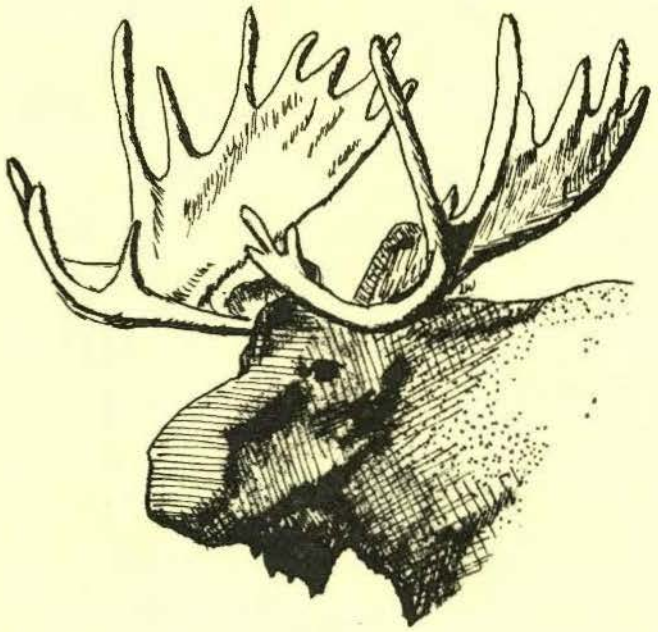
ALASKA DEPARTMENT OF FISH AND GAME
JUNEAU, ALASKA

EVALUATING AND TESTING TECHNIQUES FOR MOOSE MANAGEMENT



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Final Report
Federal Aid in Wildlife Restoration
W-17-7 through W-17-11 and W-21-1 and W-21-2, Job 1.14R

(April 1982)

FINAL REPORT

State: Alaska

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Project Nos.: W-17-7, W-17-8, W-17-9, W-17-10, W-17-11, W-21-1, W-21-2 Project Title: Big Game Investigations

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

Period Covered: July 1, 1974 through June 30, 1981

SUMMARY

Etorphine hydrochloride (M-99) mixed with xylazine hydrochloride (Rompun) continues to be the immobilizing drug of choice for moose in spite of some of the negative aspects of the combination. Dosage varied with season and condition of moose and ranged from 7 mg M-99/300 mg Rompun to 12 mg M-99/400 mg Rompun. Mean immobilization time for different populations varied from 9.6 to 15.5 minutes. Hyaluronidase (wydase) added to the immobilizing mixture appeared to decrease immobilization time, but this was difficult to accurately assess due to other variables influencing immobilization time. Diprenorphine (M 50-50) was the antagonist drug used; the dosage was based on amount of M-99 administered in each instance.

The various difficulties encountered with the drugs and projectile systems are discussed and evaluated. It is apparent that the ideal immobilizing system for moose is not yet available for field application.

Evaluation of pellet group counts in assessing moose numbers and habitat use was completed. We concluded that, under ideal conditions of sampling, pellet group censusing of moose may be accomplished with a degree of accuracy; however, in actual field application the intensity of sampling necessary to gain precision negates it as a useful management tool for moose. Pellet group counts do provide useful information on habitat selection by moose and have field application for this purpose. We tested the pellet group counts on moose within the Moose Research Center (MRC) enclosures where numbers and sex and age distribution of moose were known. Defecation rates of moose at the MRC varied from published data and differed between sex and age classes of moose.

Efforts at the MRC to apply biotelemetry procedures for obtaining heart rate and internal temperature of moose were not successful with the equipment used. We concluded that we must: (1) find an alternative to FM frequencies, (2) retransmit the signal from the transducer via a receiver-transmitter carried on the moose's collar or place a retrievable receiving and recording device on the collar, (3) develop dependable decoders, if required, and (4) establish a close working relationship with the designer and developer of equipment. The state-of-the-art for long-range field application of biotelemetry equipment is approaching workable systems, and in the near future may be applicable for our purposes.

Fixed-station telemetry monitoring for moose calf mortality was a useful adjunct to our study. Where possible, this application should be considered as a savings of time and money. Problems associated with such a system are discussed.

Our experiment at the MRC using nitrogen fertilizer to stimulate forage production on mechanically rehabilitated moose browse was completed. We concluded that for short term forage production, it was not valid. Grasses were the only class of vegetation which positively responded and grass is not an important moose forage.

We tested an electronic tissue measuring device in an attempt to assess condition of moose based on subcutaneous fat deposits. This device has been utilized for domestic livestock with success; however, we were not able to obtain accurate tissue measurements for moose. We believe the problem was related to different density of moose fat, muscle and skin, to which the instrument calibrations were not applicable.

Maintaining moose over a long period of time without regularly hauling browse cut from the field has been the primary factor in our inability to conduct long-term experiments with enclosed moose where adequate food was not naturally available. We wanted to conduct digestive physiology studies on moose which required long-term confinement of animals. To do so it was necessary to develop a ration for moose which could replace a natural diet and yet provide all the necessary nutrients. This diet was developed at the MRC and we called it the MRC Special Moose Ration. The ration proved successful for maintaining moose and we now have 4 moose that have been on the ration for 3 years.

Once the ration was developed, we were able to progress into digestive physiology studies on moose, but had to develop facilities for conducting these studies. This was accomplished and we now have holding pens for feeding moose not on trial, 4 digestion and balance trial cages, and a respiratory chamber. Design and development of these facilities is discussed.

Rumen turnover is a critical factor to determine and to assess the digestive processes in moose and for use in a carrying capacity model. We tested radioisotope markers on the MRC moose and

they provided the information necessary for these determinations.

These findings impart the importance of this type of study to develop and assess techniques applicable to research and management needs. These studies, however, would not be possible without the commitment of the Department to maintain the MRC facilities.

CONTENTS

BACKGROUND

The Moose Research Center (MRC), with known numbers of confined animals and research facilities, provides unique conditions for developing and testing techniques applicable to moose (*Alces alces*) management (Figs. 1, 2 and 3). Developments in many fields provided information, drugs, equipment and procedures potentially applicable to moose management and determined the thrust of activity under this job objective. A final report under this general job description was prepared in 1974 and covered activities from 1969 to 1974 (Franzmann et al. 1974). Techniques tested and evaluated under this project since 1974 include; immobilization with drugs, pellet-count census, biotelemetry, fixed-station telemetry monitoring, natural and artificial fertilization of moose browse, electronic tissue measurement, raising moose calves, developing a formulated ration for captive moose, developing feeding trial and digestive rates for moose, and developing a respiratory chamber for moose.

Fig. 1. Moose Research Center

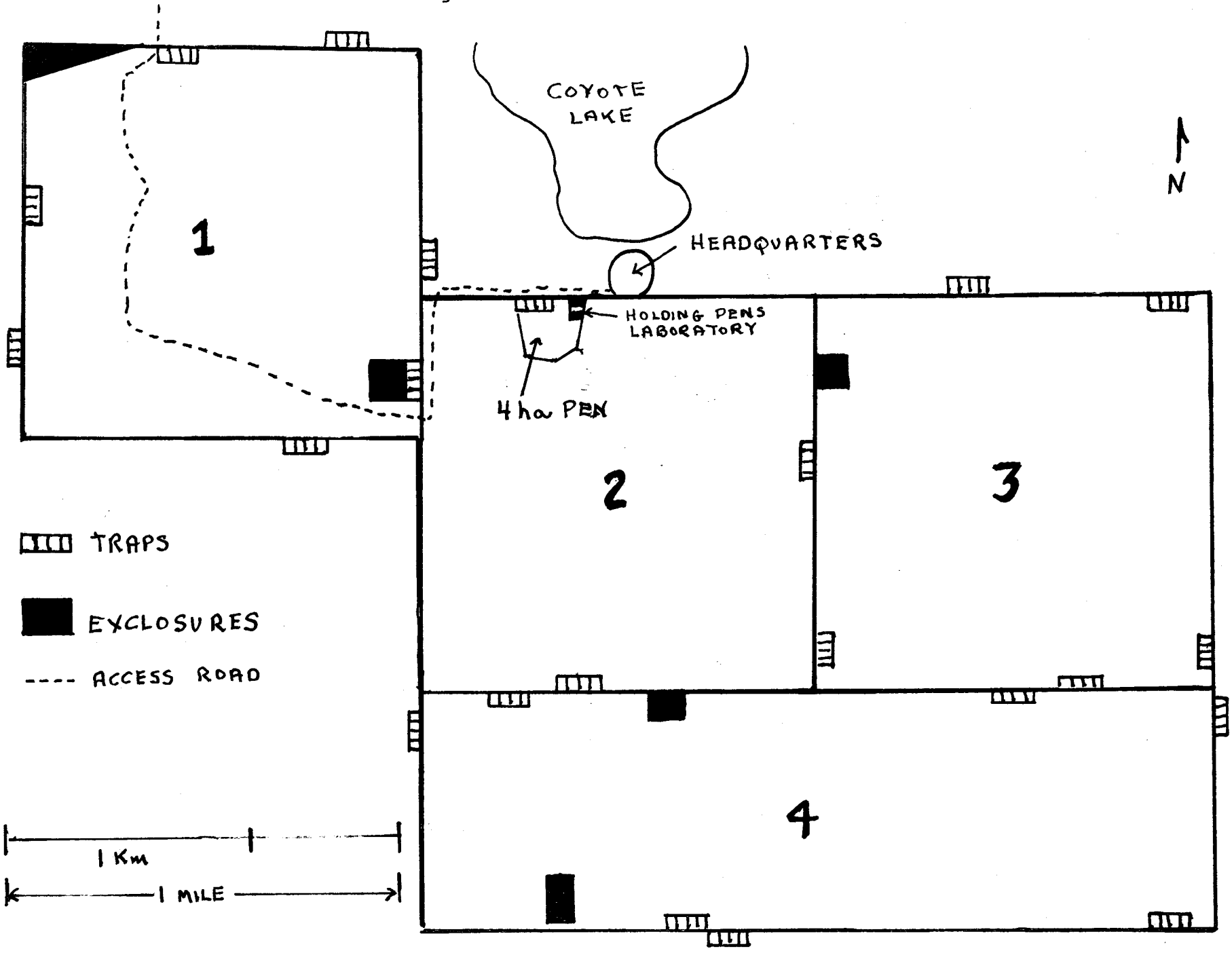
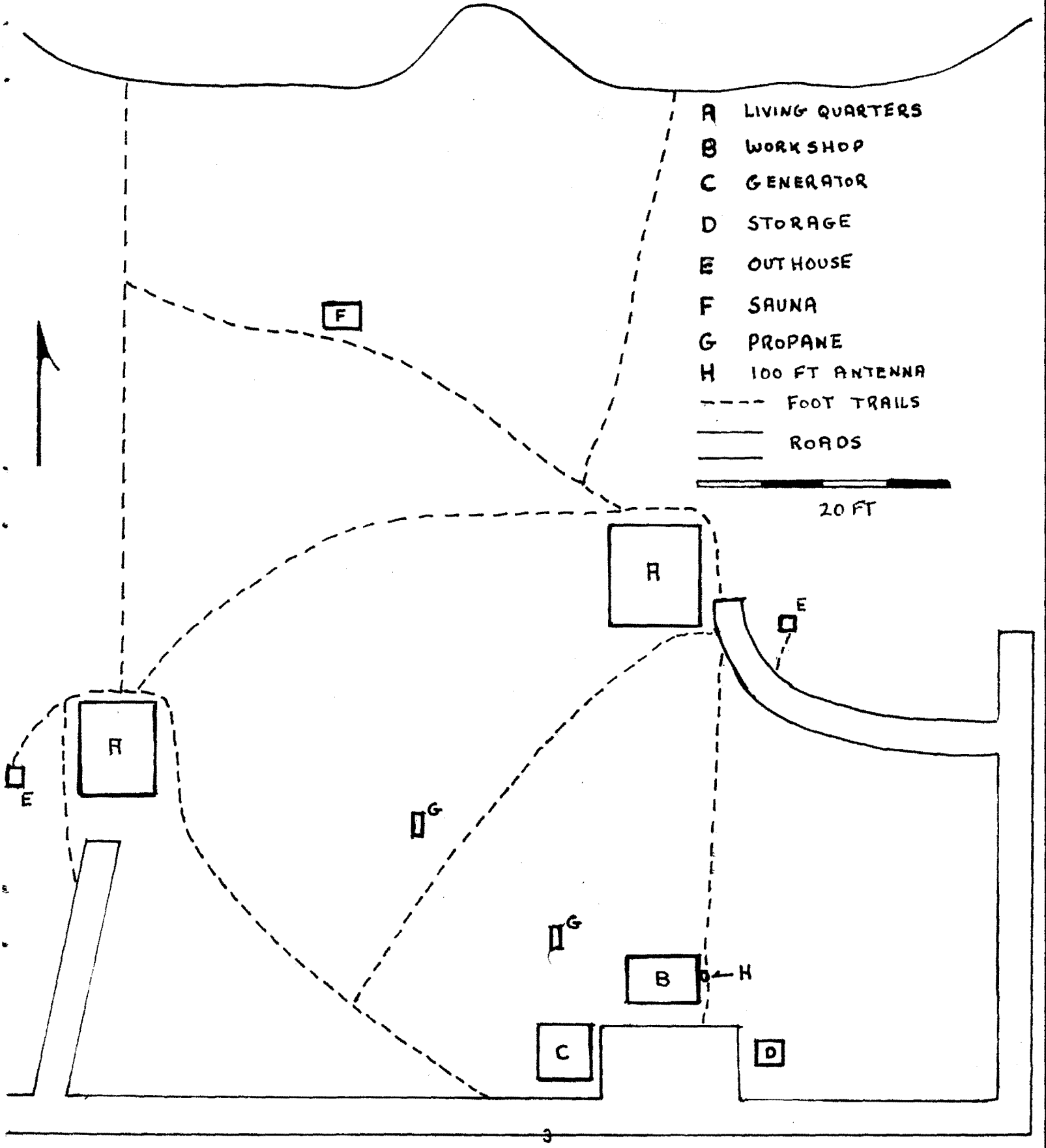
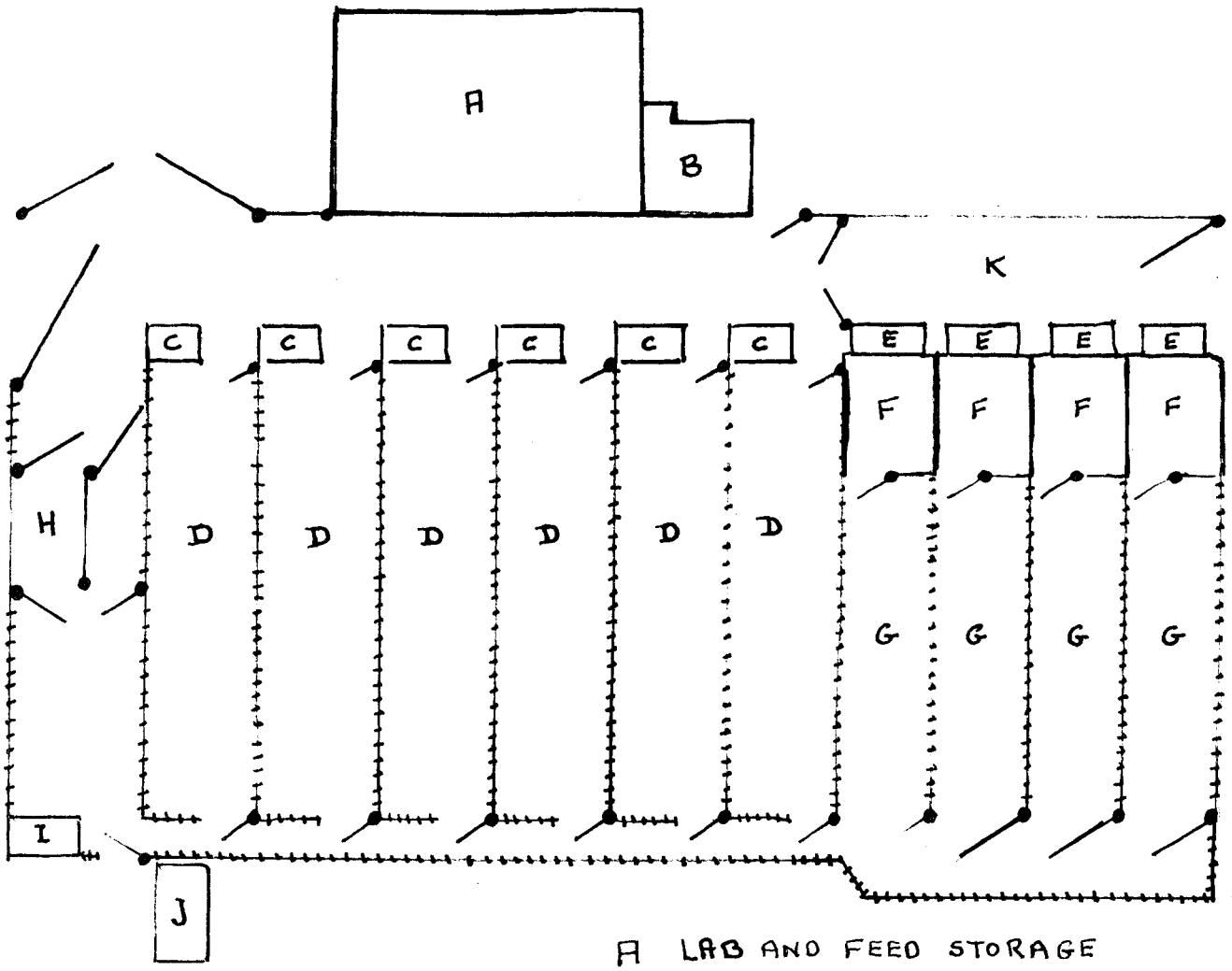


Fig. 2. Moose Research Center headquarters area.





A LAB AND FEED STORAGE
B RESPIRATORY CHAMBER
C FEED BOX 3x4
D HOLDING PEN 10x50
E FEED BOX
F DIGESTION CAGE
G HOLDING PEN 10x40
H SCALE
I WATER TANK
J SELF FEEDER
K COVERED WORK AREA

N

40 FT

GATE

FENCE

Fig. 3. Moose Research Center tame moose experimental area.

Project progress reports have presented these techniques and developments (Franzmann and Arneson 1975, 1976*b*; Franzmann and Bailey 1977*b*; Franzmann and Schwartz 1978*a*, 1979*a*; Schwartz and Franzmann 1980). In addition, several publications have come from these investigations (Arneson and Franzmann 1975; Franzmann and Arneson 1976*b*; Franzmann et al. 1976*a*, 1976*d*; Franzmann 1978, 1981; Franzmann and Flynn 1977; Gasaway et al. 1978; Ballard et al. 1979; Regelin et al. 1979, 1980, 1981; Schwartz et al. 1980; Franzmann and Schwartz 1981; and Oldemeyer and Franzmann 1981). This final report provides an appraisal of these studies.

An ideal immobilization drug should possess the following qualities:

(1) Rapid absorption and action
(2) Concentrated form-small quantity for injection
(3) Wide range of tolerance for animal
(4) Safe for handler
(5) Reversible
(6) No side effects
(7) Not subject to Dangerous Drug License
(8) Low cost
(9) Effective anesthesia level

Since the 1974 Final Report on Developing and Testing New Techniques for Moose Management (Franzmann et al. 1974) we have discontinued use of succinylcholine hydrochloride primarily due to its narrow tolerance range (Franzmann and Arneson 1974). During this report period, the immobilizing drug etorphine hydrochloride (M-99, D-M Pharmaceutical Co., Inc., Rickville, MD) and its antagonist diprenorphine hydrochloride (M 50-50, D-M Pharmaceutical Co. Inc., Rockville, MD) have been tested and routinely used. A tranquilizing drug (xylazine and hydrochloride-Rompun, Haver-Lockhart, Shawnee, KS) has been tested as an adjunct to M-99 (Gasaway et al. 1978). These drugs do not meet all the criteria for an ideal immobilizing agent. Of the nine criteria outlined for an ideal immobilizing drug, M-99 has a positive rating for only four. The negative aspects are that it is not in a concentrated form, it is potentially dangerous to the handler, it has potential side effects of hypothermia (Gasaway et al. 1978) and capture myopathy (Haigh et al. 1977), it is subject to dangerous drug licensing, and it is expensive. Nevertheless, M-99 with adjunct drugs and its antagonist M 50-50 remain the most effective immobilizing agents for moose. As new drugs become available, they will be tested at the MRC for compliance with the established ideal criteria for an immobilizing agent.

Pellet-group count census techniques, first described by Bennett et al. (1940), have been used for various species of big game. Neff (1968) extensively reviewed the subject and concluded "...pellet group counts are not a panacea or a shortcut to big game population data. However, it does appear that the method is valid, and that it can be made to yield reliable data under field

conditions." Timmerman (1974) reviewed pellet group procedures for moose and found that good information on moose deposition rates was lacking. He also discussed the potential of differential deposition rates reported by Smith (1964) and Des Meules (1968). Timmerman concluded that it remained to be proven that pellet group counts provide reliable population estimates, although they do provide a good basis for comparing relative densities between areas, and from year to year in a single area. The MRC, with known numbers of moose enclosed in four 2.59 km^2 pens, provided an opportunity to test the application of the pellet group counting technique with Alaskan moose.

The problems and promise in application of biotelemetry to MRC projects was reviewed (Franzmann et al. 1974). In 1976, we initiated testing of equipment to obtain internal temperature and heart rate via transmitters implanted in moose (Franzmann and Arneson 1976*a*).

A fixed-station telemetry monitoring system was constructed and tested at the MRC to assist in monitoring moose calves for a mortality study in conjunction with the Kenai Peninsula Predator-Prey Study (Franzmann and Bailey 1977*b*; Franzmann and Peterson 1978; Franzmann and Schwartz 1978*b*, 1979*b*). Studies requiring intensive monitoring of free-ranging species are generally accomplished by aerial monitoring (fixed-wing or helicopter). A fixed-station to monitor an area from the ground would considerably lessen the cost of a study.

Recycling of elements in an ecosystem is complex, but basically elements are derived from soil parent material. Availability of elements to the plant is governed by such factors as soil moisture, reaction, texture, and organic matter (Fleming 1973). In agricultural practices, direct fertilizer application provides another mineral element source for plants and, in turn, for animals consuming them. A potential mineralizing event occurred on the Kenai Peninsula on 23 January 1976, when Mount Augustine erupted and covered the area with volcanic ash. The ash was analyzed for potential fertilization benefits (Franzmann and Flynn 1977).

The potential for increasing production of moose forage at the MRC by application of nitrogen fertilizer was also tested (Regelin et al. 1980). No experiments have directly measured moose browse response in the northern boreal forest. However, Regelin et al. (1980) reviewed several studies which indicated that tree growth, seed production, and nutrient content of foliage can be increased by nitrogen fertilization (Cayford and Jarvis 1967, Van Cleve 1973, Coyne and Van Cleve 1977, and Salonius 1977).

Electronic tissue measurement has been routinely performed on domestic animals to measure back fat on both swine and cattle. This instrument (Scanaprobe, Ithico, Inc., Ithica, NY) was used on moose at the MRC to test its potential in evaluating relative condition of animals (Franzmann and Schwartz 1978*b*).

Many of the earlier biological studies at the MRC were based upon the indicator species concept, which basically meant that we sought to identify morphometric and physiological parameters which best reflected changes in the condition of moose, as affected by the environment. (LeResche et al. 1974; Flynn and Franzmann 1974*a*, *b*; Franzmann et al. 1974, 1975*a*, *b*, *c*, *d*, 1976*b*, *c*; 1977, 1978; Franzmann 1977, 1980; Franzmann and Bailey 1977; Franzmann and LeResche 1978). It became apparent that more refined studies needed to be undertaken to better assess carrying capacity for moose. An analytical approach which predicts carrying capacity of ungulates based upon an understanding of animal nutrition has recently been advanced (Moen 1973, Robbins 1973, and Wallmo et al. 1977). This concept of biological carrying capacity integrates the nutritional requirements of the animal with the nutrients supplied from the vegetation. To determine the nutritional requirements of moose, and thereby apply this concept, it was necessary to maintain tame moose year-round. This required development of a formulated ration for moose because the logistics and time required to maintain captive moose, by feeding with natural browse was prohibitive. Under this job, the raising and training of moose calves was accomplished (Regelin et al. 1979) and a formulated ration was tested (Schwartz et al. 1980) (Appendix I.).

Facilities at the MRC necessary to accomplish *in vivo* digestion trials were designed, constructed, and tested under this job (Schwartz and Franzmann 1980) (Fig. 3). A respiratory chamber to study energy metabolism of moose was also designed, constructed, and tested at the MRC (Regelin et al. 1981) (Appendix II.).

Non-absorbed digestive markers have been widely used to estimate various digestive functions, especially in domestic ruminants. The digestive functions include dry matter digestibility, rates of digesta passage, and feces output. Early studies (Balch 1950, Castle 1956) employed various colored stains as digestive markers. However, radio-labeled non-absorbed markers have several advantages and are presently used almost exclusively. The most commonly used marker for the water phase of digestion is chromium-51 complex with EDTA (New England Nuclear, Boston, MA) (Downes and McDonald 1964). There are several particulate matter markers used in digestive studies, such as cerium-141 or cerium-144 chloride (Ellis and Huston 1968), scandium-46 chloride (Tan et al. 1971) and several others which were reviewed by Ellis et al. (1979).

An important component of input into the moose carrying capacity model is rumen turnover time. To obtain these data, we solicited help from the University of Alaska, Institute of Arctic Biology. Doctors White and Holloman were most helpful and cooperated with us on this aspect of our studies.

In our studies, chromium-51 EDTA and ruthenium-103 chloride were used as the water phase and the particulate markers, respectively. These radio-labels have relatively short physical

half-lives as well as simple gamma spectra 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 radiolabel 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 non-absorbed digestive marker were outlined by Faichney (1975).

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

Immobilizing and tranquilizing drugs were tested on moose at the MRC and in the field to determine their induction time, tolerance range, reversibility, side effects, and general effectiveness. Drugs tested included; etorphine (M-99), diprenorphine (M 50-50), and xylazine hydrochloride (Rompun). In most instances, the drugs were administered with Cap-Chur equipment (Palmer Chemical, Douglasville, GA). At the MRC, trapped and confined moose would allow use of blowguns for delivery systems and these were investigated.

Pellet-Count Census Evaluation

One hundred and sixty 17.9 m^2 permanent browse utilization plots in Pen 1 were used for pellet group count plots. Plots were randomly located in each of seven vegetative types representing 204.3 ha of the 241.1 ha in Pen 1. The sample plots constituted 0.14 percent of the area utilized. The non-sampled area of 36.8 ha consisted of spruce-*Ledum*, grass, sedge, and water areas which were not considered winter use areas based upon winter feeding preferences of 3 tame moose on natural forage (LeResche and Davis 1971, 1973). Plots were cleared and counted and the results analyzed as outlined by Franzmann et al. (1976*d*).

Franzmann et al. (1974) were confounded by lack of consistent defecation rates for moose in attempting to refine the pellet-count census technique. To establish defecation rates for Alaskan moose, pellet groups were recorded from 25, 24 hour trackings of four adult males and four adult females in the MRC enclosures during February and March 1975 as outlined by Franzmann and Arneson (1975).

Biotelemetry

Procedures employed for biotelemetry studies were outlined by Franzmann and Bailey (1977*b*).

Fixed-Station Telemetry

A 30 m tower with two yagi antennas connected to a Falcon Five receiver (Wildlife Materials, Inc., Carbondale, IL) assisted our monitoring effort in a moose calf mortality study. The calves were radio-collared with transmitters that pulsed at a slow rate (60 beats/min) when the calf was mobile, but when the calf was immobile (1 to 4 hrs, depending on setting) the pulse tripled which, when detected, indicated a possible mortality.

The design, construction and use of the fixed-station telemetry monitoring system at the MRC were outlined in previous reports (Franzmann and Bailey 1977*b*, Franzmann and Peterson 1978, Franzmann and Schwartz 1978*b*, 1979*b*).

Fertilization of Moose Browse

Procedures employed for analyzing potential natural fertilization via volcanic ash were outlined by Franzmann and Flynn (1977). Procedures for testing artificial nitrogen fertilization of moose browse were previously outlined (Franzmann and Bailey 1977*b*, Franzmann and Schwartz 1978*a*, Regelin et al. 1980).

Electronic Tissue Measurement

Procedures for measuring fat layers over the loin, back and ribs of moose, using an electronic tissue measuring device (Scanaprobe Ithico, Ithica, NY), was outlined in a previous report (Franzmann and Schwartz 1978*a*).

Raising Moose Calves

Procedures used for raising, training and maintaining moose calves for nutrition studies were previously reported (Franzmann and Schwartz 1978*a*, 1979*a*; Regelin et al. 1979).

Developing a Formulated Ration for Captive Moose

Procedures for developing a formulated ration for captive moose were outlined by Franzmann and Schwartz (1979*a*) and Schwartz et al. (1980) (Appendix I).

Developing Feeding Trial and Digestion Crates for Moose

Schwartz and Franzmann (1980) outlined the design, construction and use of facilities at the MRC for nutrition studies.

Developing a Respiratory Chamber for Moose

Regelin et al. (1981) outlined the design, construction, equipment and use of a respiratory chamber at the MRC used to study energy metabolism of moose (Appendix II).

Radioisotope Digestive Markers

The radio-labeled markers were given as a single dose either by mixing the markers with food or by direct intraruminal administration (oral) or a gelatin capsule containing the markers. Chromium-51 EDTA and ruthenium-103 chloride were given at a dose rate of 100*m*Ci and 30*m*Ci per 100 kg body weight, respectively. Fresh fecal samples were collected at regular intervals, i.e., 0.5-1 hour intervals for the first 48 hours after dosing, then 6 hour intervals for an additional 2-3 days. Subsamples were taken for radio assay and for estimation of water content. 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 concentration 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 line were plotted against time. These data were then fit with a least-squares line. The first appearance time for the marker was calculated from the intercepts and slopes of the two least-squares lines. Feces output was calculated from the radio-labeled marker dose and the slopes of the two least-squares lines. The mean rate of passage time was calculated from the slopes of the two least-squares lines. Dry matter digestibility was calculated from dry matter intake as measured by conventional methods and feces output.

FINDINGS

Immobilizing, Reversing, and Adjunct Drugs

Etorphine (M-99) used alone as an immobilizing drug or in combination with xylazine hydrochloride (Rompun) was the only immobilizing drug tested during this report period. Diprenorphine (M 50-50, likewise, was the only reversing drug tested. Gasaway et al. (1978) reported experiences using the above drugs on free-ranging moose on the Alaska Peninsula in April 1977 and the Tanana Flats in interior Alaska in August and October 1976-77. They calculated that the preferred dose for

free-ranging Alaskan moose weighing 450-640 kg was 7 mg M-99 with 300 mg Rompun and an antagonist dose of 20 mg M 50-50. This dosage was also used to immobilize 40 Seward Peninsula moose during April 1981, with only a few moose requiring additional drug for immobilization (Gasaway, pers. commun.). However, in March 1981 Gasaway (pers. commun.) experienced difficulty immobilizing moose in interior Alaska with this dosage.

Subsequent to the Gasaway et al. (1978) report, we immobilized Kenai Peninsula moose in excellent condition (grade 8 - Franzmann et al. 1976*a*) during November and December 1980, in conjunction with a U.S. Fish and Wildlife Service study on the effect of seismic activity on moose movements. Dosages as recommended were not adequate to immobilize these moose and had to be adjusted upwards. The dosage used to effectively immobilize these moose was 12 mg M-99 with 400 mg Rompun for adult males and females. The antagonist M 50-50 was administered intravenously at the rate of 30 mg/adult moose. Forty-four moose were immobilized with this dosage; and mean down time was 9.6 minutes (n = 26). Accurate down times were not available for 18 of the moose, due to failure to record or the moose were already down when the helicopter arrived. Twenty-two moose received lesser doses: 16 received 10 mg M-99/300 mg Rompun and six received 10 mg M-99 with no Rompun). Response to the lower doses was generally poor and supplemental doses were often required for immobilization. Eight of the 22 moose immobilized with the initial injection had a mean down time of 15.5 minutes. The remainder had no recorded time or they required supplemental doses.

Of eight mortalities, six were attributed to insufficient doses and resulting subsequent overheating during the unseasonably warm weather. Capture myopathy (Haigh et al. 1977) may have been a contributing factor, but was not positively identified.

The differences in dosages of M-99/Rompun required to immobilize adult moose in these studies were probably related to the size and general condition of moose captured and the season of capture, but other factors may also have been involved. At this time therefore, insufficient information is available to determine the relative influence of these variables. Factors which should be investigated include the effects of:

1. Seasonal physiological variation in the population
2. Individual physiological variation in the population
3. Bleeding and leakage at the injection site
4. Injection into fat and bone
5. Injection into vein, artery or spinal column
6. High ambient temperature
7. Over-excited or stressed animal
8. Underestimate of weight
9. Drug quality
10. Time of day and amount of food ingested
11. Temperament of individual animals
12. Age
13. Disease or pathology

The message from immobilizing experiences in the different moose populations is that adjustments must be made in consideration of all possible influences. However, conditions of moose and season are the primary considerations in establishing the proper dosages of M-99 and Rompun in adult moose. The experienced variability in dosages from 7 mg to 12 mg of M-99 (nearly a 2-fold increase) necessitates that the operator be prepared to make adjustments.

When dosages of greater than 10 ml volume of drug are required, it is necessary to double-dart the moose on the initial dose. Cap-chur darts are manufactured to handle larger quantities (12 ml and 15 ml); however, they are considered too large for accurate flight when shot from a helicopter. We consider the 10 cc dart the largest we can efficiently use under field conditions. We are thereby limited to 10 ml volume of drug mixture. The 7 mg M-99 and 300 mg Rompun mixture fills the 10 ml dart (M-99 = 1 mg/ml Rompun = 100 mg/ml). One solution to this problem is the "double-darting" which is expensive, dangerous and more traumatizing to the animal. The other solution is that the drugs be made available in more concentrated form, and M-99 would be the logical drug to concentrate. Etorphine (M-99) is concentrated and combined with acepromazine maleate in a product called Immobilon (Rickett and Coberman Pharmaceutical Div., Hull, England). Each ml of Immobilon contains 2.45 mg of etorphine and 10 mg acepromazine maleate. The product is not available to us in the United States. The U.S. Department of Justice, Drug Enforcement Administration controls etorphine (narcotic) and has licensed only one product which is M-99 with the etorphine concentration of 1 mg/ml. For large ungulates, such as moose, it would be most desirable to have a more concentrated form of etorphine available for immobilization. Efforts have been made by individuals and groups towards this goal, but to date have been unsuccessful.

Etorphine does not meet all the criteria as an ideal immobilization drug for moose, but it is the best available. New drugs that become available will be tested at the MRC in hopes of finding the ideal immobilizing drug for moose.

Pellet-Count Census Evaluation

Evaluation of the pellet-count census technique in the MRC enclosures with known numbers of moose was completed. Results of these studies were published (Franzmann et al. 1974, 1976*a*, *b*; Oldemeyer and Franzmann 1981). Segment reports since the previous Techniques Final Report also contained progress and results of these studies (Franzmann and Arneson 1975, 1976*a*; Franzmann and Bailey 1977*b*; Franzmann and Schwartz 1978*a*).

The most important results of these studies was to demonstrate the refinement of techniques necessary to utilize pellet-counts as a census tool for moose. To begin with we could not estimate the time that moose began forming pellets in the fall. It was therefore necessary to clear the plots each fall to establish a beginning point for moose-days that the plots were exposed to.

Using published defecation rates from other areas was not valid; we overestimated moose in the enclosures using these data when plots were not cleared in the fall (Franzmann et al. 1976). However, the pellet group counts did reflect population trends in the enclosures over a 4-year period.

In our 1975 Pen 1 moose defecation rate studies, we found an average daily defecation rate for adult males of 19.6 pellet groups, which was significantly higher ($p < 0.01$) than the 14.6 rate observed for adult females. The combined mean deposition rate was 17.6/day (Franzmann et al. 1976*d*). These results indicated that to apply pellet censusing techniques to moose it would be necessary to know the adult sex structure of the population. Defecation rates of calves and yearlings would also probably be required.

Using defecation rates established for adult moose in Pen 1, we calculated from stratified total winter pellet groups (27,592) and 1976-77 total moose-days in Pen 1 (1,722), a deposition rate of 16.0 pellet groups/moose/day. In 1977-78 there were 1,122 moose-days and an average deposition rate of 18.7 groups/moose/day (Oldemeyer and Franzmann 1981). The deposition rates for the two winters are within the range of rates established for Pen 1 moose (Franzmann et al. 1976*d*).

It appears that under ideal conditions pellet group censusing of moose may be accomplished. However, in actual field application the intensity of sampling necessary to gain precision would negate its use as a practical management tool. Its use as a management tool to establish population trend over time is also confounded by the degree of sampling required.

The distribution of pellet groups in vegetative types corresponded with observed habitat use by moose at the MRC. Collins and Urness (1979) reported significant differences ($P < 0.01$) between pellet group distribution and actual distribution of elk *(Cervus canadensis)* activity during summer. In contrast, mule deer *(Odocoileus hemionus)* in Colorado had no significant difference in defecation rates between clearcuts and forests as related to time spent on forage consumption (Regelin pers. commun.). More intensive studies on moose pellet distribution in relation to habitat use are needed to confirm our data based on reports and observations not associated with the study.

Biotelemetry

The results, or rather lack of results, of our efforts to monitor moose internal body temperature and heart rate were reported (Franzmann and Bailey 1977*b*). Our difficulties were many and reflected, in a way, the state of the art at the time we attempted the studies. Biotelemetry application to wildlife has made rapid advances in recent years as exemplified in reports of working systems in the 1979 Proceedings of the Second International Conference on Wildlife Biotelemetry (Long 1979).

From our efforts, we concluded that we must (1) find an alternative to FM frequencies; (2) retransmit the signal from the transducer via a receiver-transmitter carried on the moose's collar, or place retrievable receiving and recording devices on the collar; (3) develop dependable decoders, if required, and; (4) establish a close working relationship with the designer and developer of the equipment.

Fixed-Station Telemetry Monitoring

Studies of moose calf mortality using variable pulse transmitters require intensive monitoring which, if done solely by aircraft necessitate daily flying. The fixed-station monitoring system we used provided an important adjunct to the moose calf monitoring and should be considered in other studies when the study area can be covered by such a system.

Difficulties with the system were primarily technical and related to antenna selection and placement. The system was operational for fast mode signals at close range and when the calves moved into higher elevations; however, it could not always pickup the fast mode signal from the study area (up to 9.7 km from the tower) when the collar was on the ground. Standing calves were easily monitored on slow mode. These circumstances provided another option to monitor calves, that of regularly (every hour or two) monitoring the calves with the receiver at the MRC. If a calf's signal was not heard for several hours, we would be alerted to monitor more intensively. If no signal was heard for 4 to 6 hours we would check the calf by aircraft. When a fast signal was monitored, which was the primary monitoring method, we would also respond by aircraft.

The testing of this system was in part accomplished through this Techniques job and proved to be a working system for the Kenai Peninsula moose calf mortality study.

Fertilization of Moose Browse

Analysis of volcanic ash from the Mount Augustine eruption on 23 January 1976 suggested that the fertilizing effects of the ash were lower than assumed. Tree ash (*Betula papyrifera, Picea glauca* and *Picia mariana)* was factorialy higher than volcanic ash in the soluble fractions of minerals analyzed (Franzmann and Flynn 1977). Mount St. Helen's ash from the 18 May 1980 eruption was primarily silica (59 - 68%) (Fruchter et al. 1980, Hooper et al. 1980) and did not have available elements for a fertilization effect, i.e. heavily laden with phosphorous and potassium as was speculated in the press. Effects of ash fall are not necessarily negative, as many soluble elements are made available, generally in low concentrations. All the ecological effects of a major ash fall are yet to be assessed.

Artificial nitrogen fertilization of moose browse was tested at the MRC and the short-term effects were reported by Regelin et al. (1980). They concluded that nitrogen fertilization not be

recommended as a method of short-term forage production for moose. Forbs and shrubs were not visibly altered by fertilization, but grass production was increased up to four-fold. However, grasses are seldom used by moose and may compete with preferred forbs and shrubs (Regelin et al. 1980).

Electronic Tissue Measurement

Results of testing an electronic tissue measuring device (Scanaprobe, Ithico, Ithica, NY) manufactured for domestic animals was reported by Franzmann and Schwartz (1978*a*). Lack of fat on the animals tested may have produced the erratic readings we observed. The instrument may have value in measuring the fat layer, but we were not able to demonstrate this. The instrument may be unable to adequately measure wild animal tissue.

Raising Moose Calves

Results of efforts to raise moose calves at the MRC have been reported (Franzmann and Schwartz 1978*a*, 1979*a*; Regelin et al. 1980). We successfully raised 5 orphaned calves in 1978, 1 in 1979, and 1 in 1980. These animals are now being used for digestive physiology studies at the MRC.

Developing a Formulated Ration for Captive Moose

Preliminary results and ration formulation necessary to maintain moose on an experimental diet devoid of natural browse were published by Schwartz et al. (1980) (Appendix I). This ration has sustained the MRC moose in excellent condition for nearly 3 years and provided us the opportunity to initiate intensive digestive physiology studies as outlined by Franzmann and Schwartz (1979*a*). A grant obtained from the Morris Animal Foundation by C. C. Schwartz entitled "Development Testing of a Formulated Ration for Moose" was helpful to overcome the costs associated with this project.

Developing Facilities for Digestion and Balance Trials

Design, construction, and testing of digestion stalls for digestive physiology studies at the MRC were completed during this report period. Design and use of the facilities were described by Schwartz and Franzmann (1980) (Fig. 3).

Developing a Respiratory Chamber for Moose

Design, construction, testing and use of a respiratory chamber for digestive physiology studies at the MRC was completed during this report period and described by Regelin et al. (1981) (Appendix II).

Radioisotope Digestive Markers

The procedures for handling, testing and recording the radiomarkers were worked out under this Techniques job. Preliminary findings indicate that this technique is applicable to moose rumen turnover studies. The technique will be incorporated into the Digestive Physiology job and results obtained using the technique will be reported therein.

RECOMMENDATIONS

1. Efforts should continue in testing and evaluating new immobilizing drugs for moose.

2. Efforts should continue to convince the M-99 manufacturer to concentrate the product for use in large ungulates and carnivores.

3. Under ideal conditions, pellet group censusing of moose may be accomplished; however, in actual field operation the intensity of sampling necessary to obtain precision would negate it as a useful censusing tool for moose. Intensive sampling is also necessary to assess population trends of moose via pellet group counts.

4. Pellet-group counts may provide useful information on habitat selection by moose and should be utilized where this information is needed.

5. Fixed-station telemetry monitoring for mortality was successfully used at the MRC. This type of monitoring should be considered at least as an adjunct to aerial monitoring when possible. Time and money savings were significant.

6. Nitrogen fertilization is not recommended for short-term forage production stimulation for moose. Grasses were the only class of vegetation which responded positively.

7. The electronic tissue measuring device applied to moose did not provide accurate tissue measurements and, without improvement, should not be used for moose.

8. The development and testing of new techniques developed in other areas of research should be continually evaluated for their potential application to moose management.

ACKNOWLEDGEMENTS

Although this job was conducted under the guidance of the Alaska Department of Fish and Game, many other agencies were involved to varying degrees, including the U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Kenai National Moose Range, and University of Alaska, Institute of Arctic Biology. Many individuals from these agencies assisted us during these studies and

to list individuals would do injustice to those inadvertently omitted. Our thanks are extended to all.

A special thanks to our U.S. Fish and Wildlife Service cooperators from the Denver Wildlife Research Center, John Oldemeyer and Wayne Regelin. David C. Johnson has been the biologist-in-attendance at the MRC the past year and was most helpful.

Karl Schneider coordinated all research projects at the MRC, and he and Don McKnight reviewed all the manuscripts and reports from the MRC. Their help was most significant from an operational as well as a supportive basis.

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APPENDIX I

A FORMULATED RATION FOR CAPTIVE MOOSE, PRELIMINARY REPORT [1]

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Abstract: A formulated ration has been developed for moose *(Alces alces)* that is suitable for animal maintenance or experimental purposes. It contains 11.75 percent crude protein and has an apparent dry matter digestibility of 64.3 percent. Performance was measured over 1.5 years with 6 moose. Daily gain from weaning to age 1 year was 0.62+ S. D. 0.4 kg. Possible diet problems and improvements are presented. Aspen *(Populus tremuloides)* sawdust is the primary constituent and is believed to be the major reason for the diet's success. A discussion based on extensive literature review is presented concerning fiber types, and their effects on animal welfare.

Recent studies (Moen 1973, Robbins, 1973, Wallmo et al. 1977) have advanced the concept of predicting carrying capacity of ungulates 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. Crude protein and digestible energy were considered by most nutritionists to be the most important nutrients supplied by range forage (Moen 1973, Wallmo et al. 1977). Other important nutritional entities were requisite to the health of ungulates, but were seldom the primary limiting factor.

Available literature concerning nutrient requirements, metabolic rates, and digestive capabilities for white-tailed deer *(Odocoileus virginianus)* and mule deer *(O. hemionus)* is extensive. The literature is replete with food habits studies (see Peek 1974 for review), but very little is known or understood about the nutritional requirements of moose. Gasaway and Coady (1974) reviewed the energy requirements of moose and other ruminants. Most of their discussion regarding moose requirements was inferred from other species and it was apparent that no information was available for moose. Many statements in the publication verified this fact. For example, "estimates of BMP (Basal metabolic rate) of moose is difficult, particularly considering that metabolic data has not been reported for this species (moose)" or, "Energy requirements by moose for thermoregulation in cold have not been studied" and finally "food intake,

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[1] Research funded in part by Federal Aid in Wildlife Restoration, Project W-17-11.

passage rates and digestibility in moose have received little consideration."

In the past, moose have been maintained for studies either in facilities which contained enough natural vegetation to support the animals, or by harvesting and transporting native browse to moose in confinement. Cutting browse was not only time consuming, but also expensive.

Nutritional studies with moose initiated at the Moose Research Center, Kenai, Alaska, in 1978 dictated that captive moose be maintained on a diet that was: (1) readily available, (2) inexpensive, (3) reproducible, (4) suitable to constituent alterations, and (5) met the nutrient requirements of moose. These requisites deemed it necessary to use a formulated ration rather than natural browse. An extensive literature review revealed that no such diet was available.

The following report concerns the development of a formulated ration for moose. A review of the literature dealing with forage fibers, voluntary intake, and rates of passage as they relate to the ration development is presented. The authors wish to express their thanks to M. Schwartz, D. Johnson, and D. C. Johnson for their help with animal care and digestion experiments. K. Schneider and D. McKnight reviewed the manuscript.

BACKGROUND

In general, rations are balanced for essential requirements like protein, energy, minerals, and vitamins. Adequate levels of these nutrients are generally obtained by adding various amounts of concentrates (feed grains) and roughages (hays and crop residues) to the ration and balancing the minerals and vitamins with added supplements. The majority of the roughages used in formulated diets for ruminants 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. The Weende system of proximate analysis (Henneberg and Stohmann 1960), partitioned forage into the soluble fraction (nitrogen free extract, NFE) and the insoluble fraction (crude fiber). Studies with ruminants (Ely and Moore 1959) demonstrated that in some instances, the crude fiber portion was more digestible than NFE. Criticism of this system led to the development of the Van Soest system of fractionation (Van Soest 1963, 1965; 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 are almost completely available to the animal) and (2) cell wall constituents which comprise cellulose, hemicellulose, 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.

Components of Voluntary Intake

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

The gut capacity of an animal has components of a fixed and variable nature. Hofman (1968, 1973) studied ruminal structures in relation to feeding habits and observed two basic morphological types: (1) those of quality selective feeders, and (2) bulk, large quantity grazers. Hofman surmised that several structural components of the stomach determined the physical regulation of food intake. Capacity, size of communication ostia, barriers, subdivisions or contractive mechanisms for the delay of food passage were so firmly established that they remained unaffected by dietary changes, and therefore determine the limits of the adaptive ability of a species.

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

Forage turnover time was dependent on the rapidity of clearance of forage from the digestive tract which then allowed intake. Clearance may be accomplished by means of excretion or absorption. Mertens (1973) concluded that the lower tract did not limit passage. Excretion appeared to be controlled by the reticulo-omasal orifice which acted 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 digesta. When propylene fibers of varying length were introduced into the rumen, longer fibers

caused longer and more prolonged reductions in intake (Welch 1967). Pouring water into the rumen did not affect intake (Campling and Balch 1961, Moore et al. 1960); cell contents were soluble and occupy essentially no volume when dissolved (Van Soest 1971 in Robbins 1973). Therefore, the fibrous fraction of a forage limits the rate of passage. As this fraction increases, voluntary intake declines with an increasingly negative slope (Van Soest 1965*a*).

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 relate to voluntary consumption by sheep (Troelsen and Bigsby 1964, Troelsen and Campbell 1968).

Campling (1970), Van Soest (1965*a*), and Weston (1968) emphasized the importance of rate of digestion and rate of disappearance 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 1965).

Balch and Campling (1962, 1965), Hungate (1965), Troelsen and Campbell (1968), Van Soest (1966), and Welch (1967) indicate 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 regarded 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 digestibility, 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, lignin, and low digestibility are generally considered synonymous to a slower rate of passage. With respect to lignin, Mertens (1973) theorized that 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 while lignin content was directly related to feed

particle size, it was inversely related to fecal particle size. Therefore, large lignified particles in feed are transformed into small lignified fecal particles.

One additional facet of particle size reduction phenomena is pertinent in this discussion before a hypothesis is presented concerning the development of a formulated ration for moose. 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 influence of lignin on rate of passage may explain several contradictory results. For example, contrary to Troelsen and Campbell's (1968) observation of more lignified material passing slower, 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 and low lignin content (Van Soest 1973). Likewise, grasses have a much greater amount of hemicellulose than legumes (Gaillard 1965). Analysis of Kenai Peninsula moose browse (Oldemeyer et al. 1977) reveals 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 (Table 1). Forbs are intermediate. This lig:CWC ratio represents the percentage of lignin making up the fiber portion of the forage. Browse, including leaves, is high in total fiber lignin while grass is low in fiber lignin.

Food habits of moose (LeResche and. Davis 1973, Peek 1974) indicate that the diet is composed, almost entirely of woody

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

Species	IVDMD (%) Moose	IVDMD (%) Dairy cow	Fiber (%) Cells walls	Fiber (%) ADF	Fiber (%) 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	73.1	80.7	32.2	17.7	2.4	.075	17.1
Shrubs							
Paper birch							
	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

1/ Data from Oldemeyer et al. 1977.
2/ In vitro dry matter digestion

vegetation and leaves. With the above variables in mind, we hypothesize that moose, as ruminants, evolved with certain mechanisms to process woody vegetation but lack the ability to process grasses and many forbs. Browse as a food is composed of two components: (1) the bark and bud which provide the available nutrients, and (2) a core which is composed of lignified woody material. Although the entire package (bud, bark, and woody core) is relatively low in nutrients, moose are able to meet their nutrient requirements because the non-nutritive core can be broken down rapidly into small particles capable of passing from the rumen. Thus, 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 fed diets which contain large quantities of fibrous material from grasses and forbs (most hays and crop residues) become bulk-limited because of reduced rates of passage and cannot extract enough nutrient to survive. Most formulated rations for domestic and zoo ruminants contain large quantities of grass or alfalfa hay and consequently are not suitable as moose foods. It is for these reasons that a basal diet contains sawdust as the primary fiber component.

PROCEDURES

Six hand-reared captive moose calves were used to evaluate the formulated ration. Development and testing of the ration followed recommendations of Ensminger and Olentine (1978: 469-493). In general, the ration was evaluated on the basis of (1) physical characteristics, (2) chemical analysis, and (3) biological evaluation.

The diet was analyzed chemically for crude protein (kjeldahl NX6.25), gross energy, ash, and minerals (A.O.A.C. 1956). Cell wall constituents (CWC), acid-detergent fiber (ADF), and acid-detergent lignin were determined by procedures outlined in Van Soest and Wine (1967), Van Soest (1963), and Goering and Van Soest (1970). Physical characteristics including pelleting ability, lack of crumbling of prepared pellets, and acceptance of various pellet sizes, was evaluated subjectively.

Biological evaluation consisted of two parts. Conventional digestion and balance trials (Ensminger and Olentine 1978, Church 1969) were used to evaluate the animals ability to process, digest, absorb and assimilate the various nutrients. Wooden digestion stalls (3.1 X 2.4 X 2.4 m) designed to permit complete and separate collection of feces and urine were used for digestion studies. The floors of the stalls were fitted with expanded metal sheeting to permit fecal and urine separation. During phase 1, animals were enclosed in 3.1 X 15.2 m enclosures for 10 days during which average daily food consumption was measured. During phase 2, moose were kept in the same enclosures and fed 90 percent of their phase 1 intake for 3 days. This was done to level out feed consumption, fecal output, and eliminate the analysis of orts. During the third phase, the moose were placed

in the digestion cages, offered 90 percent of their phase 1 intake, and feces and urine collected daily for 7 days. Water was available *ad libitum*. At the end of the digestion trial, a composite sample of the diet was analyzed in triplicate for moisture. Orts were subsampled and analyzed in a similar fashion. Excreta was collected once daily, weighed or the volume measured and subsampled at 20 percent by weight and 5 percent by volume for feces and urine, respectively. Urine samples were acidified with 6N H_2SO_4 to lower the pH to below 4 to prevent the loss of ammonia nitrogen. Both feces and urine were frozen (-12C) until analyzed.

RESULTS AND DISCUSSION

Ingredients (Table 2) used in the formulated moose ration, hereafter referred to as the "MRC special," were selected to provide one or more of the following: (1) essential nutrients, (2) increase palatability, (3) improve ingredient pelleting, and (4) reduce spoilage. Aspen sawdust was used as a fiber source rather than cultivated hays or crop residues because of it's fiber form and woody nature.

Sawdust was obtained from a local sawmill shortly after milling operations. Initially, we used the sawdust on an "as is" basis when preparing the ration, but because of the high moisture content, several batches of feed molded. This problem was corrected by air drying the sawdust until the moisture content was below 30 percent. We have used sawdust cut from both summer and winter harvested trees with apparent success. Trees logged during summer did contain more sap and, consequently, the sawdust required a longer time to dry.

Aspen was chosen as a sawdust source because it was: (1) eaten by moose, (2) abundant and easy to harvest, (3) lacking in terpenes or resins, and (4) successfully fed to domestic cattle. We are currently experimenting with cottonwood (*Populus tacamahacca*) and spruce (*Picea* spp.) sawdust, but no results are available at this time.

Although spruce sawdust was much more available than aspen sawdust, we were reluctant to use it initially, because of the terpenes it contained. Work by Nagy et al. (1964) with sagebrush (*Artemesia tridentata*), Oh et al. (1967) with Douglas fir (*Pseudotsuga mensiesii*), and Schwartz et al. (1980*a*, *b*) with *Juniperus spp.* has indicated that volatile oils and terpenes were inhibiting to mule deer rumen bacteria and reduced palatability of feed.

Protein and energy levels of the MRC special (Table 3) were based on dietary requirements for dairy cattle. The 11.75 percent crude protein level and digestible energy appeared adequate for moose calf growth from weaning to 1 year of age. Growth, as determined by weight gain, for 6 moose fed the MRC special, was similar to that for wild moose calves on the Kenai Peninsula

Table 2. Composition of the "MRC special" diet formulated for captive moose 1/.

Ingredient	Percent
Corn, ground yellow	28.7
Sawdust 2/	25.9
Oats, rolled	17.2
Soybean meal, powdered	7.2
Cane molasses, dry	5.7
Barley, ground	5.7
Beet pulp, ground	5.7
Vitamin premix 3/	0.3
Trace mineral salt 4/	0.7
Dicalcium phosphate 5/	1.3
Pelaid 6/	1.4
Mycoban 7/	T

1/ The diet was formed in 4.8 mm pellets.

2/ Aspen sawdust from sawmill.

3/ Each kg contained 5004.4 USP units vitamin A, 13228 IC units vitamin D_3, and 44 I units vitamin E.

4/ Guaranteed analysis: NaCl 95-98%, Zn 0.35%, Mn 0.28% Fe 0.175%, Cu 0.035%, I 0.00%, Co 007%.

5/ Guaranteed analysis: P 18.0%, Ca 31.34.0%.

6/ Pelaid, Phodeia Inc., Ashland Ohio, is a wood byproduct used to enhance pelleting.

7/ Mycoban, Van Waters and Rogers, Anchorage, Alaska, inhibits mold growth. T = 0.5 lbs/ton (0.025%).

Table 3. Chemical composition and apparent digestibility of the "MRC special" diet formulated for captive moose.

Analysis	Amount and Units
Dry matter	80.0%
Crude protein	11.75%
Ash	
Cell wall constituents	47.2%
Acid-detergent fiber	26.5%
Lignin	
Gross energy	4.45 Kcal/gram
Calcium	9750 ppm
Potassium	7140 ppm
Sodium	2910 ppm
Phosphorus	2106 ppm
Magnesium	205 ppm
Iron	62 ppm
Zinc	23 ppm
Copper	6 ppm
Selenium	0.22 ppm
Cobalt	0.1 ppm
Cromium	0.1 ppm
Dry matter digestion (in vivo)	64.3%

(Franzmann et al. 1978) through October. After November, our moose receiving the MRC special continued to gain weight throughout the winter, while the wild moose calves lost weight. The average daily gain from weaning (August 15) until May 31 the following year was 0.62 kg± S.D. 0.02. These 6 moose continued to gain weight throughout the summer until early October when rutting activity began. Average daily weight gains from May 31 until October 1 were 0.74 kg± S.D. 0.09. Animals experienced slight loss of weight during the rutting period and throughout the winter period. Weight loss per day was minimal amounting to 0.04 kg± S.D. 0.02, from November 1 through March 24th. Weight loss was a result of reduced feed intake and fat metabolism. Similar weight loss has been observed in white-tailed deer offered *ad libitum* feed throughout the winter.

Apparent digestion of dry matter of the MRC special was 64.3 percent ± S.D. 2.3 percent as determined *in vito* with 4 moose. Energy partitioning, protein, and fiber digestion were not available for reporting at this time. However, digestibility appears adequate in light of weight gains and general health and vigor of the moose receiving the diet.

Consistency of the feces, which was used as a gross indicator of digestive upset, was similar to that of wild moose. Only on a very few occasions were "loose stools" observed. One calf raised in 1979 had persistent diarrhea for over 60 days, the cause of which was unknown. The condition cleared in early winter and the animal now appears normal and is gaining weight. We do not know if its digestive upset was associated with the MRC special.

We did lose one calf early in 1979 when it was less than 2 months old. It's death was probably a result of bloat associated with excessive feeding of the MRC special. The animal was accidently given *ad libitum* feed when it was initially introduced to the diet. This problem could have been alleviated by gradual introduction to the diet, thereby allowing the digestive system adequate time to adjust to the dietary change. This is a standard practice in animal feeding. The loss of this animal does not reflect an imbalance in the feed.

While our preliminary report on the MRC special suggests that it is useful for maintaining moose, its composition should not be considered final. Continuing research into nutritional requirements of moose, particularly calves and reproductive females will no doubt indicate modifications which will improve the ration. However, we feel it is important to make these preliminary findings available because: (1) the diet appears to be adequate to sustain moose, (2) feeding the MRC special is cheaper than cutting browse (cost $260.00/ ton on April 11, 1980), and (3) with additional agencies using this diet, the MRC special will be tested over a wider range of conditions, and hopefully improved more rapidly.

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APPENDIX II

A RESPIRATION CHAMBER TO STUDY ENERGY METABOLISM OF MOOSE

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ABSTRACT: The respiration chamber and associated equipment used at the Kenai Moose Research Center to measure energy expenditure of moose is described. Methods used to construct the chamber and to measure respired gas volume and composition are discussed.

Partitioning the flow of energy through a ruminant animal requires a measurement of the energy lost in feces, urine, respiratory gases and produced as heat increment (HI). Fecal and urinary energy loss can be sampled and measured with standard digestion cages and routine laboratory analysis.

Determination of energy lost as methane and HI requires a means of measuring the exchange of respiratory gases or production of heat. Direct measurement of heat flux is difficult and requires close confinement of the animal. Indirect calorimetry is the method used most often with large-bodied animals. This technique estimates metabolic heat production from the amount of oxygen consumed and carbon dioxide produced (Klieber 1961, Blaster 1967).

A respiration chamber or face mask can be used to collect respired gases. Systems involving a chamber can be closed-circuited, where air is recirculated through the system, or open-circuit where fresh air is continuously circulated through the system. The open-circuit indirect calorimetry method has great versatility. Animals can be confined in the chamber for long periods, allowing a wide variety of experimental procedures. We describe the open-circuit respiration chamber and gas analysis equipment used at the Moose Research Center (MRC) in Alaska. Our system is similar to that used at the Ritzman Laboratory, University of New Hampshire (Haven Hays, pers. commun.). Several alterations have been made to adapt it to moose and cold temperatures in Alaska.

The Chamber

The respiration chamber is 2.4 X 2.3 X 2.2 m in size with a 0.9 X 0.9 X 2.2 m addition in one corner to accommodate a refrigeration

unit and feed bunk (Fig. 1). The chamber was constructed of 5 X 20 cm floor joists, and 5 X 10 cm wall and ceiling joists covered with high quality 1.9 cm plywood fastened with screws. A subfloor of plywood slopes to the center and one end to aid urine flow out of the chamber. The moose stand on a floor of expanded sheet metal suspended 5 cm above the sloping subfloor. The expanded metal has holes of sufficient size to allow feces and urine to pass through thus maintaining a clean, dry floor. Seven plexiglass windows (30 X 76 cm) were placed in the chamber walls. The entry door is 1 X 2.1m; it fits tightly against rubber material to prevent air leaks. All joints and screw holes were sealed with silicone and sealer and all interior walls were painted with several coats of epoxy paint to prevent air leakage.

Humidity in the chamber is controlled by a refrigeration unit [1/] suspended from the ceiling (Fig. 2c). This unit maintains humidity at about 30% and temperature between 2-4 degrees centigrade. It has a fan that continuously mixes the chamber air. Air is moved at less than 1 m/sec. This velocity does not increase heat loss (Moen 1973). Water vapor removed by the refrigeration unit is drained outside the chamber. A thermostatically controlled electric heater [2/] (Fig. 2b) warms the air during winter so the refrigeration unit will function.

Walls, floor and ceiling are insulated with fiberglass. A feeding stall with a remote control access door (Fig 2d) is located below the refrigeration unit. Food can be provided or restricted without entering the chamber.

Air volume of the chamber is 13,200 liters. Volume can be reduced to accommodate smaller animals by displacing air with large air mattresses. Chamber volume should be as small as possible without distressing the experimental animal. This allows the CO_2 level in the chamber to rapidly increase to about 1% and provides a faster response to changes in respiratory gases due to animal activity.

Outside air enters the chamber through a 4.5 cm valve (Fig. 2a). The entry valve is partially closed to keep the chamber at a slight negative pressure. This insures that any air leaks will be into the chamber and no gas expired by the moose can escape.

Gas Measurement

Gas is pumped out of the chamber at a constant rate by a reversed vacuum cleaner motor [3/]. The flow rate is regulated via reostatic control of the vacuum motor. Flow rate for an adult moose is 280 1/min. This rate maintains the CO_2 level inside

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1/ Model M100, Nor-lake Inc., Hudson WI 54016
2/ Glassheat, K & L Construction, Soldotna, AK
3/ Model L, Electrolux Co. Stanford, CT

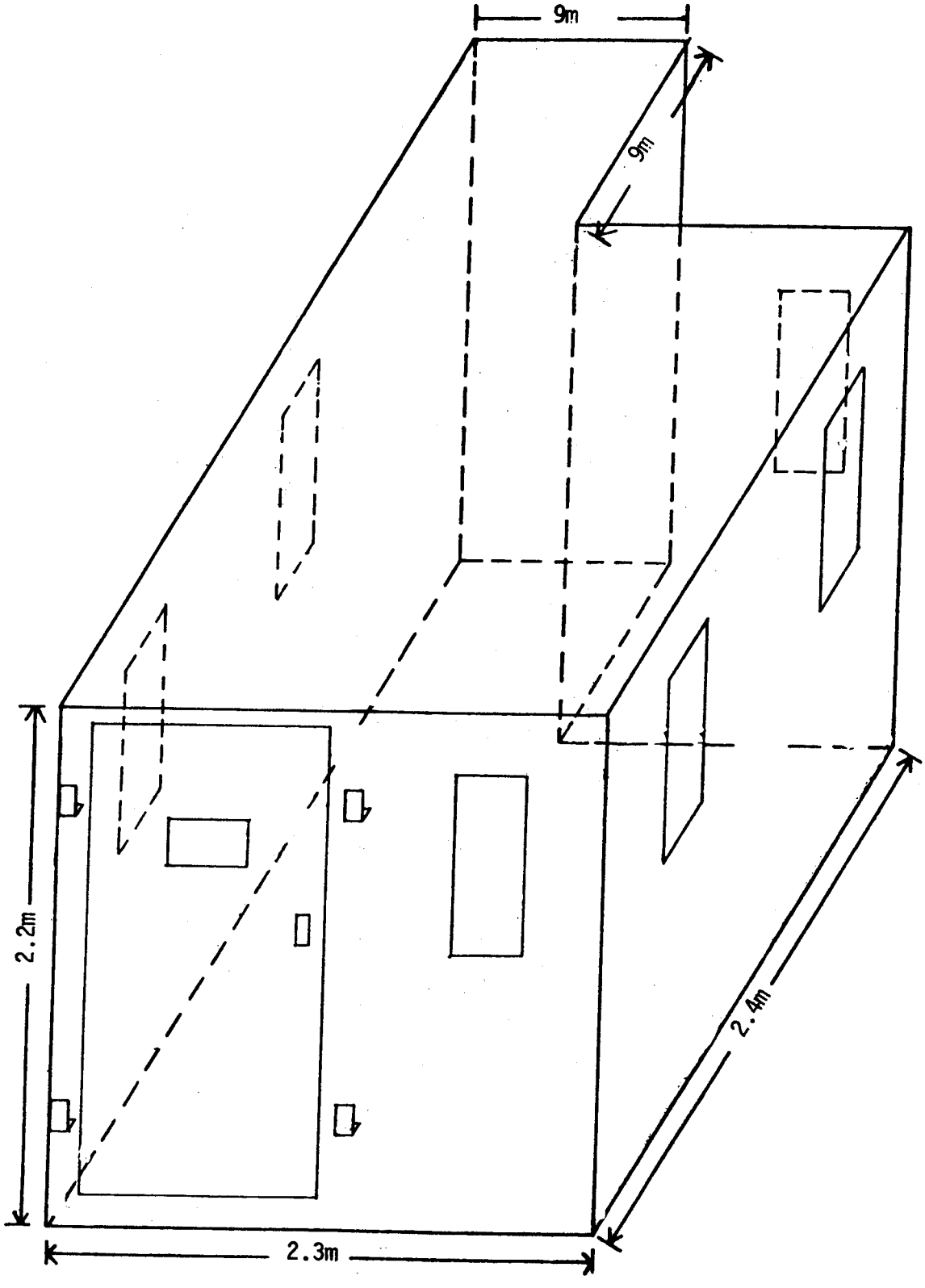

Fig. 1 Schematic view of the respiration chamber at the Moose Research Center, Alaska.

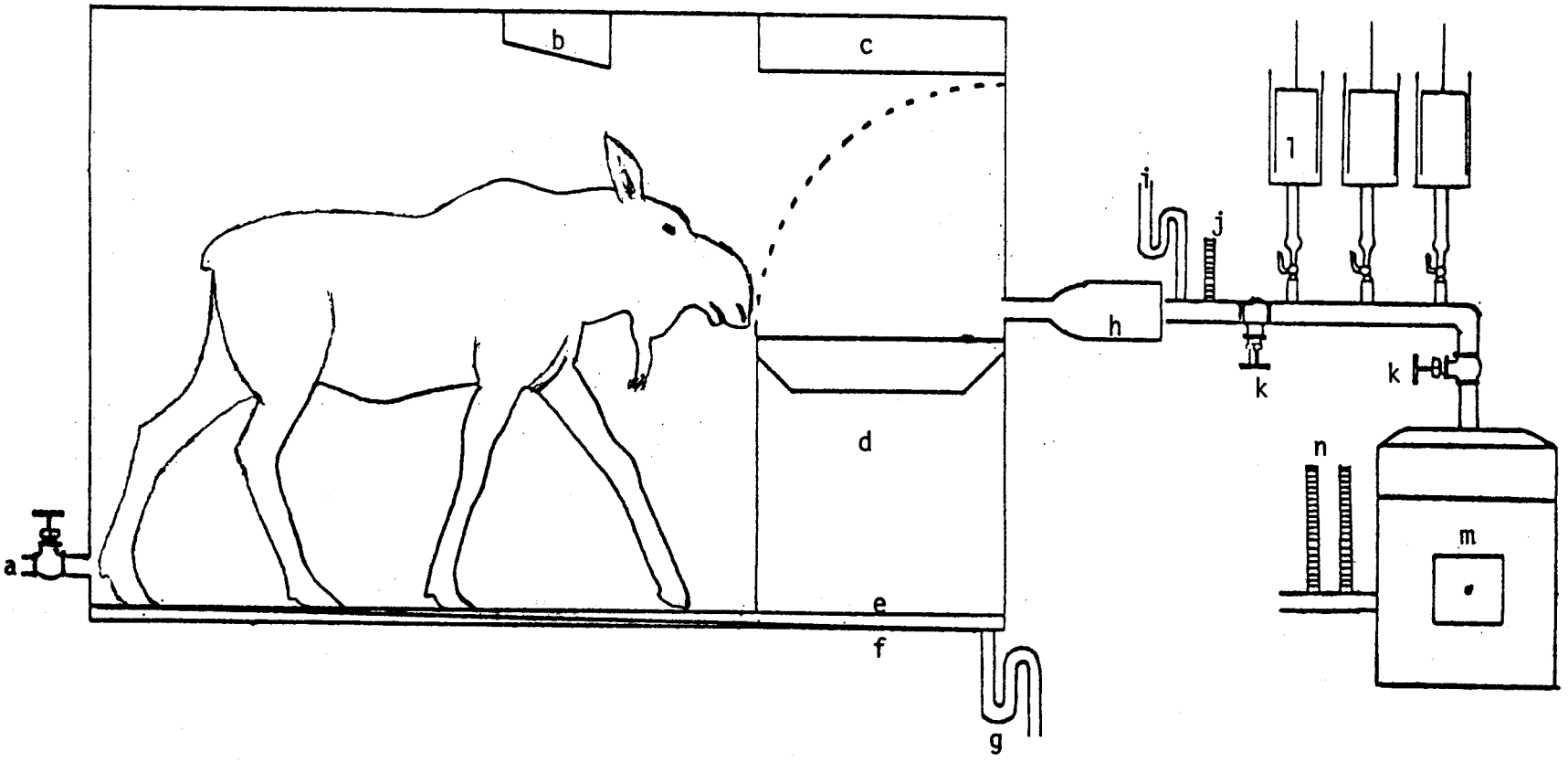

Fig. 2. Schematic drawing of the respiratory chamber and gas handling system at the Moose Research Center, Alaska. a, air inlet valve; b, heater; c, refrigerator unit; d, feed bulk; e, expanded metal floor; f, sloping subfloor; g, urine drain; h, vacuum cleaner; i, manomete; j, line thermometer; k, pressure valve, l, spiro meters; m, gas meter; n, wet and dry thermometers.

the chamber between 0.5 to 1.0%. Accurate values can be measured between this range; animals can tolerate a CO_2 level of about 1.5% without respiratory problems. The gas is pumped into a 5.1 cm plastic line where it passes through a gas meter [4] to measure total volume to the nearest liter (Fig. 2m). Pressure in the gas line is kept slightly positive by a valve placed in front of the gas meter. The positive pressure permits aliquot subsamples to be collected in three 9 l spirometers [5] (Fig. 21). Needle valves in the flow line to each spirometer allow the aliquot samples to be collected over 2- to 24-hour periods. Gas is dried by passing it through CaCl and filtered through glass filter paper prior to entering the spirometers. A stopcock valve in the main flow line (Fig. 2k) permits continuous analysis of the gas throughout the trial. This line bypasses the spirometers and flows directly to the gas analysis equipment after drying and filtering.

Temperature and moisture content of the gas is monitored by wet and dry bulb thermometers. Barometric pressure is measured with a standard mercury barometer. All gas volume measurements are converted to standard pressure and temperature before making any calculations. Air pressure inside the chamber (negative) and in the main flow line (positive) is monitored by simple homemade manometers.

Composition of the gas is determined by passing the gas through three instruments to measure oxygen, carbon dioxide, and methane (CH_4) content. Oxygen is measured in a paramagnetic analyzer [6] to the nearest 0.01%. CO_2 [7] and CH_4 [8] are measured by non-dispersive infrared analyzers, CO_2 to the nearest 0.01 and CH_4 to the nearest PPM. The instruments are connected so the same gas sample flows through each one. Gas from the spirometers, or directly from the main flow line passes through each machine at a constant rate of 500 ml/min.

The instruments are calibrated every hour during a trial against gases of known composition. Three gas mixtures are used for calibration, one being outside air and the other two provided by a chemical supply company [9] in compressed gas cylinders. The compressed gas is pumped out of the spirometers at the same rate of flow as the respiratory gas.

All instrument readings are made manually. Automatic recording devices are available for all instruments, but at considerable expense.

Heat production is calculated by multiplying the volume of O_2 consumed throughout the trial by the thermal equivalent (caloric

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[4] Model AL 1400, American Meter Co., Philadelphia, PA
[5] Warren E. Collins Co., Braintree, MA
[6] Model OM14, Beckman Instruments, Inc., Schiller Park, IL
[7] Model LB2, Beckman Instruments, Inc., Schiller Park, IL
[8] Model 865, Beckman Instruments, Inc., Schiller Park, IL
[9] Scientific Gas Co., Denver, CO

value) of the O_2 at the proper respiratory quotient (Brody, 1968). Energy expenditure is expressed in terms of heat production. Standard units of measure are either Kcal/day or KcalKg $BW^{.75}$ = Body weight of animal in Kg raised to the .75 power). The recent trend has been to express energy expenditure as kilo joules/24 hr. (1 KJ = 0.2423 Kcal).

DISCUSSION

The first chamber we built was 12.3 X 1.2 X 2.4 m in size with a small window at one end. Adult moose had great difficulty in turning around and refused to lie down. They became agitated after a few hours of confinement. It was important that the moose remain calm in a recumbent position so that accurate resting metabolic rates could be measured. We enlarged this chamber to its present size and added several windows. The new dimensions provided adequate space for the moose to lie down and turn around but minimized movement. The windows helped keep the moose calm, especially if they could observe other moose outside the chamber. The windows also allowed us to observe the moose and record their activity.

The expanded metal floor had a rough surface which we felt might injure the feet of the moose. We placed a 1.3 m^2 plywood board in the center of the chamber floor. The moose stand or lie on this board nearly all the time they are in the chamber.

During the past 18 months, we have conducted 48 energy expenditure trials in this chamber using 6 moose. The age of the moose varied from 6 to 30 months. They were either in a fasted condition (no food for 48 hours) or an *ad libitum* food intake. Length of trials varied from 2 to 24 hours. The trials have been used to measure CH_4 production in relation to food intake, energy costs of standing, and journal variation in energy expenditure. Seasonal changes in energy requirements have been examined. The measurements have a high degree of repeatability indicating the system is capable of producing precise results.

The respiration chamber has been operated at temperatures ranging from -35° C to 20° C without problems. The electric heater warms the air sufficiently, even at extremely cold temperatures to make the refrigeration (dehumidifying) system operate. The cooling system easily lowers high air temperatures. The system does not have the capability to reduce chamber temperature or increase wind velocity to critical levels for moose.

The entire system cost $17,000, excluding labor, in 1979. The gas handling and gas analysis equipment cost $14,000. The chamber with attachments cost $3,000; about half of which was accounted for my the refrigeration system.

ACKNOWLEDGEMENTS

The invaluable assistance of Haven H. Hayes in assembling the gas sampling and analysis system and the sharing of his vast knowledge of respiration chambers is gratefully acknowledged.

David C. Johnson and Douglas Waring assisted in the construction and operation of the chamber. This work was supported, in part, by the U.S. Fish and Wildlife Service and Federal Aid in Wildlife Restoration Project W-17-R.

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