
1	66 urea	1.16	0.51	17.04	5.45	3.68	1.27	0.41	0.23	1.05	0.64	0.04	0.35	0		23.40	5.16
1	133NH_4	3.25	1.07	8.97	2.74	11.25	4.85	0.37	0.21	3.09	1.99	0	0	0		26.92	5.13
1	133 urea	1.10	0.39	17.36	4.59	10.70	4.26	2.06	0.75	1.96	1.50	0	0	0		33.19	6.17
2	Control	7.34	1.86	15.27	5.30	2.42	1.91	3.81	1.88	0		0	0	0		28.84	4.44
2	66NH_4	11.65	2.42	15.68	4.91	6.57	3.31	5.75	2.36	0		0	0	0		39.67	7.21
2	133NH_4	3.74	0.97	33.48	11.12	0		1.61	0.56	0		T	–	0.15	0.15	38.99	11.03
2	66NH_4	7.05	1.83	11.02	3.60	7.28	2.04	0		0		0.25	0.17	0		25.61	3.72
3	133NH_4	8.08	2.07	3.13	2.74	26.75	3.50	0		0		0		0.48	0.53	38.45	4.00
3	Control	5.94	0.87	17.57	5.56	2.84	0.97	0	–	T	–					26.36	8.90
4	66 urea	8.94	1.99	8.86	3.45	4.92	2.39	0.09	0.08	0		0		0		22.82	3.88
4	66NH_4	11.07	1.71	12.14	3.81	13.43	2.58	0		0		T	–			36.65	4.46
4	133NH_4	7.71	2.05	3.07	2.29	14.02	4.55	0		0		1.35	1.20	0		26.15	4.86
4	133 urea	4.76	0.99	10.79	4.46	7.20	1.52	0		0		0		0		22.76	5.46

* n=10, 95% confidence interval can be calculated by $S_{\bar{x}}$ (2.26) $\pm \bar{x}$

Digestive physiology studies using the tame moose will proceed and be covered under the Moose Productivity and Physiology section of this report. Raising and maintaining the moose in confinement were necessary before starting the studies and were accomplished under this job.

PREPARED BY:

Albert W. Franzmann
Game Biologist

SUBMITTED BY:

Karl Schneider
Regional Research Coordinator

APPROVED BY:

Director, Division of Game

Research Chief, Division of Game

JOB PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: Albert W. Franzmann, Charles C. Schwartz and Wayne L. Regelin

Project No.: W-17-11 Project Title: Big Game Investigations

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

Period Covered: July 1, 1978 through June 30, 1979

SUMMARY

Data collection continued for outlined studies of moose hair element metabolism, blood chemistry and hematology, morphometric measurements and productivity and mortality of Kenai Moose Research Center (MRC) moose. Results of blood and hair analyses were not compiled or analyzed during this report period due to lack of programming capabilities. Histories of individual moose at the MRC were updated and mortalities were recorded. Success in raising and training five moose calves to yearlings and facility construction assistance from the Young Adult Conservation Corps (YACC) program and the Kenai National Moose Range made it possible to initiate digestive physiology and energy studies on moose at the MRC. Backgrounds for these studies were provided in this report by the principal investigators. Results to date on these studies are limited to raising and training experiences with moose, daily weight data, and ration formulation.

CONTENTS

BACKGROUND

Initial results of this long-term study were summarized by Franzmann et al. (1976). This study is being continued to complete various phases of ongoing investigations and to accomodate expansion of physiologic data collection and interpretation from other Alaskan moose (*Alces alces*) populations. Background for these continuing studies was outlined in Franzmann et al. (1976).

Successfully raising and maintaining captive moose calves (see Evaluation and Testing Techniques for Moose Management section this report) has provided the Moose Research Center (MRC) the opportunity to pursue digestive physiology studies of moose as identified in the objectives of this study. The background and training of Charles C. Schwartz, Biologist II assigned to the MRC, provided the expertise necessary to initiate these studies and he will be the principal investigator on the digestive physiology aspects of this job. Status and background for this work follow:

Carrying Capacity Concept

Game management biologists long have attempted to estimate the carrying capacity of native ranges to support animals. Over the years, various techniques have been developed to estimate carrying capacity. Initally subjective estimates were obtained by visually surveying an area (Jardine and Anderson 1919), but since that time more refined methods have been developed to estimate carrying capacity. These include the "forage acre" concept (Cassady 1959), plant utilization (Stoddart 1952) and indicator plant species techniques (Humphrey 1949). All these methods involved range monitoring with little or no regard for the animal species and its requirements.

Recent studies (Moen 1973, Robbins 1973, Wallmo et al. 1977) have advanced the concept of predicting carrying capacity based upon an understanding of animal nutrition. The concept of biological carrying capacity integrates the nutritional requirements of the animal with the nutrients supplied from the vegetation. There is a complex interface between the animal and the range and the flow through this system must be understood.

Crude protein and digestable energy are considered by most nutritionists to be the most important nutritional constituents supplied by range forage (Moen 1973, Wallmo et al. 1977). Other nutritional entities are requisite to the health of moose, but are seldom the primary limiting factor. Mineral deficiences have been identified as a problem in moose from the Kenai Peninsula (Franzmann et al. 1975, Flynn et al. 1977).

Other than food habits (see Peek 1974 for review) very little is known or understood about moose nutrition. Gasaway and Coady (1974) reviewed the energy requirements of moose and other ruminants. Most of their discussion regarding moose requirements, however, was inferred from other species and it was apparent that little information was available for moose.

Moose as Experimental Animals

Available literature concerning nutrient requirements, metabolic rates, and digestive capabilities for other wild ruminants especially white-tailed deer (*Odocoileus virginianus*) and mule deer (*O. hemionus*) is extensive.

Why has no one conducted similar research with moose? The answer is two-fold. First, in order to estimate and determine many of these nutritional parameters, one must study moose in captivity under controlled conditions. Very few agencies have the facilities to keep moose. Moose are currently difficult and expensive to maintain. This is mainly because fresh browse must either be cut for feed, or the moose must be kept in a facility large enough to support the animal on native vegetation. Only a few zoos in the world have moose as display animals and in all cases, fresh browse must be cut daily. This is time consuming and expensive. There is currently no formulated diet that will sustain moose indefinately. Wallach (1972) discussed the nutrition and feeding of captive ruminants in zoos. He listed the consituents of a commercial moose and deer diet but did not discuss the application or use of this diet with regard to moose. He discussed the diet as a general "deer family" diet applicable for useage with all forms of deer.

Nutritional requirements for animal species vary with sex, age, size of young and many other facts. As discussed by Kleiber (1961), there is a linear relationship between the basal metabolic rate (BMR) of adult mammals and live weight. The original concept, developed by Brody (1945), has been described as the "mouse to elephant" curve. This concept, as described by Bell (1971), indicates that in general, the smaller the animal, the higher its metabolic rate. When applying this concept to the nutrient requirements of wild animals, one must consider both the relative maintenance requirement (per unit weight per unit time) and the absolute maintenance requirement (per animal per unit time). Small ruminants have a high relative maintenance requirement because of their higher metabolic requirement. Therefore they require more protein and energy per unit body weight per day than a large ruminant. Although the relative maintenance requirement is higher for a small animal than it is for a large one, the reverse situation holds for the absolute maintenance requirement. Because of their large body size, large ruminants require a larger total energy and protein input to maintain their system, but can survive on poorer quality forage.

Consequently dietary requirements vary between deer species depending upon body size. Likewise dietary requirements can vary between age and sex classes of a species depending upon their stage of development. BMR is higher in young animals than in adults. Therefore, young, growing animals have a higher relative maintenance requirement compared to adults. We do not believe that the diet discussed by Wallach (1972) is suitable for all species of deer, especially moose. Additional review of the literature indicates no other diet was formulated specifically for moose.

Formulated Diets, Considerations and Misconceptions

Animal nutrition, as we know it, had its beginning as an art form, the foundations of which were a blend of instinct, habit, experience, folklore and conjecture (Crampton and Lloyd 1959). Over the years, animal nutrition has evolved into a complex, highly intergrated science. Although there are over 150 species of ruminant animals, most nutrition studies have been conducted on three domestic species -- cattle, sheep and goats. Only in recent years have nutrition studies been directed to wild ruminants. As a consequence, little is known or understood about the nutritional requirements of most wild species. Many misconceptions about wild ruminants have resulted from the misinterpretation of domestic ruminant studies. For example, it has long been assumed that ruminants, because of their anatomy, were roughage eaters. It was assumed that all species were capable of digesting coarse, fibrous feeds.

Recent studies by Hofmann (1968) demonstrated that digestive anatomy and subsequent dietary selection varies greatly between ruminant species. He classified ruminants into three catagories based upon feeding habits and digestive morphology: 1) roughage or grass eaters, 2) selective eaters and 3) transitional forms. Transitional forms were then divided into two catagories: (1) roughage eaters in wet environments or, (2) selective eaters in three subclasses: (a) those consuming hard-succulent leaves of desert plants, (b) animals with a seasonal intake of dry or fibrous forage, and (c) animals eating leaves and twigs. Domestic cattle fit into the roughage eater category, while domestic sheep and goats are transitional forms under subclass b.

Feeding studies with mule deer (Nagy et al. 1974, Schoonveld et al. 1974) indicate that deer develop digestive upset when fed large quantities of fibrous alfalfa hay while sheep and goats digest hay normally. From this information, it appears that certain ruminant species cannot process coarse, fibrous materials.

Ration Formulation

To paraphrase Church (1972), much has been written about the practices and principles used to formulate rations for various species of farm animals. Probably the most extensively read treatise on this subject has been presented by Morrison (1956) in his feeds and feeding text. A balanced ration has generally been defined as one which supplies all the required nutrients in optimum amounts to meet the requirements for which it is fed. Dyer (1963) cited by Church (1972) emphasized that, although it might be easily definable, it is highly improbable that a balanced ration can be formulated since the requirement for many nutrients has not been established. Hence the preference by many nutritionists to refer to the practice as ration formulation rather than ration balancing. Effective ration formulation involves the application and understanding of the nutrient requirements of the ruminant animal.

In general, rations are balanced for essential requirements like crude protein, digestible energy, macro and trace minerals plus essential vitamins. Adequate levels of these nutrients are generally obtained by adding various amounts of concentrate (feed grains) and roughage (hays and crop residues) to the ration and balancing the minerals and vitamins with added supplements. The majority of the roughages used in formulated ruminant diets are cultivated hays (i.e., grass and legume crops) and crop residues (beet pulp, corn husks and cobs, etc.); very little woody vegetation (i.e., sawdust or wood pulp) is utilized.

Fiber Analysis and Classification

The term fiber in animal nutrition has been defined in various ways, but generally refers to the "hard to digest carbohydrates" (Ensminger and Olentine 1978) found in a food. Quantitatively, fiber has been determined by chemical analysis. The Weende system of proximate analysis, which dates back to 1809 (Henneberg and Stohmann 1960), partitions forage into two fractions. The soluble fraction (nitrogen free extract, NFE) was assumed to be digestible while the insoluble fraction (crude fiber) was considered nondigestible. Studies with ruminants by Ely and Moore (1959) have demonstrated that in some instances the crude fiber portion was more digestible than NFE. This was true because part of the NFE was composed of hemi-cellulose and soluble lignin.

Criticism of this system led to the development of another system of fractionation (Van Soest 1963, 1965b, 1968; Van Soest and Wine 1967, Goering and Van Soest 1970). This system divided the plant cell into two components: (1) the cell soluble portion, which consisted of sugars, soluble carbohydrates, proteins, and lipids (which were almost completely available to the animal) and (2) cell-wall constituents which comprise cellulose, hemi-cellulose, lignin and minerals. The Van Soest system of fractionation allowed for a more accurate separation of chemical constituents in terms of nutritional availability to the ruminant animal. This system evolved with the analysis of grasses and forbs but little work was done with woody vegetation since it was of minor importance to domestic livestock. Within recent years several investigators (Oldemeyer et al. 1977, Regelin 1971 and others) have used the Van Soest system to analyze the fiber components of woody vegetation.

Components of Voluntary Intake

Milchunas (1977) and Milchunas et al. (1978) provide an excellent review of the variables which affect voluntary intake (VI) in ruminants. In summary, VI is a function of fill and turnover time under bulk limiting conditions. Evidence that ruminants are bulk limited is provided by the observed reduction in voluntary intake when water filled bladders (Campling and Balch 1961, Egan 1972), polypropylene fibers (Welch 1967), polyvinyl chloride or sawdust (Egan 1972, Weston 1966), or feed (Egan 1972, Weston 1966) are introduced into the rumen. Work by Campling et al. (1963), Freer and Campling (1963), Ulyatt et al. (1967) suggests that animals eat to a constant level of dry matter in the rumen. Therefore, rumen capacity can limit intake before the animal's requirement for energy is met. When the energy requirement is met, it appears that chemostatic or thermostatic regulation of intake occurs (Ammann et al. 1973, Baumgardt 1970, Montgomery and Baumgardt 1965).

The gut capacity of an animal has components of both a fixed and variable nature. Hofmann (1968, 1973) studied rumen and omasum structure in relation to feeding habits and observed two basic morphological types: (1) those of quality selective feeders, and (2) those of bulk, large quantity grazers. Hofmann surmised that several structural components of the stomach determine the physical regulation of food intake. Capacity, size of communication ostia, barriers, subdivisions or contractive mechanisms for the delay of food passage are so firmly established that they remain unaffected by dietary changes, and therefore determine the limits of the adaptive ability of a species. This fixed component is modified by size and/or age of the animals.

There are, however, variable factors superimposed on the genetically fixed aspects of gut capacity. Animals appear to be able to increase rumen volume in response to energy demands of lactation (Fell et al. 1964, Hutton et al. 1964, Tulloh 1966) or ballons (Mowat 1963) and inert materials (Welch 1967) in the rumen. Dry matter intake of forages at a given level of digestibility may also be altered by a density factor (Baumgardt 1970, Mertens 1973, Thornton and Minson 1973). A higher density feed would occupy less ruminal space per unit weight.

Turnover time is the relatively variable component of voluntary intake in that, within the fixed limits imposed by rumen structure, it is a function of the variable rates of digestion and propensity for particle size reduction of different forage species. This in turn, depends on the physical and chemical nature of the forage and rumination time.

Forage turnover time is dependent on the rapidity of clearance of forage from the digestive tract which then allows further intake. Clearance may be accomplished by means of excretion or absorption. Mertens (1973) concluded that the lower tract does not limit passage. Excretion appears to be controlled by the reticulo-omasal orifice which acts as a filter for large forage particles. Balch and Campling (1962, 1965) and Troelsen and Campbell (1968) found marked differences in relative particle size of ruminal and omasal digest. When propylene fibers of varying length are introduced into the rumen, longer fibers cause longer and more prolonged reductions in intake (Welch 1967). Pouring water into the rumen does not affect intake (Campling and Balch 1961, Moore et al. 1960); cell contents are soluble and occupy essentially no volume when dissolved (Van Soest 1971 in Robbins 1973). Therefore, the fibrous fraction of a forage limits the the rate of passage. As this fraction increases, voluntary intake declines with an increasingly negative slope (Van Soest 1965a).

Mastication, rumination and digestion are the means by which particles are reduced for passage. Welch and Smith (1969, 1970) found high correlations between cell-wall content of the diet and rumination time. The relative rates of breakdown and mode of breakdown of coarse roughage by artificial mastication have been thought to be related to voluntary consumption by sheep (Troelsen and Bigsby 1964, Troelsen and Campbell 1968).

Campling (1970), Van Soest (1965a), and Weston (1968) emphasized the importance of rate of digestion on rate of disappearance of digesta from the reticulorumen. However, the effect of rate of forage digestion on turnover time is of a dual nature: (1) digestion of cellulose weakens cell wall structure, thereby contributing to ease of particle size reduction, hence, rate of passage and (2) digestion of cellulose may contribute directly to the reduction of volume of material in the rumen. Considering that cell solubles when dissolved do not contribute to bulk reduction and that digestion of cellulose contributes to bulk reduction primarily through its effect on particle size reduction, then rate of passage is the primary component of turnover time. This explains the low correlation of rate of fermentation to voluntary intake (Mertens 1973, Thornton and Minson 1973) and the rather consistent relationship of VI to cell wall (Van Soest 1965a).

Balch and Campling (1962, 1965), Hungate (1966), Troelsen and Cambell (1968), Van Soest (1966) and Welch (1967) indicated the importance of rate of particle size reduction in determining rate of passage. Rumination time is highly correlated to cell wall content of the diet (Cammell and Osbourn 1972, Welch and Smith 1969, 1970) as it may also be to lignin content (Mertens 1973). Cell wall and lignin have thus been reguarded as inhibitors to physical breakdown and therefore rate of passage. Also, since cell contents are nearly completely digested by the ruminant and cell wall is of variable availability, high cell wall and/or lignin composition with other factors constant indicates relatively lower digestibility. Low digestibility seemingly implies a slower rate of passage because rate of digestion is one of the components of rate of passage. Therefore, high fiber and lignin and low digestibility are generally considered synonymous with a slower rate of passage. Mertens (1973) has theorized that with lignin somewhat the opposite could be true; that lignin provides rigidity to wood cell walls, while cellulose provides flexibility. Therefore, high lignin content would suggest greater shattering ability while high cellulose content would suggest greater resistance to mastication. Van Soest (1966) observed that, although lignin content was directly related to feed particle size, it was inversely related to fecal particle size. Therefore, the largest, most lignified feed particles are transformed into the smallest most lignified fecal particles.

One additional facet of particle size reduction phenomena is pertinent in this discussion before a hypothesis is presented synthesizing these concepts and results observed in these studies. Mertens (1973) reviewed the work of Troelsen and Campbell (1968) with respect to particle shape. Omasal particles in sheep fed alfalfa were short and broad with a more cubical shape whereas omasal particles in grass-fed animals were long, thin, and more fiber-like. At the same level of intake more large particles passed into the omasum when the animal was fed alfalfa than when fed grass. Yet, within the legume or grass families, the more lignified material passed slower due to the need for increased rumination. Mertens concluded that lignin would therefore have two opposing influences. Increased lignin requires greater rumination, yet the particles produced are of a more optimum shape for passage.

The opposing influences of lignin on rate of passage may explain several seemingly contradictory results. For example, Troelsen and Campbell (1968) observed that more lignified material passing slower. Yet, Smith (1968), feeding sheep cell wall of a constant average particle size and varying lignin content, observed similar rates of passage although rate of digestion was negatively influenced by increasing lignification. In a study by Milchunas (1977), highly lignified *Vaccinium* had a faster rate of passage than *Epilobium angustifolium* or *Agropyron spicatum* when fed to deer. Also with respect to the *Agropyron*, a grass, relatively large fecal particles were observed compared to the *Epilobium* and *Vaccinium*. Thus the work of Smith (1968), Van Soest (1966) and Milchunas (1977) all support Merten's (1973) hypothesis that high lignin content may provide greater shattering ability.

Forage Fiber Content

Chemically, the fiber content varies considerably between grass, forbs and shrubs/trees. In general, grass species have a high cell wall content but a low lignin content (Van Soest 1973). Likewise, grasses have a much greater amount of hemi-cellulose than do legumes (Gaillard 1965). Analysis of Kenai Peninsula moose browse (Oldemeyer et al. 1977) revealed apparent differences between grasses, forbs, and woody vegetation. If one looks at the ratio of lignin/cell wall constituents (Lig/CWC) certain trends are apparent. Grasses have a very low Lig/CWC ratio while shrubs are just the opposite having a high Lig/CWC ratio (Table 1). Forbs are intermediate. This Lig/CWC ratio represents the percentage of lignin making up the fiber portion of the forage. Browse is high in total fiber lignin while grass is low in fiber lignin.

Food habits of moose (LeResche and Davis 1973) indicate that the diet is composed almost entirely of woody vegetation.

Conclusions

What does all this mean? From the preceding discussion, several points can be made:

1. Very little is known about digestive physiology of moose.

2. To our knowledge, no one has developed a formulated diet capable of supporting moose.

3. Fiber is fractioned into cell wall constituents, acid detergent fiber and lignin.

4. Rumen capacity can limit intake before an animal's requirements for energy are met.

5. Mechanics for the delay of food passage are so firmly established that they remain unaffected by dietary changes, and therefore determine the limits of the adaptive ability of a species.

6. The fiber in a forage limits the rate of passage.

7. Rate of passage is the primary component of turnover time.

8. Cell walls and lignin have been considered inhibitors to physical breakdown of forage and therefore rate of passage.

9. Lignin provides rigidity to wood cell walls, while cellulose provides flexibility.

Table 1. Quality of moose forage collected during July 1974.

Species	IVDMD[1] (%) Moose	Dairy Cow	Fiber (%) Cell walls	ADF	Lignin	Lig./CWC	Protein (%)
Grass							
Bluejoint	48.1	55.9	69.8	37.8	3.7	.053	9.8
Carex sp.	41.4	53.8	78.4	33.4	5.9	.075	9.9
Forbs							
Menyanthes trifoliata	92.3	85.9	30.4	16.1	3.6	.118	13.9
Fireweed	62.2	64.7	23.8	19.3	5.4	.227	11.9
Lupine	56.9	84.4	23.1	18.8	3.7	.160	24.3
Potamogeton sp.	73.1	80.7	32.2	17.7	2.4	.075	17.1
Shrubs							
Paper birch							
Leaves	43.1	47.6	29.0	19.5	8.3	.286	16.9
Twigs	25.8	23.5	56.1	43.2	16.8	.299	9.0
Combined	42.6	38.6	38.3	26.0	11.8	.287	13.9
Dwarf birch	42.6	38.1	36.5	27.3	14.5	.397	16.8
Aspen							
Leaves	56.8	57.6	36.3	29.9	17.6	.484	13.8
Twigs	64.1	56.1	46.2	36.5	13.4	.290	8.3
Combined	-	57.4	36.8	28.6	14.4	.391	12.6
Willow							
Leaves	54.8	41.2	27.6	22.2	11.6	.420	13.5
Twigs	42.6	43.3	44.9	40.6	18.2	.405	6.9
Combined	57.8	41.7	26.6	23.9	12.7	.477	13.2
Lowbush cranberry	44.3	38.5	50.5	44.6	23.8	471	7.6
Highbush cranberry	52.8	64.4	37.8	28.2	13.1	.347	10.3

a/Data from Oldemeyer et. al. 1977.

10. Increased lignin in the diet requires greater rumination time, yet the particles produced are of a more optimum shape for passage.

11. Higher lignin in the diet may provide greater shattering ability and a consequently greater rate of passage.

12. Browse has a high fiber lignin while grass is low in fiber lignin.

13. Moose diets are primarily browse.

With these variables in mind, it is apparent that moose as ruminants evolved with certain mechanisms to process woody vegetation but may lack the ability to process grasses and forbs. Browse as a food is composed of two components: (1) the bark and bud which provide the available nutrients; and (2) the woody core which is composed mainly of liquified woody material. Although the entire package (bark, bud and woody center) is relatively low in available nutrients, moose can meet their minimum nutrient requirements because the non-nutritive core is mainly lignin. This core can be broken down rapidly into small particles capable of passing from the rumen. Thus, the rates of passage are sufficient to allow moose to digest and assimilate nutrients from the bark and bud, but not be bulk limited by the woody core. This situation is not true for grasses and many forbs. Consequently, moose given diets which contain large quantities of fibrous material from grasses and forbs become bulk limited because of reduced rates of passage and cannot extract enough nutrients to survive. Most formulated rations contain large quantities of grass or alfalfa hay and consequently are not suitable as moose food.

A grant proposal to the Morris Animal Foundation was prepared and submitted by Charles C. Schwartz entitled "Development and testing of a formulated ration for moose" which encompasses the preceding background information. The purpose was to gain additional financial support for the MRC research program.

As per the cooperative agreement establishing the MRC (see Franzmann and Bailey 1977), a biologist from the Denver Wildlife Research Center (DWRC) is assigned to the MRC to conduct vegetation and habitat research. Wayne L. Regelin was assigned to replace John L. Oldemeyer and his research direction has been formulated to obtain information for the Kenai National Moose Range and the Alaska Department of Fish and Game.

Much of the effort associated with construction of facilities (see Raising Moose Calves in Evaluation and Testing Techniques for Moose Management) to make these study efforts possible resulted from the availability of help provided through the Young Adult Conservation Corps (YACC) program. Some aspects of these studies are dependent upon continued support from this program.

OBJECTIVES

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

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

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

To determine nutritional values and digestabilities 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 optimum 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 and contrast 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 overall objective 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 objective.

PROCEDURES

Hair (Metabolism)

Procedures for collecting, handling and analyzing moose hair samples have been reported (Franzmann et al. 1975). During this report period, hair samples were collected from moose immobilized and processed at the MRC.

Blood Chemistry and Hematology

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

Morphometric Measurements and Body Weight

Specific procedures for obtaining measurement and weight information from moose have been outlined (Franzmann et al. 1978). Measurement and, when possible, weight data were obtained from moose immobilized and processed at the MRC. In addition, daily live weights were obtained from calves raised at the MRC (see Digestive Physiology section this report).

Productivity and Mortality of MRC Moose

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

Moose within the MRC enclosures were moved from one enclosure to another or released outside the enclosures to obtain approximately the following numbers and distributions: Pen 1--three bulls, three cows; Pen 2--one cow, five tame moose; Pen 3--eight cows and no bulls until late in rut; and Pen 4--no moose.

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

Digestive Physiology of Moose

Procedures are outlined as per the four objectives relating to this aspect of the job.

Objective (1): Hand-reared captive moose calves (Franzmann and Schwartz 1978) will be used to evaluate objectives of this study. Five calves (two females and three males) will be test subjects. Studies will be conducted at the Moose Research Center. Development and testing of the formulated diet will follow recommendations of Ensminger and Olentine (1978:469-493). In general, the formulated diet will be evaluated on the basis of (1) physical characteristics, (2) chemical analysis, and (3) biological evaluation.

The diet will be analyzed chemically for crude protein (Kjeldahl N X 625), gross energy, ash and minerals will be determined by procedures in A.O.A.C. (1965). Cell-wall constituents (CWC), acid-detergent fiber (ADF), and acid-detergent lignin will be determined using procedures outlined by Van Soest and Wine (1967), Van Soest (1963) and Goering and Van Soest (1970). Physical characteristics including pelleting ability, lack of crumbling in prepared pellets and acceptance of various pellet sizes will be evaluated subjectively unless statistical testing seems justified.

Biological evaluation will consist of two parts. Conventional digestion and balance trials (Ensminger and Olentine 1978, Schneider and Flah 1975, Church 1969) will be used to evaluate the animals' ability to process, digest, absorb and assimulate the various nutrients (Part 1). Wooden digestion stalls (3.1 x 2.4 x 2.4 m), designed to permit complete and separate collection of feces and urine, will be used for digestion studies. The floor of the stalls will be fitted with expanded metal sheeting to permit fecal and urine separation. During phase 1 of Part 1, animals will be enclosed in 3.1 x 15.2 m enclosures for 10 days during which average daily food consumption will be measured.

During phase 2, moose will be enclosed in the smaller digestion crates for a 5-day adjustment period. During this phase and during phase 3, moose will be offered 90 percent of their phase 1 intake. This will be done to level out consumption and eliminate the analysis of orts. During phase 3, total food consumption and fecal and urine production will be obtained daily for 7 days. Food will be offered twice daily with water available *ad libitum*. A 50-gr sample of the diet, as fed, will be collected and frozen daily. At the end of each digestion trial, a weekly composite sample of the diet will be analyzed in triplicate for percent moisture. If orts exist, they will be subsampled and analyzed in a similar fashion. Excreta will be collected several times daily and weighed or the volume measured and subsampled. Urine samples will be acidified with 6N HCL to lower the ph below 4 to prevent the loss of ammonia nitrogen.

Excreta samples for each moose, 20 percent by weight for feces, and by volume for urine, will be saved daily; feces will be frozen (-12C) and urine will be refrigerated (1C). Later moisture and nitrogen will be determined in undried feces while fiber analysis and gross energy analysis will be carried out on subsamples dried at 60C in a convection oven until air-dry. Specific gravity and nitrogen content of wet urine will be measured, and gross energy will be determined on urine dried in a vacuum oven at 60C. Moose calves will be placed in an indirect respiration calorimeter (Silver et al. 1969) for 24 hours to measure rates of oxygen consumption and carbon dioxide and methane production while being fed. After these measurements, moose calves will be fasted for 48 hours and placed back into the respiration chamber. Metabolic rate, as determined by heat production, during this fast should represent the net energy requirements. By following this schedule the energy flow can be partitioned into its various components as discussed in the background section. Nutritional information will be collected seasonally and will correspond to important periods during the annual cycle of the moose. Periods to be tested will be March, June, September and December. These correspond to late winter stress periods, calving season, rutting season and early winter.

Differences among treatment means will be determined by factorial analysis of variance. Sources of variation will be sex, season and sex by season.

Following each digestion period, jugular blood samples will be taken for determination of the various blood parimeters monitored using techniques of Franzmann et al. (1976).

The second part of the biological evaluation of the formulated diet will involve longterm monitoring of captive moose maintained solely on the artificial diet. Parimeters to be monitored will include general growth and development as determined by weight, development of abnormalties either external (i.e., rickets, poor hair coat, etc.) or internal (i.e., rumen dysfunction), general vigor, reproductive maturity and other subtle factors. We feel this part of the evaluation is essential since many defficiences or dietary problems may not manifest themselves in typical "clinical" symptoms normally described in current ruminant nutrition texts. Rather, if some problem occurs, it more than likely will take some time to develop.

Objective (2): Two pelleted, isocaloric feeds will be formulated to contain 5 and 20 percent crude protein on a dry weight basis. Four diets (treatments) will be prepared to contain 5, 10, 15 and 20 percent crude protein by mixing appropriate portions of the two formulated rations. Digestion and balance trials will be conducted to estimate minimum protein requirements similar to the methods described above. Digestible nitrogen intake will be plotted against nitrogen balance (tissue retention). The point of maximum tissue nitrogen balance should represent the animals' requirements for maximum growth (Young et al. 1973). Apparent maintenance requirements of metabolizable energy will be calculated by regression of total energy balance (TEB = metabolizable energy [ME] minus total heat production while on feed) on ME intake, both expended as kcal/kg $W^{0.75}$; the ME intake at which the resulting curve crosses zero TEB is the apparent maintenance ME requirement (Thompson et al. 1973).

Nutritional information will be collected seasonally during periods similar to those of objective 1. These studies will be conducted 1 year after the formulated diet is tested. Trials will be conducted on adult and calf moose (4-6 additional calves will be raised in 1980).

Trials will be analyzed using analysis of variance with season, sex, age and protein level as variables.

Objective (3): Blood samples will be taken from the juglar vein, processed and analyzed by methods outlined by Franzmann et al. (1976). Sampling schemes will run concurrently with the protein-energy experiments described in objective 2. Blood samples will be taken at the termination of each experimental period.

Objective (4): Digestion and balance trials to determine the ability of moose to process native browse stems of paper birch, willow, aspen, and lowbush cranberry, will be conducted using conventional digestion trials described in objective 1. Hand-clipped samples will be collected in winter, stored in plastic bags and fed as required. Samples will be clipped weekly and frozen until used. Cranberry will be collected prior to snowfall. Digestion coefficients will be calculated for individual species and for combinations of species that are proportional to winter moose diets.

FINDINGS

Hair (Metabolism), Blood Chemistry and Hematology

Samples were collected and analyzed from all moose handled during this report period,

Morphometric Measurements and Body Weight

Measurement data were collected from moose handled, but results were not compiled due to lack of programming capabilities during this report period. Daily body weights were obtained from the tame captive moose and are listed in the Digestive Physiology section of this report.

Table 2 Histories of Pen 1 individual moose at Kenai Moose Research Center, July 1, 1978 through June 30, 1979.

Moose no.	Sex	Year of birth	Significant observations Date	Event	Circumstances	No. times observed	No. times captured
43 1/	M	1968	12 Nov. 1978	Last sighted	Observed	3	0
58	M	1970	30 June 1979	Last sighted	Observed	7	0
R-70-8	F	1968	20 June 1979	Last sighted	Observed--no calf	8	0
125	F	1966	27 June 1979	Sighted	Observed--no calf observed with short yearling	9	0
UC	M	1976	22 June 1979	Sighted	Observed 1975 calf of 125	12	0
UC	?	1978	4 May	Sighted	Observed with R-70-8 (her calf of 1978)	4	0
UC	M	1978	2 June 1979	Sighted	Observed with 125 (her calf of 1978)	11	0
UC 1/	M	?	9 Oct. 1978	Sighted	Broke down fence and entered Pen 1	2	0

1/ On 22 June 1979, the remains of an uncollared male were found in Pen 1. From the tooth wear, the moose probably was male 43 but since he was not collared we are unsure at this time.

Table 3 Histories of Pen 2 moose at Kenai Moose Research Center, July 1, 1978 through June 30, 1979.

Moose no.	Sex	Year of birth	Significant observations			No. times observed	No. times captured
			Date	Event	Circumstances		
670	F	1970	NOT OBSERVED THIS YEAR			11	0
130	F	1975	23 June 1979	Observed	With new calf	11	0
UC	M	1978	22 Dec. 1979	Observed	1978 calf of 130 assumed dead	5	0
141	M	1976	2 Dec. 1978	Observed	Released to outside	3	0
129	F	1976	28 Jan. 1979	Observed	Sighted	3	0
UC	F	?	10 July 1978	Observed	Ear tags in ears (may be 670)	1	0
UC	F	?	23 June 1979	Observed	No ear tags	1	0

Table 4 Histories of Pen 3 individual moose at Kenai Moose Research Center, July 1, 1978 through June 30, 1979.

Moose no.	Sex	Year of birth	Significant observations Date	Event	Circumstances	No. times observed	No. times captured
80	M1/	1969	19 Sept. 1978	Trapped 3S	Moved to Pen 4	4	1
2870(14)	F	1970	27 June 1979	Observed	Sighted	3	1
75(15)	F	1969	24 Oct. 1978	Observed	Sighted with twin calves	4	1
72	F1/	1970	-N O D A T A T H I S Y E A R-			0	0
98	F1/	-	-N O D A T A T H I S Y E A R-			0	0
140(73)	M1/	1969	20 Sept. 1978	Trapped 3W	Moved to Pen 4	4	1
36	M1/	1967	13 July 1978	Observed	Found dead - assumed winter kill	1	0
133	F1/	-	12 Sept. 1978	Observed	Found dead	1	0
5090	F1/	1978	28 June 1978	Observed	Found dead calf of 133	1	0
13	F	1970-72	18 July 1978	Trapped 36	Previously tagged all I.D. gone	2	1

1/ These individuals are no longer residences of Pen 3.

Table 5 Histories of Pen 4 individual moose at Kenai Moose Research Center, July 1, 1978 through June 30, 1979.

Moose no.	Sex	Year of birth	Significant observations Date	Event	Circumstances	No. times observed	No. times captured
7	M	1969	19 Sept. 1978	Trapped 4NE	Processed	1	1
37	F[1/]	1969	-NO DATA THIS YEAR- assumed dead			0	0
71	F[1/]	1969	-NO DATA THIS YEAR- assumed dead			0	0
81	F	1969	14 May 1979	Observed	Sighted from helicopter	1	0
131	F[1/]	1977	-NO DATA THIS YEAR- assumed dead			0	0
132	F[1/]	?	4 May 1979	Sighted	Found dead winter mortality	3	0
UC	F	?	5 June 1979	With calf	Sighted from Super Cub	1	0
39	F[1/]		31 March 1979	Sighted	Found dead	1	0
UC	M[1/]	1977	6 July 1978	Trapped 4SE	Released to outside	1	1
140(73)	M	1969	20 Sept. 1978	Trapped 3W	Released in Pen 4	1	1
80	M	1969	19 Sept. 1978	Trapped 3S	Released in Pen 4	4	1

1/ These individuals are no longer residents of Pen 4.

Table 6 **Mortalities** within Kenai Moose Research Center enclosures July 1, 1977 through June 30, 1978.

Pen no.	Moose no.	Sex	Year of birth	Date	Cause
1	43 or UCM	M	?	22 June 1979	Winter starvation - no I.D. found, one of two individuals
3	72	F	1970	No data	Assumed dead
3	98	F	-	No data	Assumed dead
3	36	M	1967	13 July 1978	Winter starvation
3	133	F	-	12 Sept. 1978	Found dead - cause unknown
3	5090	F	1978	28 June 1978	Found dead - black bear predation calf of 133
4	37	F	1969	No data	Assumed dead
4	71	F	1969	No data	Assumed dead
4	131	F	1977	No data	Assumed dead
4	132	F	?	4 May 1979	Winter starvation
4	39	F	?	31 March 1979	Winter starvation

Productivity and Mortality of MRC Moose

Histories of individual moose through 30 June 1979 are listed in Tables 2-6. Our trapping efforts during 1978 were good and we successfully removed all the male moose from Pen 3. We were unable to reintroduce a bull into this pen during the late rut due to unsuccessful attempts to capture one of two transplanted bulls removed from Pen 3 and put into Pen 4. Efforts will again be made this year to catch a bull during the late rut for introduction into Pen 3.

Digestive Physiology of Moose

The moose calves raised at the MRC (see Evaluation and Techniques for Moose Management section of this report) provided the animals to pursue digestive physiology studies. Findings to date are limited to raising and training experiences with the moose, daily weights of moose through their first year of growth and ration formulation.

The training of the tame moose has continued daily. Animals have been placed in the metabolic chamber and digestion and balance stalls on a regular basis. The moose accept confinement in the individual 3.1 x 15.2 m enclosure for extended periods of time (up to 10 days) but are still uneasy in the smaller 1.2 x 3.1 m stalls. We are gradually extending the time periods of confinement in attempts to habituate them to the smaller stalls. Melody Schwartz has been responsible for most of the training and taming since the calves were weaned.

The moose calves were weighed daily when possible and Table 7 lists the weights for each moose on days weighed through June 30, 1979. No analyses of weight data have been completed at this time; however, growth as reflected by weight-gains appears to be higher than weights of wild moose from the Kenai Peninsula (Franzmann et al. 1978). This is evident in continued weight-gain during the winter months (October-March).

A formulated moose ration (Moose Research Center Special) was balanced and tested on the tame animals. Although chemical analysis is not available at this time, diet quality, as reflected by the weight-gains of the moose, appears optimal.

Table 7 Daily weight in kilograms of 5 captive moose hand-reared at the Moose Research Center, 1978-79.

	Animal Name (sex)				
Date	Lucile (F)	Rodney (M)	Chester (M)	Chief (M)	Angel (F)
5-25-78	17.0	16.0	-	-	-
6-26-78	18.75	18.0	-	-	-
5-27-78	19.0	19.0	-	-	-
5-28-78	19.25	19.0	-	-	-
5-29-78	19.5	20.0	18.5	-	-
5-30-78	20.0	20.0	18.0	-	-
5-31-78	19.5	19.0	18.5	-	-
6-01-78	19.75	20.0	19.5	-	-
6-02-78	19.75	20.5	19.25	-	-
6-03-78	20.25	20.75	19.5	-	-
6-04-78	20.0	21.75	20.0	-	-
6-05-78	21.0	22.0	20.0	-	-
6-06-78	21.5	22.25	20.75	-	-
6-07-78	21.5	22.5	20.25	-	-
6-08-78	21.5	22.5	20.75	30.75	19.75
6-09-78	21.5	23.5	21.25	30.25	19.75
6-10-78	23.0	24.0	21.5	30.0	20.0
6-11-78	22.5	24.5	21.5	20.5 increased	21.0
6-12-78	22.5	25.75	21.5	30.75 feeding	20.75
6-13-78	23.5	25.75	23.25	31.5 level	21.25
6-14-78	23.75	26.00	23.0	33.5	21.75
6-15-78	24.25	26.75	24.0	33.0	23.0
6-16-78	-	26.5	24.3	-	-
6-17-78	24.25	28.75	24.25	33.0	22.0
6-18-78	24.5	29.0	24.75	33.5	23.0
6-19-78	25.0	28.25	25.0	33.0	23.0
6-20-78	25.75	30.0	24.75	34.25	23.75
6-21-78	28.0	31.75	25.0	37.0	24.5
6-22-78	28.5	32.0	25.75	38.0	24.75
6-23-78	28.75	32.5	26.0	38.0	24.75
6-24-78	28.25	32.75	26.75	38.5	25.25
6-25-78	29.5	35.75	27.5	40.0	25.0
6-26-78	30.25	33.5	27.25	40.25	25.0
6-27-78	29.0	35.5	28.0	40.0	27.25
6-28-78	30.0	34.25	28.0	40.25	26.0
6-29-78	33.5	36.0 changed	29.0 changed	40.0 changed	28.0
6-30-78	32.75 changed	36.5 schedule	28.5 schedule	41.75 schedule	27.75
7-01-78	31.5 schedule	36.5	29.0	41.75	28.0
7-02-78	33.5	36.75	30.0	41.0	28.25
7-03-78	36.25	39.75	32.25	44.75	31.5
7-04-78	35.0	40.0	32.5	44.75	30.75
7-05-78	37.0	40.0	31.5	47.25	31.5
7-06-78	37.0	41.0	32.0	47.0	32.0
7-07-78	38.0	44.0	31.0	46.75	32.25
7-08-78	41.5	45.5 moved scale	34.75 moved	48.75 moved	34.75
7-09-78	39.5	46.75	32.5 scale	48.25 scale	34.75
7-10-78	42.0	47.0	33.5	53.5	37.0
7-11-78	42.0	47.5	33.75	54.0	37.0
7-12-78	43.0	49.75	34.25	53.0	37.5

Table 7 (cont.). Daily weight in kilograms of 5 captive moose hand-reared at the Moose Research Center, 1978-79.

	Animal Name (sex)				
Date	Lucile (F)	Rodney (M)	Chester (M)	Chief (M)	Angel (F)
7-13-78	43.5	49.5	33.75	54.5	37.0
7-14-78	43.75	51.25	36.25	54.0	38.25
7-15-78	44.0	53.0	35.75	56.75	39.5
7-16-78	46.0	55.0	37.25	57.75	40.0
7-17-78	47.0	57.5	38.0	60.0	42.0
7-18-78	49.0	57.0	38.5	61.5	43.5
7-19-78	49.5	58.5	40.0	61.5	43.0
7-20-78	50.5	63.5	42.5	62.75	45.0
7-21-78	51.5	62.0	42.0	65.0	45.0
7-22-78	54.0	62.5	41.75	66.5	45.5
7-23-78	55.0	65.0	47.75	69.5	-
7-24-78	57.0	65.0	44.75	66.0	48.0
7-25-78	55.5	67.25	44.5	68.0	49.25
7-26-78	56.0	67.0	45.0	69.5	49.25
7-27-78	58.76	68.75	46.5	69.5	50.75
7-28-78	57.75 changed	69.0 changed	46.75 changed	70.0 changed	- changec
7-29-78	58.0 schedule	69.25 schedule	49.25 schedule	72.5 schedule	51.5 schedul
7-30-78	59.0	70.5	47.5	74.5	51.5
7-31-78	60.0	72.0	49.25	75.0	53.0
8-01-78	59.0 releveled	69.5 releveled	49.0 releveled	73.25 releveled	51.25
8-02-78	60.5 scale	71.5 scale	46.25 scale	74.0 scale	53.25
8-03-78	64.0	74.75	49.0	77.75	54.75
8-04-78	64.0	75.0	50.0	79.25	56.5
8-05-78	64.5	75.0	50.25	80.75	56.75
8-06-78	65.0	76.0	53.0	81.0	57.25
8-07-78	64.75	76.5	53.25	81.0	58.0
8-08-78	65.0	76.5	54.0	82.0	58.0
8-09-78	67.0	77.75	56.5	82.75	58.0
8-10-78	67.75	79.75	56.0	85.0	58.25
8-11-78	69.5	82.5	55.75	54.25 turned	60.0
8-12-78	70.25 started	87.0	58.0	88.25 all ♂'s	61.5
8-13-78	71.75 using	87.5	61.25	88.0 to Pen 2	62.75
8-14-78	71.0 Pen 2 for	84.0	60.0	86.5 put plywood	63.0
8-15-78	73.75 grazing	88.0	62.0	91.0 on scale	64.75
8-16-78	73.75	89.5	63.5	91.0	65.5
8-17-78	73.75	89.5	63.5	91.75	66.25
8-18-78	75.25	91.0	64.5	93.5	68.5
8-19-78	76.25	92.0	64.5	93.5	68.75
8-20-78	76.0	93.0	66.0	96.25	68.5
8-21-78	78.0	96.5	68.25	100.5	70.5
8-22-78	78.25	98.0	68.0	101.0	70.5
8-23-78	80.0	98.25	69.5	100.75	72.75
8-24-78	81.5	99.0	71.25	103.0	75.0
8-25-78	81.0	100.0	73.25	103.0	73.5
8-26-78	83.5	102.75	74.5	107.0	77.75
8-27-78	83.75	106.5	75.25	110.0	77.5
8-28-78	-	-	-	-	-
8-29-78	86.0	103.0	75.0	-	79.0

Table 7 (cont.). Daily weight in kilograms of 5 captive moose hand-reared at the Moose Research Center, 1978-79.

Date	Lucile (F)	Rodney (M)	Chester (M)	Chief (M)	Angel (F)
			Animal Name (sex)		
8-30-78	87.5 changed	105.75	77.75 went to	108.0	79.25
8-31-78	88.0 feedings	110.0	77.5 3 feeding	112.5	79.5
9-01-78	89.0	112.5	80.5	113.5	84.0
9-02-78	90.75	112.0	81.5	113.5	81.0
9-03-78	91.5	112.25	80.5	116.0	84.25
9-04-78	93.5	114.0	83.25	117.25	86.25
9-05-78	94.0	118.0	82.0	117.25	88.0
9-06-78	93.0	113.0	84.0	117.25	87.0
9-07-78	94.0	117.0	83.0	119.25	87.0
9-08-78	96.0	118.5	86.0	120.5	89.0
9-09-78	95.5	118.5	83.5	119.0	90.0
9-10-78	97.5	123.0	86.0	124.0	92.0
9-11-78	100.5	121.5	84.5	123.0	91.25
9-12-78	101.5	124.0	88.0	127.0	93.5
9-13-78	100.0	123.5	86.0	124.0	95.0
9-14-78	102.0	120.0	87.5	124.0	91.5
9-15-78	100.0	127.0	88.5	130.0	95.0
9-16-78	103.0	131.0	90.0	133.0	96.5
9-17-78	104.0	131.5	90.0	133.0	98.0
9-18-78	105.0	133.0	91.0	131.5	99.0
9-19-78	104.0	127.5	91.0	128.5	99.5
9-20-78	108.0	129.0	93.0	135.0	106.0
9-21-78	-	-	-	-	-
9-22-78	104.5	134.0	96.0	137.5	99.0
9-23-78	109.0	132.0	96.0	133.0	98.5
9-24-78	110.5	136.5	96.0	140.0	103.0
9-25-78	109.0	135.5	96.5	140.5	102.0
9-26-78	111.75	135.5	96.0	139.25	104.0
9-27-78	-	-	-	- milk	- milk
9-28-78	113.0	137.0	99.75	139.0	105.0
9-29-78	113.0	137.0	101.5	140.5	109.0
9-30-78	112.5	138.0	101.5	138.5	107.0
10-01-78	117.0	138.5	103.0	144.0	107.0
10-02-78	117.5	144.0	107.5	147.5	111.0
10-03-78	119.0	146.0	106.0	147.0	112.0
10-04-78	126.5	148.0	109.5	149.0	120.0
10-05-78	123.5	146.0	111.0	151.5	116.0
10-06-78	126.5	146.5	112.0		117.0
10-07-78	123.5	147.5	111.0	157.0	119.0
10-08-78	124.0	145.0	112.5	152.5	114.0
10-09-78	-	-	-	-	-
10-10-78	127.0	147.5	115.0	153.5	118.0
10-11-78	128.0	155.0	115.0	156.0	118.0
10-12-78	132.0	154.0	116.0	160.0	121.0
10-13-78	132.0	158.0	-	160.5	124.0
10-14-78	132.0	158.0	117.5	161.0	121.0
10-15-78	132.0	158.0	119.5	161.5	123.0

Table 7 (cont.). Daily weight in kilograms of 5 captive moose hand-reared at the Moose Research Center, 1978-79.

Date	Animal Name (sex)				
	Lucile (F)	Rodney (M)	Chester (M)	Chief (M)	Angel (F)
10-16-78	136.0	161.0	121.0	165.5	126.5
10-17-78	139.0	163.0	124.0	167.5	128.5
10-18-78	136.0	159.0	118.0 out all	164.0	126.0
10-19-78	136.5	161.0	124.5 night	165.0	126.0
10-20-78	136.5	162.0	126.0	166.0	129.0
10-21-78	138.0	161.0	115.0 out all	160.0 out all	129.0
10-22-78	140.0	162.0	127.0 night	164.0 night	128.0
10-23-78	147.5	160.0	121.0	162.5	128.0
10-24-78	-	-	- wet	-	-
10-25-78	141.0	162.0	130.0	165.5	131.0
10-26-78	143.0	163.5	129.5	166.5	135.5
10-27-78	145.0	168.0	133.0	170.0	137.5
10-28-78	144.0	167.0	133.0	169.0	137.0
10-29-78	146.0	169.5	135.0	173.0	140.0
10-30-78	144.5	168.5	138.0	175.0	140.5
10-31-78	148.0	174.5	137.0	176.5	142.0
11-01-78	-	-	- scale	-	- scale
11-02-78	146.0	169.0	135.0 froze	177.5	142.0 froze
11-03-78	146.0	168.0	135.0	175.0	140.0
11-04-78	not taken	-	- scale	-	- scale
11-05-78	149.0	174.0	137.0 froze	171.0	143.0 froze
11-06-78	151.0	179.0	138.0	179.0	-
11-07-78	154.0	178.0	141.0	179.5	149.0
11-08-78					
11-09-78	wormed	wormed	wormed	wormed	wormed
11-10-78	frozen scale	frozen scale	scale froze	scale froze	scale froze
11-11-78	152.0	180.0	141.0	181.0	152.0
11-12-78	154.0	178.0	142.0	178.0	151.0
11-13-78	froze	froze	froze	froze	froze
	out in Pen 2	out in Pen 2	out in Pen 2	out in Pen 2	out in Pen 2
11-22-78	157.5			178.5	151.0
11-23-78	157.0	181.0	143.0	184.0	153.0
11-24-78	155.0	182.0	144.0	182.0	155.0
11-25-78	152.0	187.0	143.0	182.0	154.0
11-26-78	156.0	188.0	148.0	187.0	hurt hoof
11-27-78	156.0	188.0	149.0	188.0	hurt hoof
11-28-78	159.0	191.0	149.0	190.0	hurt hoof
11-29-78	157.0	183.0	143.0	187.0	154.0
12-01-78	159.5	186.0	149.0	188.0	hurt hoof
12-02-78	-	-	-	-	-
12-03-78	-	-	-	-	-
12-04-78	160.0	192.0	152.0	194.0	-
12-05-78	162.5	192.0	155.5	198.0	162.0
12-06-78	-	-	-	-	-
12-07-78	165.0	192.0	156.0	193.0	164.0
12-08-78	166.0	196.0	161.5	199.0	167.0
12-09-78		-	-	-	-
12-10-78	170.0	-	-	199.0	-
12-11-78	169.5	195.0	159.0	196.0	169.0
12-12-78	166.5	190.5	159.0	199.0	167.0

Table 7 (cont.). Daily weight in kilograms of 5 captive moose hand-reared at the Moose Research Center, 1978-79.

Date	Animal Name (sex)				
	Lucile (F)	Rodney (M)	Chester (M)	Chief (M)	Angel (F)
12-13-78	165.0	195.0	158.0	198.0	164.0
12-14-78	-	-	-	-	-
12-15-78	167.5	196.5	158.0	200.0	hurt hoof
12-16-78	-	-	-	-	wild from
12-17-78	-	-	-	-	handling
12-18-78	-	-	-	-	"
12-19-78	173.0	201.0	-	201.0	"
12-20-78	-		167.0	-	"
12-21-78	-	214.0 p.m.	-	212.0 p.m.	"
12-22-78	180.0	202.5 weight	166.0	204.0 weight	182.0
12-23-78	-	-	-	-	-
12-24-78	182.0	-	-	210.0	184.0
12-25-78	181.0	208.0	170.0	213.0	180.0
12-26-78	-	206.0	-	207.0	181.0
12-27-78	-	-	-	-	-
12-28-78	179.0	207.0	170.0	209.0	180.0
12-29-78	183.0	-	-	-	-
12-30-78	182.0	204.0	-	207.5	182.0
12-31-78	183.0	207.0	171.0	209.0	183.0
01-01-79	181.0	210.5	171.5	208.5	185.0
01-02-79	-	-	-	-	-
01-03-79	184.0	209.0	171.0	209.0	-
01-08-79	180.0	204.0		211.0	189.0
01-10-79	189.0	214.0	179.0	216.0	190.0
01-11-79	191.0	217.0	179.0	216.0	190.0
01-12-79	191.0	215.0	178.0	214.0	192.0
01-13-79	187.0	213.0	177.0	213.0	192.0
01-14-79	191.0	218.0	182.0	217.0	194.0
01-17-79	197.0	223.0	190.0	221.0	202.0
01-20-79	190.0	215.0	181.0	217.5	194.0
01-21-79	188.0	212.0	182.0	220.0	192.5
01-22-79	190.0	216.0	181.5	214.0	195.0
01-24-79	190.0	217.5	182.0	215.0	196.0
01-25-79	192.0	219.0	184.0	215.5	199.0
01-26-79	-	-	-	-	195.0
01-28-79	196.0	218.5	188.0	220.5	198.5
01-29-79	195.0	216.0	-	218.0	196.0
01-30-79	198.0	220.0	192.0	222.0	197.0
01-31-79	198.0	223.0	190.0	222.0	200.0
02-03-79	199.0	223.0	185.0	222.0	200.0
02-04-79	199.0	220.0	189.0	221.0	200.0
02-5→02-9-79	-20° windy	-20° windy	-20° windy	-20° windy	-20° windy
02-10-79	200.0	228.0	194.0	223.0	
02-11-79	199.0	225.0	190.0	226.0	205.0
02-12-79	199.0	220.0	190.0	223.0	-
02-13-79	200.0	223.0	191.0	223.0	200.0
02-14-79	200.0	220.0	193.0	223.0	202.0

Table 7 cont.). Daily weight in kilograms of 5 captive moose hand-reared at the Moose Research Center, 1978-79.

Date	Lucile (F)	Rodney (M)	Chester (M)	Chief (M)	Angel (F)
02-16-79	202.0	224.0	190.0	222.0	204.5
02-19-79	200.0	225.0	197.0	225.5	205.0
02-20-79	199.0	223.0	193.0	225.0	-
02-21-79	201.0	230.0	194.0	224.0	205.0
02-24-79	-	-	200.0	-	202.0
02-27-79	205.0	227.0	196.0	227.0	206.0
02-28-79	204.0	228.0	-	230.0	210.0
03-01-79	202.0	233.0	198.0	228.0	209.0
03-02-79	203.0	226.0	200.0	227.0	-
03-03-79				228.5	
03-04-79	202.0	225.0	-	-	208.0
03-05-79	202.0	224.0	194.0	227.0	205.0
03-07-79	202.0	227.0	200.5	226.0	208.0
03-08-79	206.0	228.0	203.0	233.0	209.0
03-10-79	205.0	231.0	201.0	230.0	205.0
03-11-79	206.0	228.0	202.0	230.0	207.0
03-16-79	210.0	229.0	205.0	230.5	210.0
03-23-79	208.0	236.0	-	231.0	213.0
03-24-79	214.0	240.0	212.0	232.0	217.5
03-26-79	209.0	232.0	205.0	231.0	212.0
03-28-79	209.0	2 -	-	230.0	210.0
03-29-79	210.0	236.5	207.5	231.5	216.5
03-31-79	210.0	235.0	209.0	232.5	213.0
04-01-79	213.0	238.0	208.0	234.0	216.5
04-02-79	212.0	-	208.5	231.0	216.0
04-05-79	211.0	239.5	213.0	235.5	217.5
04-06-79	221.0	242.5	215.0	244.0	217.0
04-07-79		246.0	-	240.0	-
04-09-79	217.0	244.0	214.0	239.5	217.0
04-10-79					220.5
04-11-79	216.0	242.0	215.0	242.0	
04-12-79	-	246.5	-	245.5	225.0
04-14-79	224.0	246.5	220.0	246.0	225.0
04-16-79	224.0	248.0	218.5	247.0	227.0
04-17-79	220.0	245.5	220.0	244.0	226.0
04-18-79	220.0	248.0	218.5	245.5	223.0
04-19-79	220.0	244.0	218.5	245.5	223.0
04-20-79	222.0	246.0	221.0	247.5	224.0
04-22-79	228.5	250.0	228.0	256.0	-
04-26-79	226.0	250.0	222.5	248.0	225.0
04-27-79	225.0	248.0	226.0	250.0	227.0
04-29-79	227.5	251.0	227.0	254.0	227.5
05-01-79	226.5	251.0	230.0	253.0	227.0
05-02-79	226.0	255.0	230.0	249.0	228.0
05-03-79	227.5	257.0	232.0	254.0	231.5
05-06-79	226.0	255.0	229.0	256.0	232.0
05-07-79	228.0	255.0	232.0	253.0	232.0
05-10-79	224.0	252.0	230.0	254.0	233.0
05-11-79	229.5	256.5	229.0	255.0	233.0

Table 7 (cont.). Daily weight in kilograms of 5 captive moose hand-reared at the Moose Research Center, 1978-79.

Date	Animal Name (sex)				
	Lucile (F)	Rodney (M)	Chester (M)	Chief (M)	Angel (F)
05-12-79	225.0	256.0	232.0	254.0	231.5
05-14-79	229.0	261.0	230.5	257.0	237.0
05-15-79	229.0	259.0	235.5	262.0	239.0
05-16-79	231.0	264.0	235.5	263.0	238.0
05-17-79	230.0 moldy	260.0 moldy	235.0 moldy	262.5 moldy	236.0 moldy
05-18-79	234.0 feed	264.0 feed	235.0 feed	- feed	- feed
05-20-79	231.5 "	258.0 "	- "	267.0 "	238.0 "
05-21-79	233.5 "	265.0 "	239.0 "	264.0 "	241.0 "
05-22-79	228.0 "	263.0 "	234.0 "	256.5 "	240.0 "
05-23-79	231.0 "	261.0 "	236.0 "	262.0 "	237.0 "
05-24-79	231.0 "	258.5 "	235.0 "	257.0 "	240.5 "
05-27-79	- "	266.0 "	237.0 "	259.0 "	242.0 "
05-29-79	232.5 "	256.0 "	237.0 "	264.5 "	246.0 "
05-30-79	238.0 new feed	266.0	240.0	262.5	243.0
05-31-79	238.0	261.0	239.0	265.0	246.5
06-01-79	240.0	267.0	246.0	262.0	248.0
06-02-79	240.0	270.0	241.0	263.0	245.0
06-03-79	239.0	276.0	245.0	264.0	244.0
06-04-79	242.0	275.0	239.0	270.0	249.0
06-05-79	243.0	273.5	246.0	266.0	250.0
06-06-79	245.0	276.0	250.0	274.0	251.0
06-07-79	244.0	275.0	252.0	273.0	248.0
06-08-79	241.0	272.0	247.0	276.0	248.0
06-09-79	251.0	275.0	254.0	278.0	253.0
06-10-79	249.0	275.0	254.0	280.0	251.0
06-11-79	249.0	267.0	249.0	276.0	248.0
06-18-79	243.0	279.0	257.0	283.0	256.0
06-20-79	247.0	283.0	261.0	270.0	260.0
06-21-79	243.0	281.0	261.0	275.0	260.0
06-22-79	246.0	283.0	256.0	288.0	263.0
06-23-79	255.0	281.0	258.0	287.0	265.5
06-24-79	250.0	282.0	257.0	285.0	260.0
06-29-79	258.0	281.0	265.0	291.0	281.0
06-30-79	251.0	285.0	270.0 (wet)	-	265.0

LITERATURE CITED

Ammann, A. P., R. L. Cowan, C. L. Mothershead, and B. R. Baumgardt. 1973. Dry matter and energy intake in relation to digestibility in white-tailed deer. J. Wildl. Manage. 37:195-201.

A.O.A.C. 1965. Official methods of analysis. 10th edition. Association of Official Agricultural Chemists, Washington, D.C. 957pp.

Balch, C. C. and R. C. Campling. 1962. Regulation of voluntary food intake in ruminants. Nutr. Abstr. Rev. 32:669-686.

Balch, C. C. and R. C. Campling. 1965. Rate of passage of digesta through the ruminant digestive tract. In Physiology of digestion in the ruminant. R. W. Doughorty (Ed.). Butterworth's, Washington, D.C.

Baumgardt, R. R. 1970. Control of feed intake in the regulation of energy balance. In Physiology of digestion and metabolism in the ruminant. Proc. Third Intl. Symp. Cambridge, England. A. J. Phillipson (Ed.). pp 235-253.

Bell, R. H. V. 1971. A grazing ecosystem in the Serengeti. Sci. Am. 225(1):86-93.

Brody, S. 1945. Bioenergetics and growth. New York. Reinhold.

Cammell, S. B., and D. F. Osbourn. 1972. Factors influencing the total time spent chewing by sheep given diets containing long, dried forages. Proc. Nutr. Soc. 31:63A-64A.

Campling, R. C. 1970. Physical regulation of voluntary intake. In Physiology of digestion and metabolism in the ruminant. Proc. Third Intl. Symp., Cambridge, England. pp 226-234.

Campling, R. C. and C. C. Balch. 1961. Factors affecting the voluntary intake of food by cows. 1. Preliminary observations on the effect, on the voluntary intake of hay, of changes in the amount of the reticulo-ruminal contents. Brit. J. Nutr. 15:523-530.

Campling, R. C., M. Freer, and C. C. Balch. 1963. Factors affecting voluntary intake of food by cows. 6. A preliminary experiment with ground pelleted hay. Brit. J. Nutr. 17:263-272.

Cassady, J. T. 1959. General review of methods and techniques for measuring production and utilization. In techniques and methods of measuring understory vegetation. U.S. Forest Servict. South and Southwest For. Exp. Sta. Proc. 1959. pp 5-10.

Church, D. C. 1969. Digestive physiology and nutrition of ruminants. Vol. 1., Digestive physiology. Dept. Animal Sci., Oregon St. Univ. Corvallis. 316pp.

Church, D. C. 1972. Digestive physiology and nutrition of ruminants. Vol. 3., Practical nutrition. Dept. Animal Sci., Oregon St. Univ. Corvallis. 350pp.

Crampton, E. W. and L. E. Lloyd. 1959. Fundamentals of nutrition. W. H. Freeman and Co. San Francisco. 494pp.

Egan, A. R. 1972. Nutritional status and intake regulation in sheep. VII. Control of voluntary intake of three diets and the responses to intraruminal feeding. Aust. J. Agric. Res. 23:347-361.

Ely, R. E. and L. A. Moore. 1959. The nutritive value of forages with emphasis on the polysaccharide fraction. Pages 173-185. In H. B. Sprague, (Ed.) Grasslands. Publ. No. 53. Am. Assoc. Adv. Sci., Washington, D.C.

Ensminger, M. E. and C. G. Olentine. 1978. Feeds and nutrition - complete. Ensminger Publishing Co., Calif. 1417pp.

Fell, B. F., R. M. Campbell, and R. Boyne. 1964. Observations on the morphology and nitrogen content of the alimentary canal of breeding hill sheep. Res. Vet. Sci. 5:175-185.

Flynn, A., A. W. Franzmann, P. D. Arneson, and J. L. Oldemeyer. 1977. Indications of copper deficiency in a subpopulation of Alaskan moose. J. Nutrition. 107:1182-1189.

Franzmann, A.W. and T.N. Bailey. 1977. Moose Research Center Report. Alaska Dept. Fish and Game. P-R Proj. Rep. W-17-9. 76 pp. Multilith.

Franzmann, A. W., A. Flynn, and P. D. Arneson. 1975. Levels of some mineral elements in Alaska moose hair. J. Wildl. Manage. 39:374-378.

Franzmann, A. W., R. E. LeResche, P. D. Arneson, and J. L. Davis. 1976. Moose productivity and physiology. Alaska Dept. Fish and Game Fed. Aid in Wildl. Rest. P-R Proj. W-17-2, W-17-3, W-17-4, W-17-5, W-17-6 and W-17-7. 87pp.

Franzmann, A. W., R. E. LeResche, R. A. Rausch, and J. L. Oldemeyer. 1978. Alaskan moose measurement and weights and measurement-weight relationships. Can. J. Zool. 56(2):298-306.

Franzmann, A. W. and C. C. Schwartz. 1978. Moose Research Center Report. Alaska Dept. Fish and Game Fed. Aid in Wildl. Rest. P-R Proj. W-17-10. 11 pp.

Freer, M. and R. C. Campling. 1963. Factors affecting the voluntary food intake by cows. 5. The relationship between the voluntary intake of food, the amount of digesta in the reticulo-rumen and the rate of disappearance of digesta from the alimentary tract with diets of hay, dried grass, or concentrates. Brit. J. Nutr. 17:79-88.

Gaillard, B. D. E. 1965. Comparison of the hemicelluloses from plants belonging to two different plant families. Phytochem. 4:631-634.

Gasaway, W. C. and J. W. Coady. 1974. Review of energy requirements and rumen fermentation in moose and other ruminants. Naturaliste Can., 101:227-262.

Goering, H. K. and P. J. Van Soest. 1970. Forage fibre analyses. Agricultural Research Service. USDA Agric. Handbook No. 379.

Henneberg, W. and F. Stohmann. 1960. Bergundung elner rationeller Futterung der Wienderkaver. Vol. I. Schwetschtke U. Sohn. Braunschweig. 4.

Hofmann, R. R. 1968. Comparisons of the rumen and omasum structure in East African Game ruminants in relation to their feeding habits. Symp. Zool. Soc. Lond. 21:179-194.

Hofmann, R. R. 1973. The ruminant stomach. Stomach structure and feeding habits of E. African game ruminants. E. Afr. Monogr. in Biol. 2:38-45.

Humphrey, R. R. 1949. Field comments on the range condition methods of forage survey. J. Range Manage. 2:1-10.

Hungate, R. E. 1966. The Rumen and its Microbes. Academic Press, New York.

Hutton, J. B., J. W. Hughes, R. P. Newth, and K. Watanabe. 1964. The voluntary intake of the lactating dairy cow and its relation to digestion. Proc. N. Z. Soc. An. Prod. 24:29-33.

Jardine, J. T. and M. Anderson. 1919. Range management of the National Forest. U.S. Dept. Agr. Bull. 790. 98pp.

Kleiber, M. 1961. The fire of life. John Wiley and Sons, Inc., New York. 454pp.

LeResche, R. E. and J. L. Davis. 1973. Importance of nonbrowse foods to moose on the Kenai Peninsula, Alaska. J. Wildl. Manage. 37(3):279-287.

Mertens, D. R. 1973. Application of theoretical mathematical models to cell wall digestion and forage intake in ruminants. Ph.D. Thesis. Cornell University, Ithaca. 187pp.

Milchunas, D. G. 1977. In vivo - in vitro relationships of Colorado mule deer forage. M.S. Thesis. Colo. State. Univ., Fort Collins. 133pp.

Milchunas, D. G., M. I. Dyer, O. C. Wallmo, and D. E. Johnson. 1978. In-vivo/in-vitro relationships of Colorado mule deer forages. Colo. Div. of Wildl. Special Report No. 43. 44pp.

Moen, A. N. 1973. Wildlife Ecology: an analytical approach. W. H. Freeman and Co. San Francisco. XVIIiii + 458pp.

Montgomery, M. J. and B. R. Baumgardt. 1965. Regulation of food intake in ruminants. 2. Rations varying in energy concentration and physical form. J. Dairy Sci. 48:1623-1628.

Moore, L. A., J. W. Thomas, and J. F. Sykes. 1960. The acceptability of grass/legume silage by dairy cows. Proc. VIII Int'l. Grassl. Cong. pp 701-704.

Morrison, F. B. 1956. Feeds and feeding. 22nd ed. The Morrison Pub. Co., Ithaca, N.Y.

Mowat, D. M. 1963. Factors affecting rumen capacity and the physical inhibition of feed intake. Ph.D. Thesis, Cornell University.

Nagy, J. G., D. L. Baker, J. A. Bailey, D. S. de Calesta, D. E. Reeder, and G. G. Schoonveld. 1974. Middle Park Cooperative deer study. Physiology and prevention of deer starvation. Final Report. Colorado Div. Wildl. Proj. W-38-R-28. 554pp.

Oldemeyer, J. L., A. W. Franzmann, A. L. Brundage, P. D. Arneson, and A. Flynn. 1977. Browse quality and the Kenai Moose population. J. Wildl. Manage. 41(3):533-542.

Peek, J. M. 1974. A review of moose food habits studies in North America. Naturaliste Can. 101(1):195-215.

Regelin, W. L. 1971. Deer forage quality in relation to logging in the spruce-fir and lodgepole pine type. M.S. Thesis. Colo. State Univ., Fort Collins. 50pp.

Robbins, C. T. 1973. The biological basis for the determination of carrying capacity. Ph.D. Thesis. Cornell University, Ithaca. 239pp.

Schneider, B.H. and W. P. Flah. 1975. The evaluation of feeds through digestibility experiments. Univ. Georgia Press, Athens. 423pp.

Schoonveld, G. G., J. G. Nagy, and J. A. Bailey. 1974. Capability of mule deer to utilize fibrous alfalfa diets. J. Wildl. Manage. 38:823-829.

Silver, H., N. F. Colovos, J. B. Holter, and H. H. Hates. 1969. Fasting metabolism of white-tailed deer. J. Wildl. Manage. 33:490-498.

Smith, L. W. 1968. The influence of particle size and lignification upon the rate of digestion and passage of uniformly labeled carbon-14 plant cell walls in sheep. Ph.D. Thesis. University of Maryland. 132pp.

Stoddart, L. A. 1952. Problems in estimating grazing capacity of ranges. Proc. 6th Int. Grass Congress. Vol. II. Penn. State College, College. Pa. 1367-1372pp.

Thompson, C. B., J. B. Holter, H. H. Hayes, H. Silver, and W. E. Urban. 1973. Nutrition of white-tailed deer. 1. Energy requirements of fawns. J. Wildl. Manage. 37(3):301-311.

Thornton, R. F. and D. J. Minson. 1973. The relationship between apparent retention time in the rumen, voluntary intake, and apparent digestibility of legume and grass diets in sheep. Aust. J. Agric. Res. 24:889-898.

Troelsen, J. E. and F. W. Bigsby. 1964. Artificial mastication - a new approach for predicting voluntary forage consumption by ruminants. J. Anim. Sci. 23:1139-1142.

Troelsen, J. E. and J. B. Campbell. 1968. Voluntary consumption of forage by sheep and its relation to the size and shape of particles in the digestive tract. Anim. Prod. 10:289-296.

Tulloh, N. M. 1966. Physical studies of the alimentary tract of grazing cattle. IV. Dimensions of the tract in lactating and non-lactating cows. N.Z.J. Agric. Res. 9:999-1008.

Ulyatt, M. J., K. L. Blaxter, and S. McDonald. 1967. The relations between the apparent digestibility of roughages in the rumen and lower gut of sheep, the volume of fluid in the rumen and voluntary intake. An. Prod. 9:463-470.

Van Soest, P. J. 1968. Structural and chemical characteristics which limit the nutritive value of forages. Pages 63-76 In C. M. Harrison (Ed.) Forage economics-quality. Am. Soc. Agron. Spec. Publ. 13.

Van Soest, P. J. and R. H. Wine. 1967. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. J. Assoc. Off. Anal. Chem. 50(1):50-55.

Van Soest, P. J. 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. J. Assoc. Off. Agric. Chem. 46:829-835.

Van Soest, P. J. 1965a. Symposium on factors influencing the voluntary intake of herbage by ruminants: voluntary intake in relation to chemical compostion and digestibility. J. Anim. Sci. 24:838-843.

Van Soest, P. J. 1965b. Use of detergents in analysis of fibrous feeds. III. Study of effects of heating and drying on yield of fiber and lignin in forages. J. Assoc. Off. Agric. Chem. 48:785-790.

Van Soest, P. J. 1966. Forage intake in relation to chemical composition and digestibility: some new concepts. Proc. Southern Pasture Forage Crop Improvement Conf. 24pp.

Van Soest, P. J. 1973. The uniformity and nutritive availability of cellulose. Fed. Proc. 32:1804-1808.

Wallach, J. D. 1972. The nutrition and feeding of captive ruminants in zoos. Pages 292-307, In D. C. Church, (Ed.) Digestive physiology and nutrition of ruminants, Vol. 3, practical nutrition. Dept. Animal Scil, Oregon State Univ., Corvallis. 350pp.

Wallmo, O. C., L. H. Carpenter, W. L. Regelin, R. B. Gill, and D. L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. J. Range Manage. 30:122-127.

Welch, J. G. 1967. Appetite control in sheep by indigestible fibers. J. Anim. Sci. 26:849-854.

Welch, J. G. and A. M. Smith. 1969. Influence of forage quality on rumination time in sheep. J. Anim. Sci. 28:813-818.

Welch, J. G. and A. M. Smith. 1970. Forage quality and rumination time in cattle. J. Dairy Sci. 53:797-800.

Weston, R. H. 1968. Factors limiting the intake of feed by sheep. III. The mean retention time of feed particles in sections of the alimentary tract. Aust. J. Agric. Res. 19:261-266.

Weston, R. H. 1966. Factors limiting the intake of feeds by sheep. I. The significance of palatability, the capacity of the alimentary tract to handle digesta, and the supply of gluconeogenic substrate. Aust. J. Agric. Res. 17:939-954.

Young, V. R., Y.S.M. Taylor, W. M. Rand, and N. S. Scrimslaw. 1973. Protein requirements of man: efficiency of egg protein utilization at maintenance and submaintenance levels in young men. J. Nutr. 103(8):1164-1174.

PREPARED BY:

Albert W. Franzmann and Charles C. Schwartz
Game Biologists

APPROVED BY:

Donald E. McKnight
Director, Division of Game

SUBMITTED BY:

Karl Schneider
Regional Research Coordinator

Donald E. McKnight
Research Chief, Division of Game