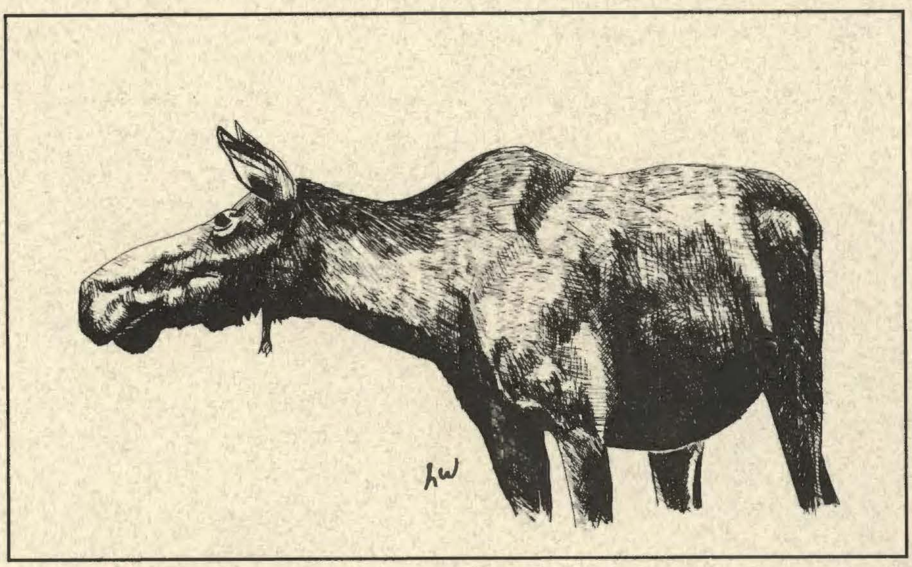
Alaska Department of Fish and Game
Division of Wildlife Conservation

Federal Aid in Wildlife Restoration
Research Progress Report
1 July 1992 - 30 June 1993

Evaluation and Testing of Techniques for Moose Management

by
Kris J. Hundertmark
Charles C. Schwartz
and
Curtis C. Shuey



Study 1.45
Project W-24-1
December 1993

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PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: Kenai National Wildlife Refuge, Soldotna, Alaska; Dr. Steve Monfort, National Zoological Park, Smithsonian Institution, Front Royal, Virginia; Dr. Thomas Thelen, Department of Biology, Central Washington University, Ellensburg, Washington; Kathleen Appell, School of Veterinary Medicine, University of Wisconsin, Madison, Wisconsin

Project No.: W-24-1 Project Title: Wildlife Research and Management

Study. No.: 1.45 Job Title: Evaluation and testing of techniques for moose management

Period Covered: 1 July 1992-30 June 1993

SUMMARY

Six adult cow moose (*Alces alces*) presumed to be pregnant were maintained on restricted (approximately 75% *ad libitum*) rations from December through April to determine the effect of nutritional restriction on gestation length. Although this degree of restriction was known to cause weight loss in captive moose, five of the six cows gained weight over the duration of the study. The single cow that lost weight aborted during the trial and was removed from the analysis. The remaining five cows exhibited a mean (SD) gestation of 229.2 (2.3) days, which was not significantly different ($\underline{t} = 1.77$, $\underline{P} = 0.30$) from the expected length of 231 days. Feces were collected from captive moose to continue our studies of monitoring estrus and pregnancy. Analysis of these data is not complete.

We collected semen from five yearling bulls via electro-ejaculation to determine semen productivity and viability. Two samples were collected from each bull weekly for a period of three weeks. Analysis of these data is not complete.

Genetics studies continued with the collection of samples from Subunit 6C, the preparation of a proposal to study the population genetics of moose, and a modeling exercise to determine the population and genetic effects of various selective harvest systems.

We continued to study the efficacy of hay as an emergency winter feed by providing hay to adults and calves throughout the winter. Although moose that were fed hay did not fare as well as moose that were fed a balanced ration, they did not show signs of nutritional stress based upon changes in mass and urinary chemistries. Grass hay apparently can serve as an emergency ration for moose that are in relatively good physical condition; however, the performance of nutritionally-stressed moose fed hay has not been documented.

Key Words: *Alces alces*, electro-ejaculation, feces, formulated ration, gestation, genetics, hay, modeling, moose, reproduction, selective harvest system, semen production, snow-urine, urine, weight, winter feeding.

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BACKGROUND

The Moose Research Center (MRC), with known numbers of confined animals and facilities to handle them, provides unique conditions for developing and testing techniques applicable to moose management. This study has been continuously active since 1969 when the MRC became functional. Four Federal Aid final reports covering the period from 1968 through 30 June 1991 have been published (Franzmann et al. 1974, Franzmann and Schwartz 1982, Franzmann et al. 1987, Schwartz et al. 1993), in addition to more than 30 journal publications (see Schwartz et al. 1993).

Mean (SD) gestation length in moose is 231 (5.4) days (Schwartz and Hundertmark 1993). Although little variation was reported in that study, limited observations at the MRC indicate that moose experiencing moderate or severe nutritional deprivation during pregnancy may exhibit longer gestation lengths (Schwartz and Hundertmark 1993). We designed a study to quantify the relationship between poor nutrition and gestation in captive moose.

Studies of reproduction in captive moose would benefit from a technique that would reliably assess onset of estrus and pregnancy. Monfort et al. (1993) evaluated the effectiveness of using urine and feces to assess pregnancy and estrus in moose and found that they were promising indicators but that further work needed to be done with feces before this medium could be used reliably. During this reporting period we continued to evaluate feces as an indicator of estrus and pregnancy.

The need to obtain information for better assessment of "optimum" bull/cow ratios in Alaska moose populations hinges on a thorough understanding of the reproductive cycle. We recently completed an evaluation of the female cycle (Schwartz and Hundertmark 1993); however, the reproductive vigor of bulls during the rut has not been described. Specifically, the number of ejaculations of which a bull is capable over a given period of time has never been documented, nor has the motility or volume of semen produced by yearling bulls. These aspects of male reproductive biology are important in determining appropriate bull:cow ratios in exploited moose populations. The consequences of altered or nonoptimal breeding during the rut have been attributed to low bull:cow ratios, but with no clear supporting evidence. Nevertheless, the issue remains and is in need of systematic research. During this reporting period we investigated semen production and viability in five yearling bulls.

During the severe winter of 1989-90 a public outcry arose to supplementally feed starving moose on the Kenai Peninsula and in the Matanuska-Susitna Valley. The typical feed offered to moose by well-meaning members of the public was locally-grown grass hay, which we believed to be nutritionally inadequate for moose in poor condition. Members of the public who attempted to feed commercially-available moose feed (MRC ration) reported mixed success, with many individuals reporting that moose would not eat it, even though it was a nutritionally complete and balanced ration (Schwartz et al. 1985). Conversely, anecdotal accounts from the public and some ADF&G staff indicated that moose readily ate hay and actually exhibited outward signs of nutritional recovery. We attempted to evaluate the effectiveness of hay as an emergency food using controlled feeding studies at the MRC.

The use of population genetic data in wildlife management has become more widespread in recent years (see Dratch and Pemberton 1991). Application of these concepts to moose was restricted because of the prevailing theory that moose did not show adequate levels of measurable genetic diversity. However, Hundertmark et al. (1992) demonstrated that moose can exhibit relatively great amounts of diversity and suggested that genetic monitoring be incorporated into management programs. This is particularly relevant in southcentral Alaska where we manage moose harvest by antler-size restriction. In response to this situation, we have developed a research proposal (Appendix A) to address genetic aspects of moose management in Alaska. As part of this study, during this report period we used a computer model (Thelen 1991) to assess genetic changes in populations subjected to different harvest strategies.

This report contains information collected from 1 July 1992 through 30 June 1993. Active jobs include: reproduction studies (Job 5), and miscellaneous techniques (Job 7).

OBJECTIVES

To test and evaluate techniques that are potentially useful for management of moose. (Study Objective)

To investigate the basic parameters of moose reproduction. (Job 5).

To test miscellaneous techniques. (Job 7).

METHODS

Job 5. Reproduction Studies

Effect of food restriction on estrus length: Six pregnant females with known breeding dates were placed on restricted amounts of a formulated ration (Schwartz et al. 1985) beginning on 14 December and continuing through 29 April. Amount of food offered (g/kg $BW^{0.75}$) daily during the months December through April was 55, 45, 45, 38, and 36 g, respectively, based upon weekly weights. Any uneaten food (orts) was weighed and subsampled for dry-matter determination. Feed was assumed to contain 89% dry matter. We determined intake by subtracting dry weight of orts from dry weight of feed offered. On 30 April all animals were offered approximately 40% more feed and this amount was increased until animals were being fed *ad libitum* on 7 May. We weighed animals weekly from 18 December through 5 March to monitor condition. Dates of parturition were recorded for all cows, and compared these dates to normal gestation lengths (Schwartz and Hundertmark 1993).

Use of feces for estrus and pregnancy detection: Three yearling females were held in a pen with a bull that was vasectomized by procedures described by Franzmann and Schwartz (1987). We observed the cows daily and noted date of estrus based upon observed mounting by the bull. We collected fecal samples from three adult females were collected daily from 1 October through 21 December 1992 for use in estrus detection. We selected this period because it encompassed the first three estruses of cows at the MRC (Schwartz and Hundertmark 1993). The samples were stored frozen until they were shipped to S. Monfort for analysis.

We collected fecal samples for testing pregnancy detection from three adult females that we assumed were pregnant based upon breeding behavior. We collected samples from each animal weekly beginning in late October and extending through late May. Two of these cows gave birth in May; the other did not give birth and showed no evidence of having aborted. These samples were stored frozen until they were shipped to S. Monfort for analysis.

Semen production and viability: The five yearling bulls used in this study were fed a pelleted ration *ad libitum*. We sampled each animal two times each week beginning on 25 September and continuing through 15 October. Animals were immobilized with 3 mg carfentinal citrate and 50 mg xylazine hydrochloride using a CO_2 pistol and capture dart. Once immobilized, we placed each animal on its right side, and removed excessive fecal material from the rectum by hand. We estimated testicle volume by measuring scrotal circumference. We then stimulated the animals rectally using a portable electro-ejaculation probe (Electrojac III, Ideal instruments, MI). Upon successful ejaculation we injected all animals with 300 mg Naltrexone and monitored them until they were standing.

We collected semen samples in vials surrounded by a water jacket and took them immediately to the laboratory where they were maintained at 37.5 C in a water bath. We noted and recorded semen color, pH, and volume. A sample was placed on a microscope slide and examined at 40x magnification for motility. An additional sample was placed in a hemacytometer and the number of sperm cells/ml was measured. We prepared sperm smears by placing a small amount of semen on the slide and staining with eosin-neogrosin. For each slide, we categorized sperm cells into the following categories (1) normal, (2) acrosome, (3) head, (4) proximal droplet, (5) mid-piece, and (6) tail. For each slide a total of 400 cells were counted. We evaluated each smear with Dif Quick for evidence of bacterial infection.

Job 7. Miscellaneous Projects

Analysis of genetic diversity: We collected liver samples from hunter-killed moose in Subunit 6C in September 1992. We collected liver, heart, kidney, and muscle samples from two adult females at the MRC that were killed for use in another study. These samples are stored frozen at this time.

Methodology for the comparison of genetic effects of different selective harvest systems is listed in Appendix A.

Use of hay as an emergency winter feed: See Appendix B.

RESULTS AND DISCUSSION

Job 5. Reproduction Studies

Effect of food restriction on estrus length: Of the six cows in this study, five gained weight from mid December through early March (Fig. 1), indicating that nutritional restrictions were not severe. Apparently, the feed restriction placed upon these cows was not adequate even though cows placed on similar intake levels in a previous study experienced significant weight losses (Schwartz et al. 1988). The primary difference between these two studies was that cows in the earlier study were confined in small holding pens, while those in this study were allowed access to a larger enclosure. Once in the larger area the cows had access to poor quality forage, particularly white spruce (*Picea glauca*), which moose will eat when nutritionally stressed (Appendix C). Although spruce probably does not contribute greatly to an animal's nutritional requirements, it may have allowed them to achieve a full rumen and consequently initiated a resting/ruminating bout which allowed them to conserve energy. Conversely, moose kept in holding pens paced the fencelines, probably because of hunger, and expended more energy.

The single cow that did not gain weight was in poor condition at the start of the trial and aborted on 6 May. The remaining five cows gave birth after a mean (SD) gestation of 229.2 (2.3) days, which was not greater (t = 1.77, P = 0.30) than the mean of 231 (5.4) days reported by Schwartz and Hundertmark (1993). One of these cows gave birth to a dead fetus, which was slightly larger than normal (19.5 kg, 47 cm hind foot length). We believe that the size of this fetus may have caused problems during birth which led to its death. Therefore, we have included this cow in the analysis because we believe she had an otherwise normal pregnancy.

Use of feces for estrus and pregnancy detection: These data are presently being analyzed.

Semen production and viability: These data are being analyzed at this time.

Job 7. Miscellaneous Projects

Analysis of genetic diversity: The tissue samples collected during this report period have not been submitted for analysis.

Results of the modeling exercise are included in Appendix A.

Use of hay as an emergency winter feed: Results of this study are in Appendix B.

A paper was presented at the 29th North American Moose Conference and Workshop concerning use of computer modeling as a management tool. We continued to prepare (Schwartz and Hundertmark) and edit (Schwartz) chapters for the book "Moose of North America: ecology and management."

RECOMMENDATIONS

We plan to continue to evaluate new drugs and related products as they become available. We may again investigate the effect of nutrition on gestation length with lower intake levels. We will document the genetics study in a separate Federal Aid report after this year.

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Prepared by:

Kris J. Hundertmark
Wildlife Biologist II

Charles C. Schwartz
Wildlife Biologist III

Curtis C. Shuey
Fish and Wildlife Technician IV

Submitted by:

David A. Anderson
Research Coordinator

Approved by:

David G. Kelleyhouse, Director
Division of Wildlife Conservation

Steven R. Peterson, Senior Staff Biologist
Division of Wildlife Conservation

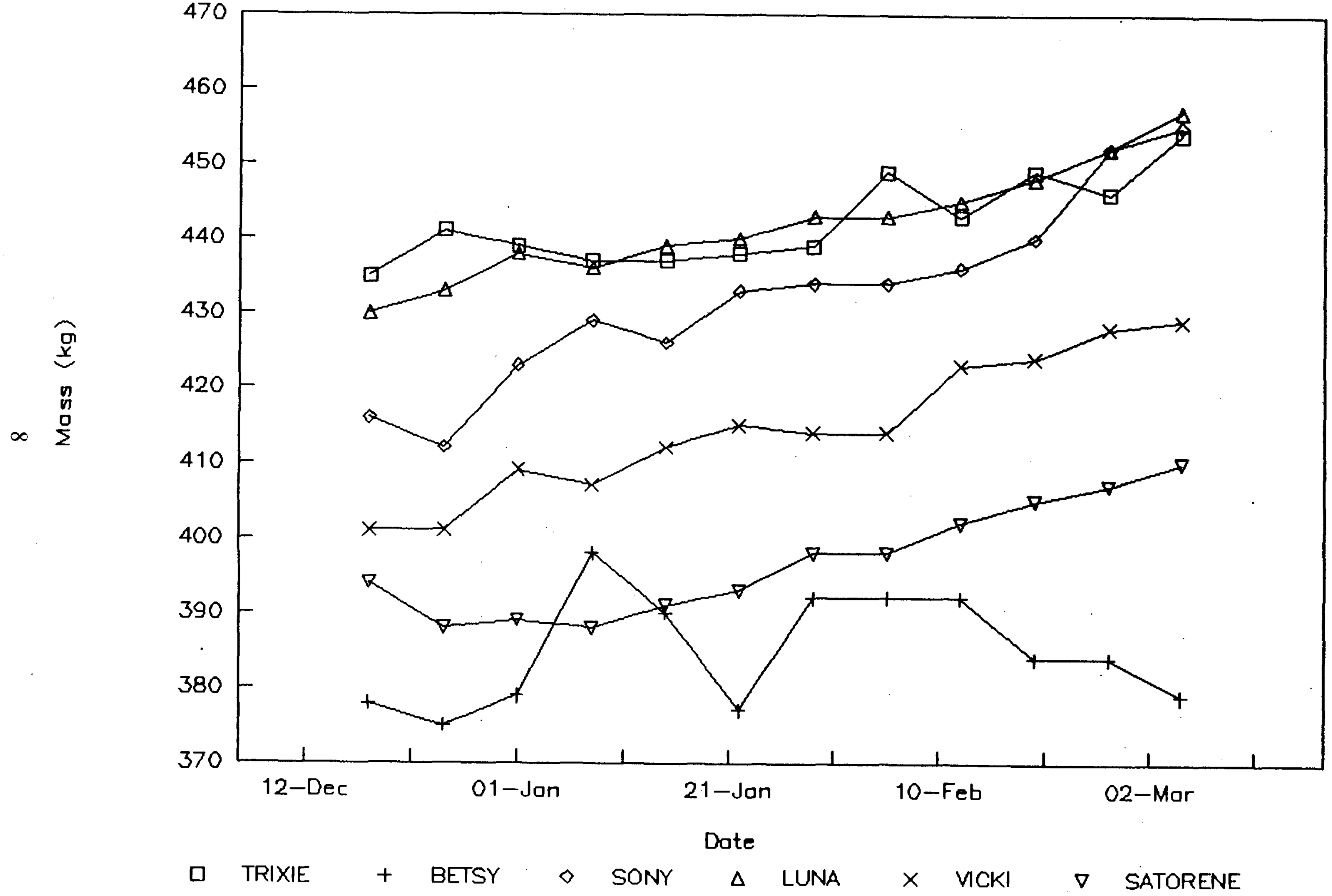

Figure 1. Body mass of six cows maintained on restricted intake during gestation.

Appendix A. Proposal for studying population genetics of moose.

WILDLIFE RESEARCH STUDY PLAN
Alaska Department of Fish and Game
Division of Wildlife Conservation
Kris J. Hundertmark, Principal Investigator

I. STUDY TITLE: Influence of Selective Harvest Systems on Population Genetics of Alaskan Moose

A. NEED/PROBLEM

1. Problem statement

In 1987, the Alaska Board of Game approved a selective harvest system (SHS) for bull moose (*Alces alces*) on the Kenai Peninsula. This system limited bull harvest to those with either a spike or forked antler, or animals with at least a 50-in antler spread or at least 3 brow tines on one antler. One of the many reasons cited for instituting this system was that focusing harvest on spike/fork yearlings would serve to eliminate "inferior" bulls from the gene pool. This statement was predicated on the assumptions that antler characteristics are inherited, that age-specific variation in antler size is related to genetics, and that antler characteristics are indicative of overall individual fitness.

The SHS implemented on the Kenai Peninsula has proven to be an effective method for managing moose harvest (Schwartz et al. 1992). Consequently, the Alaska Board of Game has adopted this system to many Game Management Units (GMUs) connected by the state road system between Anchorage and Glennallen, as well as most areas of Southeast Alaska. Implementation of this SHS will impact a large proportion of the state's moose populations. In light of this proposal, we need to gain a better understanding of the genetic aspects of harvest systems based upon antler configuration. Specifically, the assumptions driving this system, as well as the changes in genetic structure brought about by this system, need to be quantified before we can truly understand the impact of SHS on moose genetics.

2. Background

As public demand for consumptive and non-consumptive use of moose increases it is contingent upon the state to manage populations more intensively, which in turn requires a more complete knowledge of population processes. In attempting to understand temporal and spatial differences in the attributes of moose at the population (e.g. natality, mortality) and individual animal (e.g. antler size, body condition) levels, biologists focus primarily on nutrition, predation, and harvest rates. The possibility that genetic factors are responsible for many intra- and inter-population differences in these parameters is distinct; however, there is a paucity of information concerning population genetics of moose. In order to manage moose populations more effectively, we must understand the degree to which genetics contributes to antler development and the extent to which antler development reflects fitness. Additionally, the potential effects which antler-based management strategies may have on genetics must be described.

The genetic component of phenotypic expression, although universally recognized by biologists, has not been considered in a management context perhaps due to the lack of simple techniques for data collection and analysis or the perception that cause-effect relationships could not be ascertained. However, during the last 2 decades techniques have been developed to assess population genetics in wild animals (see Hedrick and Miller 1992) and subsequent investigations have demonstrated that information gained from such analysis can be useful to managers (see Dratch and Pemberton 1992).

The initial efforts to describe genetic variation in wild populations focused on electrophoretic variation of loci coding for enzymes. These studies focused on the relationships between overall genetic variability (most often expressed as heterozygosity) and physiological or morphological characteristics of individuals or populations. Mitton and Grant (1984:489-90) summarized the prevailing theories explaining these relationships as: "... (a) the enzymes mark blocks of chromosomes and are fortuitously linked to genes directly affecting growth and development; (b) protein polymorphisms constitute a sample of genes whose heterozygosity reflects a continuum between highly inbred (low heterozygosity) and randomly outbred (high heterozygosity) individuals; and (c) the genotypes of enzyme polymorphisms typically exhibit different kinetic characteristics; these differences affect the flow of energy through metabolic pathways and thereby influence growth, development, and oxygen consumption." In essence, this means that (a) the dynamics of enzyme polymorphisms mirror those of closely linked loci and therefore act as markers, (b) the genotypes observed in a population are indicative of the breeding history of that population, and (c) individuals exhibiting heterozygosity are thought to be able to take advantage of multiple metabolic pathways for energy processing, making them better able to adapt to a variable environment.

The most widely-studied game species in this context is the white-tailed deer (*Odocoileus virginianus*), which exhibits a great amount of genetic variability (Smith et al. 1984). Studies at the Savannah River Ecology Lab have demonstrated relationships between heterozygosity and body condition of over-wintering females (Cothran et al. 1983), conception timing (Chesser and Smith 1987), male body size and antler characteristics (Scribner and Smith 1991), number of fetuses (Johns et al. 1977), and rate of fetal development (Cothran et al. 1983).

Although genetic diversity is thought to be maintained in natural populations by means of stabilizing selection (Pemberton et al. 1991), populations subject to hunting can exhibit unexpected trends in genetic composition due to different mortality rates. Improperly designed hunting seasons can cause dramatic changes in the genetics of populations without causing a decline in population size. Thelen (1991) demonstrated that certain SHS for elk (*Cervus elaphus*) based on antler characteristics actually resulted in a decrease in desirable genetic traits, while others had the opposite effect. Ryman et al. (1981) demonstrated that certain harvest regimes for moose can cause rapid declines in effective population size (N_e), an index of the rate of genetic drift (random loss of genetic material), and that populations in which only males are harvested are more susceptible to these changes because they have an inherently lower N_e because of their characteristic skewed sex ratios. Scribner et al. (1985) demonstrated that two different hunting methods (still vs. dog hunting) had different effects on genetic diversity of white-tailed deer populations without changing population composition. Hartl et al. (1991) detected differences in allele frequencies in populations of red deer (*Cervus elaphus*) that differed in the amount of hunting pressure on spike-antlered yearlings. Therefore, the type of SHS imposed on a population can have a dramatic effect on genetic structure, and consequently influence population processes that are of interest to managers.

Electrophoretic variation has also been used to determine population subdivisions, or breeding units. Species in which population subdivision has been detected include white-tailed deer (Manlove et al. 1976), elk (Dratch and Gyllensten 1985), caribou (*Rangifer tarandus*, Røed and Whitten 1986), mule deer (*Odocoileus hemionus*, Scribner et al. 1991), and moose (Ryman et al. 1980, Chesser et al. 1982). Describing this variation is useful in quantifying such concepts as dispersal and population identity as well as understanding inter-population differences in population parameters. As populations should be managed at the level of the breeding unit (Smith et al. 1976, Ryman et al. 1981), this information can be of extreme importance to management agencies.

Recently, genetic analyses have identified relationships between alleles at specific loci and selective pressures. Pemberton et al. (1988, 1991) detected a relationship between gene frequencies at a particular locus and juvenile survival and adult fecundity in red deer. Hartl et al. (1991) demonstrated that selective harvesting of spike-antlered red deer caused a decline in frequency over time of a specific allele. This latter study is supported by Templeton et al. (1983), who demonstrated that the number of antler points in white-tailed deer likely is controlled by a single gene.

The degree to which genetics contributes to antler expression (heritability) in moose is unknown. Arguments for either nutrition or genetics as the primary force behind antler growth are common (see Goss 1983). The limited data available indicate that the form of the antler and its potential size are genetically controlled. Harmel (1983) reported that of the offspring produced by a male white-tailed deer with superior antlers, only 5% exhibited spikes as yearlings whereas 44% of the offspring of a male with inferior antlers had spikes. As all of the deer in this study were maintained on high-quality feed, it is apparent that the size of antlers is heritable. The heritability of brow tines is unknown.

B. OBJECTIVES

1. Determine genetic structure of moose populations across the state.

H_{10}: Estimates of genetic diversity will not differ among moose populations across the state.

H_{1A}: Estimates of genetic diversity will differ among moose populations across the state.

2. Determine if differences in antler characteristics noted for different regions of Alaska are related to genetic factors.

H_{20}: Populations characterized by superior antlers (larger age-specific antler spreads and palmated brows) will not exhibit more genetic diversity than those characterized by inferior antlers.

H_{2A}: Populations characterized by superior antlers (larger age-specific antler spreads and palmated brows) will exhibit more genetic diversity than those characterized by inferior antlers.

3. Determine the degree to which antler characteristics are heritable.

H_{30}: Antler morphology of offspring has no relation to antler morphology of parents.

H_{3A}: Antler morphology of offspring is related to antler morphology of parents.

4. Determine if antler characteristics are related to other phenetic correlates such as body size and growth rate.

H_{40}: Antler morphology (size) is not related to body size or growth rate.

H_{4A}: Antler morphology (size) is directly related to body size or growth rate.

5. Determine if N_e of moose populations subjected to SHS changes over time in comparison with control populations.

H_{50}: Temporal changes in N_e will not differ between populations subject to SHS and general hunts.

H_{5A}: Temporal changes in N_e will differ between populations subject to SHS and general hunts.

6. Determine if SHS causes a decline in the number of animals with inferior antlers.

   H_{6O}: The percentage of spike-fork yearlings in populations subject to SHS will not decrease over time.

   H_{6A}: The percentage of spike-fork yearlings in populations subject to SHS will decrease over time.

7. Determine if genetic diversity of populations is related to historical population trends.

   H_{7O}: Populations characterized by historically low bull:cow ratios and/or low population densities will exhibit no differences in genetic diversity compared with populations that are close to management objectives.

   H_{7A}: Populations characterized by historically low bull:cow ratios and/or low population densities will exhibit lower genetic diversity compared with populations that are close to management objectives.

C. EXPECTED RESULTS AND BENEFITS

In general, this study will provide us with a much better understanding of the relationship between population structure and genetic diversity in Alaska moose populations. Specifically, we will determine the extent to which genetic factors influence antler morphology in moose, and the prevalence of these factors in various moose populations across the state. We will gain a better understanding of the relationship between genetic diversity and historic population trends. This information is needed before we can determine the effect of antler-based SHS on moose population genetics, which will allow us to make better management decisions that will enhance desirable genetic traits in moose populations across the state.

D. APPROACH

Job 1. Collect tissue samples from moose populations across the state.

A sample of skeletal muscle, as well as kidney, liver, and heart tissue if possible, will be collected from as many animals as possible, utilizing harvested animals as well as road-kills. The desired sample size will be a minimum of 20 individuals per population per year. Tissue samples will be frozen until analyzed and will be subjected to standard electrophoretic analysis (Acquaah 1992). Genetic variability will be expressed as heterozygosity (H), alleles per locus (A), and percent polymorphic loci (P). Genetic differentiation among populations will be determined by use of F statistics (Wright 1965) and Nei's genetic distance (Nei 1978).

Job 2. Measure antler characteristics of bulls from different populations across the state.

Antler characteristics will be measured at hunter check stations in certain moose populations across the state. The populations of interest are Kenai Peninsula (GMU 15A and 15B-East), Copper River Delta (GMU 6D), Three Day Slough (GMU 21D), and Stikine River/Thomas Bay (GMU 1B). Antler measurements will conform to standard Boone and Crockett scoring procedures. A tooth will be extracted for age determination (Sergeant and Pimlott, 1959).

Job 3. Conduct a captive breeding program to assess heritability of antler and body size.

This job will be conducted at the MRC using moose acquired from different parts of the state that are known to have different antler forms. Four newborn calves (2 male, 2 female) will be captured in each of two moose populations. These areas are tentatively identified as the Three Day Slough area of the Koyukuk River, an area known for producing moose with large brow formations, and the Kenai Peninsula, which is known for producing moose without palmate brow tines. These animals will be hand-reared at the MRC to allow them to become accustomed to human presence and handling. All animals will be allowed to forage on natural vegetation during the summer and will be provided a formulated ration (Schwartz et al. 1985) *ad libitum* during the winter to maximize nutritional effects on antler and body growth.

Selective breeding will follow the methodology of Harmel (1983). Bulls will be bred to cows from their geographic areas as yearlings and 2-yr-olds. All offspring will be ear-tagged and weighed at birth. Male offspring will be placed in a large pen and fed a formulated ration *ad libitum*. Females will be retained to be bred to their fathers as yearlings and 2-year-olds. Male offspring will be weighed weekly in September, and their antlers will be removed, weighed and measured. Weights and antler measurements will be analyzed by partitioning the variance among sires and siblings (Wright 1969). Pedigrees of all MRC moose will be constructed to determine if these data can be used in this analysis.

Electrophoretic testing will be conducted on blood and ear tissue samples to determine genetic composition of all animals.

Job 4. Calculate changes in composition in populations subject to SHS and control populations under general hunts.

For five years, annual survey and inventory data from all units in which SHS was implemented, as well as adjacent control units, will be compiled to determine changes in population composition and harvest attributable to SHS. Bull:cow, calf:cow, and yearling bull:cow ratios will be compared. Effective population size will be determined by computer modeling using the algorithms of Ryman et al. (1981).

Job 5. Laboratory analysis of tissue samples.

Electrophoretic analysis of tissue samples will be conducted either at the University of Alaska-Fairbanks or a similar facility. Number of loci examined will be determined by the types of tissue samples obtained, but at a minimum the 20 loci examined by Hundertmark et al. (1992) will be scored.

Job 6. Report writing.

An annual progress report will be prepared each year with a due date of 1 August. A final report will be prepared at the conclusion of the study, due on 1 August 1998. Preparation and submission of articles to scientific journals will be accomplished prior to 1 August 1999.

E. SCHEDULE

Job No.	Description	FY 94	FY 95	FY 96	FY 97	FY 98
1	Collect tissue samples	0.2	0.2	0.2	0.2	0.2
2	Measure antlers	1.0	1.0	1.0	1.0	1.0
3	Captive breeding	10.0	13.0	16.0	19.0	22.0
	Raise moose calves					
	2 F&W Tech II @ 2 months ea.	11.0	0.0	0.0	0.0	0.0
4	Changes in composition	1.0	1.0	1.0	1.0	1.0
5	Laboratory analysis	6.0	6.0	6.0	6.0	6.0
6	Report writing	0.5	0.5	0.5	0.5	0.9
	Travel to meetings	1.5	1.5	1.5	1.5	1.5
	Computer hardware/software	3.0	0.6	0.6	0.6	0.6
	Total cost	34.2	23.8	26.8	29.8	33.2

F. GEOGRAPHIC LOCATION

Soldotna (Moose Research Center)

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Appendix B.

POPULATION AND GENETIC EFFECTS OF SELECTIVE HARVEST SYSTEMS IN MOOSE: A MODELING APPROACH.

Kris J. Hundertmark[1], Thomas H. Thelen[2], and Charles C. Schwartz[1]

[1]Alaska Dept. Fish and Game, Kenai Moose Research Center, 34828 Kalifornsky Beach Rd., Soldotna, AK 99669; [2]Central Washington University, Department of Biology, Ellensburg, WA 98926

ABSTRACT: We evaluated the changes in population structure and genetic composition of a simulated population of moose (*Alces alces*) subjected to a variety of harvest plans based upon antler morphology. Legal bulls in the different selective harvest plans were characterized by having at least one spike or forked antler (spike/fork), bulls having an antler spread of ≥36 inches (91 cm), or ≥ 50 inches (127 cm), and bulls with either a spike/fork antler or a spread of ≥ 50 inches. In these selective harvest plans, in which spreads of a certain size defined legal bulls, an alternative harvest criterion was the existence of at least one brow palm with three or more tines. A plan allowing harvest of bulls with either a spike or fork antler or a spread of ≥ 50 inches, but which ignored brow tines was also used, as was a plan allowing the harvest of any antlered bull. The model assumed that antler growth was controlled by a polygenic two-allele (favorable/ unfavorable) system and that brow palm formation was controlled by a two-allele monogenic locus and was independent of antler size. The plans were evaluated based upon their ability to maximize harvest, post-hunt bull:100 cow ratios, and frequency of favorable antler alleles. All harvest plans, with the exception of random hunting, yielded post-hunt bull:100 cow ratios of >20, but the plan with a 36-inch legal threshold was characterized by extremely low ratios of large (≥ 50-inch spread) bulls:100 cows. Random hunting produced the highest annual harvest, followed by the plan with the 36-inch threshold, the plans with the 50-inch threshold, and the spike/fork plan. Spike/fork hunting caused an increase in frequency of favorable antler alleles, but this was offset by hunting for animals above a legal spread threshold, particularly the 36-inch threshold. Those plans enabling harvest based on brow tines caused significant declines in favorable brow alleles. Frequency of alleles favoring antler growth was effected by hunting on a brow tine basis, and frequency of alleles favoring growth of brow tines was effected by hunting on a spread basis even though loci controlling these traits were not linked. Of the plans we simulated, the one under which legal bulls are defined as either spike/fork or ≥ 50 inches in spread best met the objectives with the exception that alleles favoring growth of brow tines were not maintained. We propose that a plan utilizing a spike/fork season followed by a limited-participation any bull season would be a suitable alternative to plans based upon antler spread and brow tines.

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In 1987, a harvest plan was implemented for moose hunting on the Kenai Peninsula, Alaska. This plan (designated hereafter as SF/50) defined legal bulls as those having a spike/fork (SF) antler or those with an antler spread of at least 50 inches (127 cm). To assist hunters in identification of large bulls in the field, hunters had the option of taking a bull with at least 3 brow tines on one brow palm in lieu of estimating the spread. Management objectives which caused implementation of SF/50 instead of an "any bull" season included providing greater numbers of bulls in the post-hunt population while maintaining reasonable harvest levels. A detailed description of this plan as well as the response of hunters and of moose population parameters to the first five years of this program were documented by Schwartz et al. (1992).

An additional objective of the SF/50 plan was to focus hunting pressure on yearling bulls with "inferior" antler structure (spikes and forks). Bulls that have antlers larger than forks as yearlings were not subject to hunting mortality until they achieved a spread of 50 inches or had at least 3 brow tines on one brow palm. This protection allowed animals with "superior" antlers to reach maturity and provided them an opportunity to breed. The degree to which this objective was met was not evaluated, nor was the effectiveness of harvest plans using different definitions of legal bulls in meeting these population and genetic objectives.

The impact of selective harvest on the genetic composition of a population is dependent in part on the degree to which the genotype contributes to the phenotype (heritability). The heritability of antler characteristics in moose is unknown. Arguments for either nutrition or genetics as the primary force behind antler growth are common (see Goss 1983). The limited data available indicate that the form of the antler and its potential size are genetically controlled. Harmel (1983) reported that of the offspring produced by a male white-tailed deer (*Odocoileus virginianus*) with superior antlers, only 5% exhibited spikes as yearlings, whereas 44% of the offspring of a male with inferior antlers had spikes. As all of the deer in this study were maintained on high-quality feed, it is apparent that the size of antlers is heritable to at least some extent, and Harmel et al. (1988) reported estimates of heritability of 0.5 and 0.75 for certain antler characteristics.

Thelen (1991) described changes in harvest levels and in frequencies of alleles controlling antler growth in simulated populations of elk (*Cervus elaphus*) subjected to different harvest plans. Harvesting elk based upon a minimum antler-point criterion always decreased the frequency of alleles favoring production of points, whereas harvesting only spike-antlered elk increased these frequencies. He noted that maximizing total harvest and trophy harvest was not consistent with maintaining the frequency of favorable antler alleles, and concluded that combining selection criteria offered the best compromise between genetic gains and harvest levels. We evaluated a number of harvest plans used for moose management in Alaska to determine their effect on harvest, genetic composition, and post-hunt bull:cow ratios.

METHODS

A stochastic population model similar to that developed by Thelen (1991) was used to simulate populations being subjected to different harvest plans. The model took populations through annual cycles of birth of calves, summer mortality of calves, harvest, breeding, and winter mortality of adults and calves. All adult mortality was assumed to occur in winter. Each animal in the population was characterized by age, sex, and antler genotype and phenotype.

The initial population was created using estimates of age structure from a population from the northern Kenai Peninsula, Alaska (Schwartz et al. 1992). Survival rates of females were based upon those reported for the northern Kenai Peninsula by Bangs et al. (1989) but were adjusted slightly to produce a stable population. Summer and winter survival rates of calves were 0.55 and 0.40, respectively. Annual survival rates of females older than calves were 0.88, 0.95, 0.90, 0.85, 0.80, 0.70, 0.60, 0.45, 0.25, and 0.0 for ages yearling, 2-5, 6-10, 11-12, 13-14, 15-16, 17, 18, 19, and 20, respectively. Male survival rates were based upon those of females but were reduced by an exponential decay function in which a bull's antler-size-dependent survival (ASDS) decreases as it ages and its antler size increases. In the function,

$$ASDS = 1 - [(SCORE - SOD)/60]^2,$$

SCORE is a numerical value (explained later) determined by a bull's genotype and the environment unique to that bull, and SOD is an age dependent value which reflects a score at which survival begins to drop. SOD values for calves and yearlings were 40, and for bulls aged 2-7 were 20, 16, 12, 8, 6 and 4, respectively. For bulls 8 years old or older the value of SOD was 2. We assumed that mortality would increase as a function of antler size because the energy required to produce and carry large antlers, as well as that required to achieve and maintain dominance during rut would place large-antlered animals in a greater energy deficit during winter compared with smaller antlered animals. With these assumptions, the initial ratios of all bulls and large bulls:100 cows were 80 and 34, respectively.

Based upon data from the Kenai Peninsula moose population (Alaska Dept. of Fish and Game, unpubl. data) we assigned a harvest rate equal to 50% of all legal bulls. We did not assume a relationship between the age of the bull and a learned ability to avoid hunters, unlike the model developed for elk by Thelen (1991).

Reproductive rates (calves/cow) were 0.0 for calves, 0.22 for yearlings, 1.27 for ages 2-15, 0.14 for ages 16-19, and 0.0 for age 20 (Schwartz and Hundertmark 1993). To produce these rates in the model we assumed that 12% of yearlings would produce single calves, 5% would produce twins, and 83% would produce no offspring. Respective values for other age classes were 63%, 32%, and 5% for ages 2-15, and 8%, 3%, and 89% for ages 16-19. The sex ratio of offspring at birth was 1:1 (Schwartz and Hundertmark 1993).

Antler growth was assumed to be an age-dependent polygenic trait. In the model, 5 pairs of genes and environmental influences were assumed to contribute to an antler growth score (SCORE). For each locus, there were two possible alleles: favorable and unfavorable, which contributed 4 and 0 points to the genotype score, respectively. Thus, the genotype score for antler growth varied from 0-40 (allele score x two alleles/locus x five loci). The model tracked the frequency of favorable antler alleles (Q_A) and favorable brow alleles (Q_B). Environmental scores were generated randomly from a distribution with the same mean and variance as the genotype scores and one was permanently assigned at birth to each male. A combination of an individual's genotype and environmental scores created its antler phenotype score which determined age-specific antler size. The degree to which the genotype and environmental scores contributed to the phenotype score was determined by the chosen level of heritability (the proportion of phenotype explained by genotype). We assumed a heritability of 0.5 (equal contribution of the two factors), but we also ran the simulation using heritability values of 0.25 and 0.75 to determine the effect of other heritabilities on our results.

Slower rates of antler growth in yearlings were manifested in spike/fork antlers. Antlers of this size were assumed to be present only in yearlings, and accounted for 60% of antlers in this age class (Schwartz et al. 1992). Other yearlings and bulls older than yearlings have palmated antlers that were characterized by a spread measurement. Age-dependent antler spreads (Table 1) were assigned to the initial population based upon data from hunter check stations on the Kenai Peninsula. Maximum spreads occurred in animals 8-12 years old (Gasaway et al. 1987). The number of brow points is assumed to be under monogenic control, but is also influenced by an animal's age and unpredictable environmental factors. In our initial population, 27% of bulls 2 years or older had 3 or more brow points on at least one brow palm. Of the 2-year-olds, 16% of those homozygous for the favorable allele, and 2% of the heterozygotes, had 3 brow points on one side (the limit of 3 is a simplification having no outcome on the results). Among deer 3 and older, 60% of homozygous favorable and 24% of heterozygotes had 3 brow tines. All homozygous unfavorable bulls had a maximum of 2 brow tines on one side.

For our analysis we evaluated 7 different harvest plans. One plan assumed no harvest, another the harvest of any antlered bull (any-bull plan), and the other 5 were selective harvests based on antler type. These last 5 include: a spike/fork plan (SF), in which only bulls with a spike or forked antler were legal; SF/50; a 36-inch plan, in which any bull with an antler spread of ≥ 36 inches or with at least 3 tines on one brow palm was legal; a 50-inch plan, in which any bull with an antler spread ≥ 50 inches or with at least 3 tines on one brow palm was legal; another 50-inch plan (SF/50/NB) that is identical to SF/50 except that the brow tine criterion was eliminated. All of these systems, with the exception of SF and SF/50/NB, are or were used for moose management in Alaska.

As our model was stochastic, we ran ten simulations of each plan, from which we generated means and variances of estimates of population and genetic composition. Each simulation lasted 50 years. Estimates of population composition and allele frequencies were generated from the initial population (year 0) and from year 50. Harvest data represent means from years 20-50 of the simulations.

RESULTS AND DISCUSSION

Population Composition

Changes in sex and age composition of the population were apparent among the seven plans after 50 years of simulation (Table 2). The number of bulls older than calves present in the that year's pre-hunt population was highest with no harvest and lowest under the plan allowing the harvest of any bull. Among the plans providing selective harvest, the 36-inch and SF/50 plans yielded the least number of bulls prior to the hunt and the SF plan provided the most large bulls. Despite having among the lowest number of bulls and the lowest number of large bulls, the 36-inch plan resulted in the highest total harvest among plans allowing for harvest, while the SF plan was characterized by the lowest total harvest.

Numbers of medium-sized bulls (> spike/fork but with spreads <50 inches) and large bulls (spread ≥ 50 inches) in the final pre-hunt populations varied greatly (Table 2). The number of medium bulls was highest under the 50-inch plan no harvest plans and lowest under the any bull and random and SF plans. However, all selective harvest plans tended to conserve more medium bulls than the any bull plan, and the 50-inch plan maintained more bulls in this category than when no harvesting occurred. Large bulls were most abundant under the no harvest and SF plans, and were least abundant under the any-bull and 36-inch plans.

The bull:100 cow ratio (Table 2) of the no harvest option was similar to that of the initial population. This plan also was characterized by the greatest ratio of large bulls:100 cows. Of the selective harvest plans, the spike/fork plan yielded the highest bull:100 cow ratios while the 36-inch plan had the lowest. The large bull:100 cow ratios were extremely high under the no harvest and SF plans, were intermediate under SF/50, 50-inch, and SF/50/NB plans, and were very low under the any-bull and 36-inch plans.

Genetic Parameters

All of the plans had a change in Q_A, the frequency of alleles favorable for spread (Table 3). The slight but significant difference in frequency for the no harvest plan (1.1% decline over 50 years) may have resulted from genetic drift. The two plans causing the greatest declines were the 36-inch and 50-inch plans (-27.8 and -16.1%, respectively), while the any-bull and SF plans caused the greatest increases (10.7 and 13.2%, respectively).

When any bull can be harvested legally, the proportion of older bulls in the population decreases. Consequently, a greater incidence of mating by young bulls occurs, in particular those bulls with larger antler mass, relative to an unhunted population. As young bulls have smaller antlers than older bulls they do not exhibit much of a decrease in survival related to large antler size. The reduction in survival is higher for older bulls, particularly those with the largest antlers. Moreover, this decrease in survival is cumulative over time. Therefore, Q_A tends to be higher among young bulls. Harvesting only spike/fork bulls does not change the population composition greatly but does increase Q_A due to elimination of small-antlered yearling bulls and retention of the large-antlered yearlings. The greater occurrence of these genetically-superior large-antlered bulls tends to increase the proportion of favorable alleles in the breeding population.

Changes in Q_B, the frequency of the favorable brow allele, were related directly to the presence or absence of a 3-brow-tine criterion in the harvest plan. Those plans with this criterion (SF/50, 36-inch, and 50-inch plans) were characterized by 41.4, 22.4, and 50.0% declines over 50 years, respectively. Differences among these declines were significant (Table 3).

It is apparent from these simulation results that different antler-spread criteria had different effects on Q_B. The 50-inch plan caused the greatest declines in Q_B, followed by the SF/50 and 36-inch plans. It is apparent that focusing harvest on animals with greater spreads causes greater declines in these alleles, and that the spike/fork criterion has an ameliorating effect. Conversely, comparison of the SF/50 and SF/50/NB plans (Table 3) indicates that inclusion of the brow tine option in a plan results in less of a decline in Q_A.

The inclusion of the brow-tine option lessens the decline in Q_A for 2 reasons. First, harvesting animals based on the presence of 3 brow tines tends to increase Q_A in general because harvest is focused on older animals, resulting in an age effect similar to that discussed earlier for the any-bull plan. Second, animals with inferior antler spreads are more likely to be harvested based on brow tines than are their superior-antlered counterparts. By the time an animal reaches the minimum legal spread, the hunter tends to select him on that basis; therefore, there is no direct selection against favorable brow alleles after this point. Bulls with relatively low potential for antler growth would spend more years in the medium class than would bulls with greater growth potential, and therefore would have a higher probability of being harvested based on the presence of legal brow tines. The SF/50/NB plan shows more of a decrease in Q_A compared with the SF/50 plan because the brow tine option gives hunters more seasons to take a particular inferior bull with 3 brow tines as compared to a superior bull, as the superior bull reaches the legal spread at an earlier age. Thus, by including the brow tine option, we are increasing selection for favorable antler alleles. By this same principle, the SF/50 plan results in less of a decrease in Q_B compared to the 50-inch plan. The addition of the SF option to a plan increases Q_A (Table 3), which causes bulls to reach the legal spread at an earlier age than without this option. Thus, fewer animals would be harvested based upon hunter selection for brow tines, which in turn would cause less of a decline in brow alleles.

Obviously, hunter behavior influences the degree to which this interaction is expressed. Bulls with spreads slightly greater than the minimum threshold often are harvested based upon the presence of three brow tines. To account for this we altered the 50-inch plan by reducing the hunting mortality fifty percent for bulls with less than 3 brow tines that had spreads from 50-55 inches (127-140 cm). This had the effect of increasing Q_A from 0.4160 to 0.4251, decreasing Q_B from 0.2502 to 0.2409, and decreasing harvest from 293 to 266.

The degree to which each selective harvest plan meets the three objectives can be evaluated with a three-dimensional plot (Fig. 1). The plans that best meet all three objectives were those having a minimum legal spread of 50 inches (the SF/50, 50-inch, and SF/50/NB plans). These plans vary little in terms of bull:cow ratios and therefore can be evaluated on harvest potential and Q_A. In this respect, the SF/50 plan is superior. The disadvantage of this plan is that it significantly reduces Q_B, which could be corrected by eliminating the brow tine option from the plan or by raising the legal threshold from three to four tines. The choice between these options depends upon the predominant antler growth form in the area being managed. Eliminating this option on the Kenai Peninsula undoubtedly would cause hunter dissatisfaction because many hunters rely on brow tines to identify legal bulls. Also, in this population very few bulls develop four or more tines.

Analysis of the influence of heritability indicates that higher values tended to cause more rapid genetic changes and associated population changes (Table 4). For instance, those plans that increased Q_A (any bull, SF, and SF/50) under a heritability of 0.5 were characterized by lesser spike/fork and equal or greater harvest of medium and large bulls when using a heritability of 0.75. Despite these differences, the relative differences between the harvest systems were the same regardless of heritability.

MANAGEMENT IMPLICATIONS

The post-hunting bull:100 cow ratio is a parameter of great interest to moose managers because of its potential ramifications on reproduction. In Alaska, the generally accepted minimum ratio is 20 bulls:100 cows. All of the plans, with the exception of random harvest, easily achieved this benchmark. However, the ratio of large bulls:100 cows varied considerably. The 36-inch plan had approximately three times as many bulls:100 cows than did the any-bull plan, yet these two plans had similar, and low, ratios of large bulls:100 cows. Similarly, the SF/50 plan showed an eightfold difference in large bulls when compared to the 36-inch plan despite a similar bull:100 cow ratio. In our simulations, the SF plan was the only scenario that resulted in a population of large bulls similar to that of the no harvest plan, but SF resulted in no trophy harvest. Of the other plans, those specifying a legal spread of ≥ 50 inches (SF/50, 50 inch, and SF/50/NB) yielded what we believe to be adequate post-hunt numbers of large bulls and provided for the highest trophy harvest. Any-bull and 36-inch plans were characterized by low trophy harvests as well as low numbers of large bulls for viewing. Under these two plans the paucity of large bulls prior to the hunting season, combined with a greater harvest would result in many instances of yearling bulls acquiring mates. Such a circumstance could lead to second and third estrus breeding (Rausch 1965, Rausch et al. 1974) which could lead to lower over-winter survival of calves. Aside from reproduction concerns, the presence of large bulls in the population can be an important management consideration in areas where interest in wildlife viewing and/or trophy hunting is high.

Populations characterized by low hunter participation or low harvest rates will respond differently than we described. In his analysis of the effects of selective harvest on elk, Thelen (1991) determined that changes in allele frequencies were related directly to magnitude of harvest rates. Thus, under lower harvest rates the genetic changes we described would be less pronounced, and higher harvests would produce the opposite effect.

Until heritability of moose antler characteristics is determined, the selection of an appropriate harvest plan should be based upon its relative performance in terms of management objectives, rather than absolute numbers. It was apparent that a spike/fork criterion favored greater antler development in the population whereas minimum spread criteria inhibited this. Combinations of these two selection criteria were intermediate in their effects. Defining legal animals by a brow tine criterion was universally deleterious to superior brow formation, and management strategies that include such a harvest criterion should be evaluated to determine if such a change is acceptable.

Schwartz et al. (1992) proposed an alternative to SF/50, which consists of a general SF season with unlimited hunter participation followed by an any-bull hunt based upon a limited number of permits. The number of permits issued would be dependent upon the number of bulls that could be taken and still maintain an acceptable bull:100 cow ratio. Although we did not evaluate such a plan, from the information presented herein we can conclude that it would be desirable from a management standpoint. The disadvantage of the SF plan was the limited harvest it afforded, whereas the disadvantage of a random plan was the low bull:100 cow ratio. Both plans were very desirable from a genetics standpoint. By combining these two plans, the disadvantages of both could be minimized without severely limiting their advantages. Also, this combination would eliminate any need to select animals based upon brow tines.

Fulfillment of harvest demand, reproduction, and viewing are all important considerations dependent upon the number of bulls in a population. Balancing these conflicting objectives in populations subjected to high hunting mortality can best be accomplished via selective harvests. Managers must be aware, however, of the genetic ramifications of the selection criteria upon which their systems are based. The appropriate harvest plan can be selected only after population objectives are quantified and the genetic consequences are evaluated.

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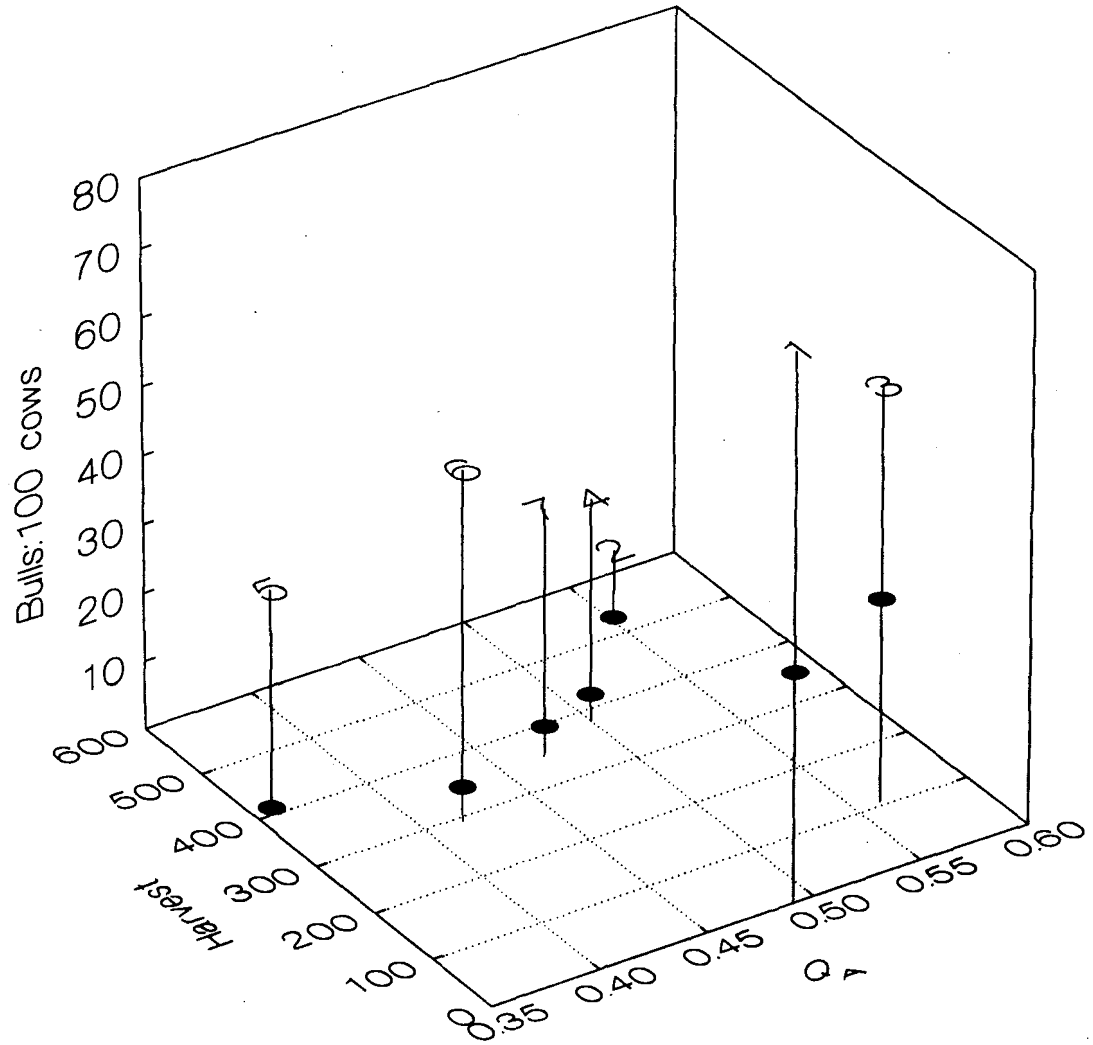

Figure 1. Comparison of mean annual harvest in years 30-50 of the simulations, post-hunt ratios of bulls:100 cows, and the frequency of favorable antler alleles (Q_A) in year 50 for each of seven selective harvest plans (1 = no harvest, 2 = any bull, 3 = SF, 4 = SF/50, 5 = 36 inch, 6 = 50 inch, and 7 = SF/50/NB). Total elevation of spikes indicates the estimate of all bulls:100 cows, and the filled circles indicate the estimate of large bulls:100 cows for each plan. Ten simulations were conducted for each plan.

Table 1. Percentage of bulls in four age classes characterized by antler size in the initial population.

Age	Spike/ fork	<36 inches	≥36 and <50 inches	≥50 inches
1	60	25	15	
2-3		25	60	15
4-5			60	40
≥6			5	95

Table 2. Mean (SD) numbers of bull moose in three size/age classes prior to harvest in the final year of the simulations (year 50), mean (SD) annual harvest during years 20-50, and post-hunt bull:100 cow ratios in the final year.

Harvest system	Number in final population prior to harvest			Annual harvest (years 20-50)			Bull:100 cow ratios after final harvest	
	Yearling	Medium[a]	Large[b]	Spike/fork	Medium[c]	Large	All bulls: 100 cows	Large bulls: 100 cows
No harvest	462 (30.2)	1494 (50.1)	1418 (42.9)	0 (0)	0 (0)	0 (0)	79.4	33.4
Any bull	603 (24.9)	420 (18.2)	61 (9.3)	124 (2.9)	368 (8.1)	31 (4.4)	10.5	0.6
SF	504 (30.0)	1000 (24.8)	1354 (31.3)	106 (2.6)	0 (0)	0 (0)	60.4	29.7
SF/50	539 (30.4)	1051 (35.3)	388 (14.3)	134 (4.9)	60 (2.0)	185 (2.7)	32.6	4.1
36 inch	557 (22.8)	1381 (48.6)	55 (7.8)	0 (0)	375 (6.7)	31 (1.0)	32.4	0.5
50 inch	520 (27.0)	1694 (52.0)	438 (20.5)	0 (0)	85 (3.3)	208 (6.7)	51.0	5.0
SF/50/NB	529 (23.5)	1118 (27.3)	420 (24.3)	140 (3.4)	0 (0)	210 (2.8)	36.1	4.4

[a] Bulls older than yearlings that had antler spreads <127 cm.

[b] Bulls older than yearlings that had antler spreads ≥127 cm.

[c] Includes yearlings with palmated antlers.

Table 3. Mean (SD) frequencies of alleles favoring growth of antlers (Q_A) and brow tines (Q_B) in the initial (year 0) and final (year 50) populations. Q_B was 0.5000 in the initial population. Ten simulations were run for each harvest plan.

Harvest system	Initial Q_A	Final Q_A	Final Q_B
No harvest	0.4958^{a}(0.0022)	0.4904^{Aa}(0.0033)	0.5065^{Ba}(0.0113)
Any bull	0.4967^{a}(0.0017)	0.5500^{Ab}(0.0053)	0.5002^{Ba}(0.0104)
SF	0.4953^{a}(0.0008)	0.5611^{Ac}(0.0039)	0.4946^{Ba}(0.0128)
SF/50	0.4959^{a}(0.0020)	0.4995^{Bd}(0.0074)	0.2932^{Ab}(0.0156)
36 inch	0.4955^{a}(0.0012)	0.3576^{Ae}(0.0056)	0.3878^{Ac}(0.0160)
50 inch	0.4959^{a}(0.0013)	0.4160^{Af}(0.0078)	0.2502^{Ad}(0.0076)
SF/50/NB	0.4963^{a}(0.0017)	0.4697^{Ag}(0.0024)	0.5100^{Ba}(0.0169)

^{A} Mean final frequency of alleles differs ($\underline{P}$ > 0.01, paired $\underline{t}$-test) from initial frequencies.
^{B} Mean final frequency of favorable alleles does not differ ($\underline{P}$ > 0.01, paired $\underline{t}$-test) from initial frequencies.
^{a,b,c,d,e,f,g} Means within the same column having the same superscript are not significantly different ($\underline{P}$ > 0.01, ANOVA and Tukey pairwise comparisons).

Table 4. Mean final allele frequencies (Q_A and Q_B) and harvest levels for model runs using heritabilities of 0.25 and 0.75.

Selective Harvest System	Heritability = 0.25					Heritability = 0.75				
			Harvest					Harvest		
	Q_A	Q_B	Spike/fork	Medium	Large	Q_A	Q_B	Spike/fork	Medium	Large
No harvest	0.4981	0.5020	0	0	0	0.4934	0.5057	0	0	0
Any bull	0.5239	0.5203	141	358	23	0.5721	0.4901	105	384	31
SF	0.5290	0.5011	119	0	0	0.5771	0.5063	90	0	0
SF/50	0.5079	0.2907	131	61	179	0.5218	0.2871	123	61	186
36 inch	0.4456	0.4306	0	387	36	0.3476	0.3874	0	375	25
50 inch	0.4674	0.2685	0	84	214	0.4098	0.2518	0	91	194
SF/50/NB	0.4953	0.4976	133	0	215	0.4887	0.4999	137	0	210

Appendix C.

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Charles C. Schwartz
Alaska Department of Fish & Game
Moose Research Center
34828 Kalifornsky Beach Road, Suite B
Soldotna, Alaska 99669

SUPPLEMENTAL FEEDING OF MOOSE DURING WINTER: CAN HAY SERVE AS AN EMERGENCY RATION?

Charles C. Schwartz[1], Kris J. Hundertmark[1].
[1]Alaska Department of Fish & Game, Moose Research Center, 34828 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669.

ABSTRACT: When severe winters result in starvation of moose (*Alces alces*) in the proximity of human development, people often demand emergency feeding programs. In spite of the controversy surrounding such programs, political decisions may dictate that resource agencies feed starving moose. Consequently, we tested the feasibility of using locally grown grass hay as an emergency ration. In two concurrent experiments (trial 1), 16 captive moose were maintained on either hay or a pelleted ration. In a separate experiment (trial 2), 8 moose calves were fed grass hay for the duration of winter and their health and mass dynamics recorded. Over the 11 weeks of trial 1, adults eating the hay lost an average of 53.0 kg, whereas those consuming the pellets gained 36.3 kg. Calves eating hay gained 5.0 kg, whereas those eating pellets gained 29.5 kg. Calf moose in trial 2 showed no adverse physiological effects from the diet and maintained body mass throughout the winter. Mean urinary urea:creatine rations (U:Cr) differed ($\underline{P}$ = 0.004) between moose fed hay and pellets, but not among periods in trial 1. These results indicate a difference in intake of nitrogen, but consistency among nitrogen balance over time. Phosphorus:Cr (P:Cr) ratios were not different between treatments ($\underline{P}$ = 0.42) but differed among periods ($\underline{P}$ = 0.06), corresponding to a decline in dry matter intake which is typical for moose during winter. Cortisol:Cr (C:Cr) ratios did not differ between treatments ($\underline{P}$ = 0.82) or among periods ($\underline{P}$ = 0.19), indicating that the level of physiological stress experienced by the moose did not change. We conclude that although the pellets served as a more complete ration for emergency feeding, locally grown grass hay can serve as an emergency food for moose in reasonably good physical condition. We also tested seven new flavors to improve the palatability of our formulated ration. Moose consumed significantly more feed flavored with milkey whay when compared to the standard ration and the other 6 flavors tested. Recommendations concerning emergency feeding are discussed.

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As human settlements expand into the northern environments, people come in contact with moose. Community developments generally occur along water courses, in valleys, or other areas that traditionally represent moose winter range. As these settlements develop, the boreal forest is cleared for roads, subdivisions, and other human habitation. When land is cleared but not permanently altered (i.e., paved), seral vegetation rapidly recolonizes many sites. Road rights-of-way, power line easements, driveways, and house lots, represent some of these areas of disturbance. These revegetated areas are a sources of high quality food that attract moose and keep them in close proximity to humans (Child et al. 1991, Del Frate and Spraker 1991, McDonald 1991).

Severe winters tend to concentrate moose on their winter range. When severe winters occur and moose starve in town and other settled areas, the public witnesses first hand the physical plight of dying animals. They often demand emergency winter feeding. Although there is controversy about the biological impacts of winter feeding and its usefulness in population management, politically motivated programs often dictate that resource agencies "feed moose".

During the winter of 1989-90 in south central Alaska, extreme snowfall precipitated high moose mortality associated with railroad (Modafferi 1991) and automobile collisions (Del Frate and Spraker 1991), and starvation of calves and adults. This high death rate of moose resulted in a politically motivated program to feed moose.

The winter of 1989-90 not only generated controversy about the wisdom of an emergency feeding program, but there was also disagreement about what to feed. There is virtually no information available in the literature concerning winter feeding programs for moose. Supplementally feeding hay to mule deer (*Odocoileus hemionus*) has failed to prevent starvation (Carhart 1943, Doman and Rasmussen 1944), and can result in acute digestive problems (Schoonveld et al. 1974). At the other extreme, feeding high energy concentrates to ruminants adapted to a poor roughage diet can cause ruminal acidosis and death (Wilson et al. 1975, Wobeser and Runge 1975). Consequently, a special ration has been formulated specifically to feed starving deer during winter (Baker and Hobbs 1985).

Anecdotal information suggested that moose eat hay during winter (Denniston 1956), and they are capable of digesting it (Hjeljord et al. 1982, Renecker et al. 1983, Renecker and Hudson 1990). We know that moose are seasonally adaptive concentrate selectors (Kay et al. 1980, Hofmann 1985, 1989). Moose choose foods that are of relatively high nutrient value, readily fermentable, and passed through the system rapidly (Schwartz 1992). Moose accomplish this by eating mainly woody browse. Food passes rapidly through the digestive system because highly lignified browse when masticated (Renecker and Hudson 1990), shatters into large cuboidal particles (Mertens 1973, Milchunas et al. 1978). These particles pass rapidly from the rumen (Renecker and Hudson 1990).

Renecker et al. (1983) and Renecker and Hudson (1990) compared the efficiencies of cattle (a grazer), wapiti (*Cervus elaphus*) (a mixed feeder), and moose (a concentrate selector) to digest browse, grass hay, and alfalfa. They concluded that moose were most sensitive to diet, propelling browse more rapidly than cattle, but retaining grass hay and lucerne longer than either wapiti or cattle.

For a ruminant to maximize energy utilization, it must balance the time food is retained in the rumen for digestion with the time it takes to pass material through the system. Retention of food in the rumen allows for more complete digestion, whereas rapid passage allows for more food to be processed. Evolutionarily, the moose employs a strategy of retaining forage just long enough to digest the soluble components and then passes the fibrous material through the system rapidly. This strategy contrasts to that of a roughage eater (cattle) which consumes a poor quality diet and retains the food in the rumen for a long period of time to ensure adequate digestion of the fiber. Hence cattle are efficient at processing hay, whereas moose are efficient at processing browse. The ability of cattle to process browse or moose to process hay is compromised by the chemical nature of the foods and the differences in physiological adaptions of the digestive system.

Moose in captivity which were fed hay for several years developed chronic digestive upset and eventually died (Schwartz et al. 1980, Schwartz 1992). This fact let to the development of a formulated ration which contained wood fiber and is currently used to successfully keep moose in captivity (Schwartz et al. 1985).

During the severe winter of 1989-90 there was a public outcry to supplementally feed starving moose on the Kenai Peninsula and in the Matanuska-Susitna Valley. The typical feed offered to moose by the public was locally grown grass hay, which we believed to be nutritionally inadequate for moose in poor condition. Responsible members of the public, following our recommendations, attempted to feed our commercially available moose ration. Some people reported success, but many indicated that starving moose refused to eat the diet even though it was a nutritionally complete (Schwartz et al. 1985). Similarly, anecdotal accounts from the public and ADF&G staff suggested that some moose readily ate hay and outwardly exhibited signs of nutritional recovery, while others refused it.

Although it was documented that starving moose ate hay, there was no data available concerning it's successful use as an emergency ration. Could moose digest hay efficiently enough to survive the winter? Did hay contain adequate nutrients to meet minimum maintenance requirements? Would moose consuming hay for an extended period develop chronic digestive upset and die like moose living in zoos? Finally, was the formulated ration feasible and useful as an emergency food, and was it better than hay?

METHODS

We conducted our studies over 2 winters. We studied captive moose at the Moose Research Center (MRC), located on the Kenai Peninsula in southcentral Alaska. Moose were obtained from wild stock on the Kenai Peninsula, interior Alaska (Fairbanks area), or Matanuska Valley north of Anchorage. All were of the subspecies *A. a. gigas*. Most animals were hand-reared and trained to accept handling (Regelin et al. 1979). Others were raised by tame cows and were habituated to confinement, and trained to accept handling for mass determination and human presence.

Trial 1.

During the first winter, sixteen moose were assigned to one of 2 treatments and fed either a pelleted ration (Schwartz et al. 1985) or locally grown mixture of brome grass (*Bromus inermis*) and timothy (*Phleum pratense*) hay during winter. All adult cows were pregnant. Animals were fed the pellets from a self-feeder, whereas hay was placed on the ground. Each treatment group was fed *ad libitum*. To simulate an emergency feeding program, free water was not offered; animals obtained their moisture by eating snow.

We conducted trials to determine intake, weight change, and physiological status as measured by snow-urine analysis for treatment (hay) and control (MRC ration) groups. Each group consisted of 8 moose: 4 adult and 4 female calves in the control group, and 4 adult female and 4 male calves in the hay group. The trials began on 17 January and continued through 6 April, 1992 (11 weeks). Control moose were housed in a 4 ha enclosure and offered feed *ad libitum* in a bulk feeder. Treatment moose were housed in a 3 ha enclosure and locally-grown grass hay was offered *ad libitum* by spreading it on the ground in several locations in the enclosure.

We monitored mass dynamics by weighing each animal once a week throughout the trial. Animals were trained to walk onto a cattle scale that was accurate to 1 kg (Schwartz et al. 1987). Differences in gain or loss of body mass over the duration of the trial were determined with a t-test. Calves and adults were analyzed separately.

We measured dry matter intake during week 5 and 10. Animals were housed in individual holding pens and offered *ad libitum* quantities of either hay or pellets for a 7 day period. Intake during these periods was expressed on a dry matter basis, with feed samples dried at 60 C for 48h. Moose fed hay often dropped some on the ground. Consequently we estimated the loss of hay offered by simulating a 24 hour feeding. We placed a known quantity of hay in the feeder, and removed it in a fashion to simulate a feeding moose. Uneaten hay was cleaned from both the feed bunk and the ground, following the protocol used during the regular experiment. The amount of mass not accounted for as eaten and orts, was considered experimental error. We replicated this experiment 3 times. Differences in intake between treatments, time periods, and age class were tested using ANOVA.

Urine was collected approximately biweekly by either maneuvering a container attached to a pole into the urine stream during urination (most samples) or collecting freshly deposited urine in snow. Samples collected during 3 arbitrarily-defined periods: 1 (Weeks 1-2), 2 (Weeks 4-7) and 3 (Week 11) were submitted for analysis for U, P, C, and Cr. Nutritional status of moose was evaluated by expressing U and P as ratios to Cr (DelGiudice et al. 1989). Cortisol:Cr ratios were used to assess physiological stress levels which can be elevated during nutritional deprivation (Saltz and White 1991). Ratios were $\log_e$-transformed before being subjected to ANOVA with period (1-3) and trial (hay vs. MRC) as categorical variables.

Trial 2.

During the second winter, seven moose calves (4 males and 3 females) were fed a locally grown mixture of brome grass and timothy hay *ad libitum*. Animals obtained their moisture by eating snow. The trials began on 25 December and continued through

5 May, 1993 (19 weeks). We weighed calves weekly to track mass dynamics and monitored average daily consumption of hay throughout the winter. We conducted 2 trials to determine intake. Moose were housed in a bare 30 X 30 m enclosure.

We monitored daily consumption of the group by keeping track of the mass of hay offered daily and estimating the amount of remaining at the end of each 24 hour day. This data was used to monitor consumption rates and evaluate wastage.

We measured dry matter intake during week 10 and at the end of the trial in week 19. Hay consumption was measured by providing *ad libitum* amounts of hay to all 7 animals together in the holding pen. After 24 hours, the uneaten hay was collected and weighed. Average daily consumption was calculated for all animals.

Rump fat was measured in 5 calves using the ultrasound technique described by Stephenson et al. (1993).

Evaluation of Flavor Additives.

In the summer of 1991, 8 adult female moose were used in a trial to determine preferences for the MRC ration containing 8 different flavorings. Each animal was offered all 8 feeds *ad libitum* for a 24-hour period, with the different feeds being placed in separate compartments in a feed bunk. Assignment of animals to pens and feeds to compartments was randomized with a Latin Squares design. Each animal was offered 9 kg (fresh weight) of each flavored feed, and in certain cases some animals were supplemented with 5 additional kg of certain flavors to assure that they had an *ad libitum* supply. Refused food was collected and weighed. Difference between fresh weights of feed offered and feed refused was considered feed consumed. Rank transformations of amount consumed (response variable) were subjected to ANOVA for Latin Squares (Conover and Iman 1981, Hora and Conover 1984, Akritas 1990) with animals and feed placement being blocking variables.

Feed flavors tested included: apple, anise-molasses, horse, milkey whay, mineral (Crest Flavor Co., Kansas City, Mo.), carmel (Far-Mor Inter., Dolton, Ill), dairy krave (Feed Flavors, Inc., Wheeling, Ill.) and our standard ration flavored with anise (Don Chemical, Anchorage, Ak.).

RESULTS

Chemical composition indicated that the MRC ration contained more protein and less fiber but was equally digestible when compared to the hay samples. The hay contained more moisture and less ash than the pellets.

Trial 1.

Moose in the hay treatment took over 10 days to eat hay. This was probably due to two things, (1) similar to wild moose, our animals did not recognize the hay as a food source, and/or (2) our moose were more accustomed to eating the MRC ration and found hay unpalatable. However, once they become hungry enough, they accepted the hay and ate it readily. Two cows, one in each treatment, were removed from the study after they aborted their fetuses.

Our simulation results indicated that 1.1-2.5 percent of the hay offered during intake trials was lost on the ground. Consequently, our estimates of hay intake were slightly inflated. Analysis of variance of intake data revealed a non-significant month effect ($\underline{P} = 0.864$), so we pooled measurement of intake over the two periods. Regardless of treatment, calves (69.8 g/kg $BW^{0.75}$/d) consumed significantly ($\underline{P} = 0.002$) more dry matter than adults (53.6 g/kg $BW^{0.75}$/d)(Table 2). Similarly, regardless of age, moose eating MRC ration consumed (73.7 g/kg $BW^{0.75}$/d) significantly more ($\underline{P} < 0.0001$) dry matter than moose eating hay (51.9 g/kg $BW^{0.75}$/d). There was also a significant treatment by age interaction ($\underline{P} = 0.03$) because adult cows in the hay treatment consumed about half the dry matter of moose eating pellets, whereas calves in both treatments ate similar amounts.

Changes in body mass reflected differences in dry matter intake (Fig. 1.). Cows consuming the pelleted ration gained an average of 36.3 kilograms (SD = 5.9) during the 11 weeks of study, whereas cows consuming hay lost an average of 53 kg (SD = 7.5)($\underline{t} = 16.2$, $\underline{P} = 0.001$, df = 3.8). The 4 calves eating hay maintained body mass during the trial ($\bar{x} = 5$ kg, SD = 2.4), whereas calves feeding on MRC ration gained mass ($\bar{x} = 29.5$ kg, SD = 14.9) ($\underline{t} = 3.2$, $\underline{P} = 0.04$, df = 3.2).

Mean U:Cr ratios differed ($\underline{F}_{1,37} = 9.71$; $\underline{P} = 0.004$) between moose feeding on hay ($\bar{x} = 2.96$, SE = 0.50) and on MRC ration ($\bar{x} = 5.48$, SE = 0.46) but not among periods ($\underline{F}_{2,37} = 0.033$; $\underline{P} = 0.90$), suggesting that nitrogen intake, but not nitrogen balance differed between hay and pellet fed moose. One observation was deleted from analysis due to anomalous ratios (Fig. 2).

Phosphorus:Cr ratios did not differ between trials ($\underline{F}_{1,37} = 0.65$; $\underline{P} = 0.42$) but differed among periods ($\underline{F}_{2,37} = 3.08$; $\underline{P} = 0.06$), declining over time (Fig. 3). This decline reflected the decrease in intake observed (DelGiudice et al. 1989). Moose feeding on hay were sampled (Period 1) within 1 week of being weaned from MRC ration, which would account for the similar P:Cr ratios between the trials for Period 1. As moose continued to feed on hay their P:Cr ratios declined and remained noticeably lower than those of moose fed the formulated ration for the remainder of the study.

Cortisol:Cr ratios did not differ between moose in the 2 trials ($\underline{F}_{1,37} = 0.05$; $\underline{P} = 0.82$) or among periods ($\underline{F}_{2,37} = 1.73$; $\underline{P} = 0.19$), and mean C:Cr ratios were similar to those observed in unstressed mule deer (*Odocoileus hemionus hemionus*) (Saltz and White 1991).

Trial 2.

The calf moose consuming only grass hay from late-December through April were able to maintain their body mass throughout the winter (Fig. 5). All animals appeared healthy at the end of the experiment although ultrasound measurements indicated no measurable rump fat. Average daily consumption of hay ranged from 5.3-4.5 kg/day per calf. This equates to 100-83 g/kg $BW^{0.75}$/day. (NOTE: THESE ARE WET WEIGHTS, DRY MATTER DETERMINATIONS ARE YET TO BE COMPLETE. THESE VALUES WILL DECREASE BY ABOUT 20%).

Evaluation of Flavor Additives.

Amounts of feed consumed differed among the 8 types of flavored feed offered ($F = 2.57$; $P = 0.027$), but was not affected by animal ($F = 0.97$, $P = 0.47$) or location ($F = 0.95$, $P = 0.48$). The mean rank for milkey whay differed from those of flavors 2-6 (Table 4). Flavor 8 (control) was not included in the multiple comparison because we wanted to evaluate new flavors only. However, it is interesting to note that flavor 8 ranked 2nd in amount consumed, indicating that only 1 flavor tested met or exceeded taste preference for the standard MRC ration.

DISCUSSION

Based on changes in weight and urine chemistries we concluded that moose feeding on hay were in poorer condition after 11 weeks than moose feeding on MRC ration, but were still relatively healthy. Although differences in weight dynamics between the 2 groups were obvious, the magnitudes of the differences were less than expected. The 3 adults feeding on hay (not including the cow that aborted) lost between 8-10% of their body mass over the course of the trial. This lack of a significant decrease in condition can be attributed to the excellent condition of all animals entering the trials. In this respect, we believe that our experiment did not reflect conditions which wild moose would experience in a severe winter prior to being supplementally fed. Consequently we conduced trial 2 where we fed calves for the entire winter. Based upon this hay feeding trial, we must conclude that hay can serve as an emergency ration.

There is one important part of our studies that differs from what normally occurs in the wild. Moose in both of our trials were in good body condition at the start of the feeding experiment. Moose in the wild are usually close to death before emergency feeding programs commence.

During the severe winter of 1989-90 on the Kenai Peninsula calves were in negative energy balance in late autumn, and winter-related mortality was widespread by January 1990. Attempts to feed moose during this time often failed either because wild moose refused to eat emergency rations or because their physical condition had already deteriorated beyond the point of recovery.

Cows, particularly those with nursing calves, rely on autumn and early winter ranges to accrue fat for the winter, gaining weight through December (Schwartz et al. 1987). Early, deep snows would inhibit this critical fat deposition, thus accelerating nutritional decline. Consequently, when deep snows precluded movements of wintering moose, some starved.

Artificial rations fed to moose must contain adequate digestible energy to meet maintenance requirements, particularly for animals with depleted fat reserves. Both rations we tested seem to meet this criteria. In addition, emergency rations must be palatable to wild moose. Neither hay nor pellets meets this requirement in all cases, although moose tend to eat hay more readily.

An emergency ration must be easy to handle and feed. The pellets came in 50 pound bags and were easily fed from a self feeder. There was little waste. Hay was also easily handled and additionally could be thrown from an aircraft. However, hay placed on the ground was often wasted. During trail 1, we estimated that in excess of 50% of all hay fed remained uneaten. Animals often bedded, defecated, or urinated on the hay. During trial 2, we eliminated much of this problem by placing the hay in a oval shaped water trough. Wastage was reduced to less than 25%. However by feeding from a trough, deployment of hay from the air becomes more complicated.

An important consideration of any emergency feeding program is the economics. Although we do not have actual measures of the costs associated with the 1989-90 winter, we can make projections based on the known intakes of our animals (Table 4). It cost about $4.75 and $4.02 per day to feed a cow and calf moose hay, whereas feeding pellets cost $3.77 and $3.20, respectively. We assumed a 50 percent wastage for the hay which is what we observed in trial 1. If the hay were fed from bunks or troughs as we did in trial 2, the cost per day to feed hay would drop to $3.10 and $2.64 for a cow and calf moose.

To feed animals during the critical winter period, the cost of the program would be between $396 and $543 per animal depending upon feed used and animal age (Table 4). The lowest cost was $325 per winter for cow moose fed hay with a wastage of only 20%.

Feed costs might be reduced by feeding less food (i.e., below *ad libitum*). However, it is our experience at the MRC that dominate individuals tend to eat to fill and prevent submissive animals from feeding. Consequently, restricting food will not provide "some food to all moose", but will more than likely result is dominant animals surviving and less dominant ones starving.

It might also be assumed that emergency fed animals will consume some natural foods in addition to the emergency ration, thereby reducing the total feed requirement. We did observe the cow moose on the hay diet consuming spruce. Spruce is not a good food source, and we suspect that these animals were stressed from eating hay. During very extreme winters, deep snow generally restricts animals to small areas. Once emergency food is made available, we suspect that the animals using this food will travel very little to obtain natural browse.

There is also a question about the benefits to the population of feeding and justification of its costs. As stated by Baker and Hobbs (1985), the data are still out on many of the potential biological costs of feeding. They state that emergency feeding can increase the potential for disease transmission. It may reduce wildness or cause detrimental effects on spatial distribution. By preventing the culling effects of winter on weak animals, feeding may harm the genetic quality of a population.

Feeding moose definitely reduces their wildness and often exacerbates moose/human conflicts. Wild moose that are habituated to humans often become aggressive and mean. For example, of 201 nuisance animals calls recorded by Fish and Wildlife Protection in Anchorage (Ted Ruddell, pers. comm.), over 80 percent dealt with moose. An estimated 50 percent of the moose calls resulted from people feeding moose. Of significance was: (1) all 15 reported animal attacks were moose, not bears, (2) 40 percent of 25 defense of life and property cases dealt with moose, (3) human/animal conflicts were twice the rate of injured animal calls, and (4) 100 percent of the aggressive animals destroyed (n = 5) were moose. The decision to destroy a moose only occurs after numerous contacts with the animal, significant threat to humans, utilizing all available deterrents, and consulting with the Department of Fish and Game. In Soldotna, in 1992, there were 132 calls from the public recorded concerning nuisance moose. Members of the public killed 14 and FWP killed 4. Finally, the number of calls received by Fish and Wildlife Protection does not reflect the number of calls received by Alaska Fish & Game.

Finally, are the costs of feeding moose offset by the benefits? As stated by Baker and Hobbs (1985) clearly, economic justification of feeding depends on estimating the dollar value of each animal saved--a difficult estimate to come by. If our estimates are accurate, then the break-even point is between $396 and $543.

The decision to feed moose becomes a balance sheet between cost and benefits. The economic value of a moose varies with human use, rareness, sex and age, contribution to population biology, and many other factors. Thus the decision to feed is not simply made when the cost side of the equation is smaller than the value of a moose. For example, the economic value of a bull moose ($181-508) to a sport hunter far exceeds the cost of feeding it during the winter. But winter feeding programs are not selective about which animals get fed. Cows and calves predominate in any hunted population. Consequently, the economics of feeding must consider population biology, the relationship of the population to carrying capacity, harvest strategies, habitat quality, and an array of other factors. Populations at carrying capacity (K) have surplus animals which will likely die from compensatory causes. Feeding moose from a population at K is probably a waste of money. Decisions to implement emergency feeding programs should be based upon biological and economical considerations and not on emotion.

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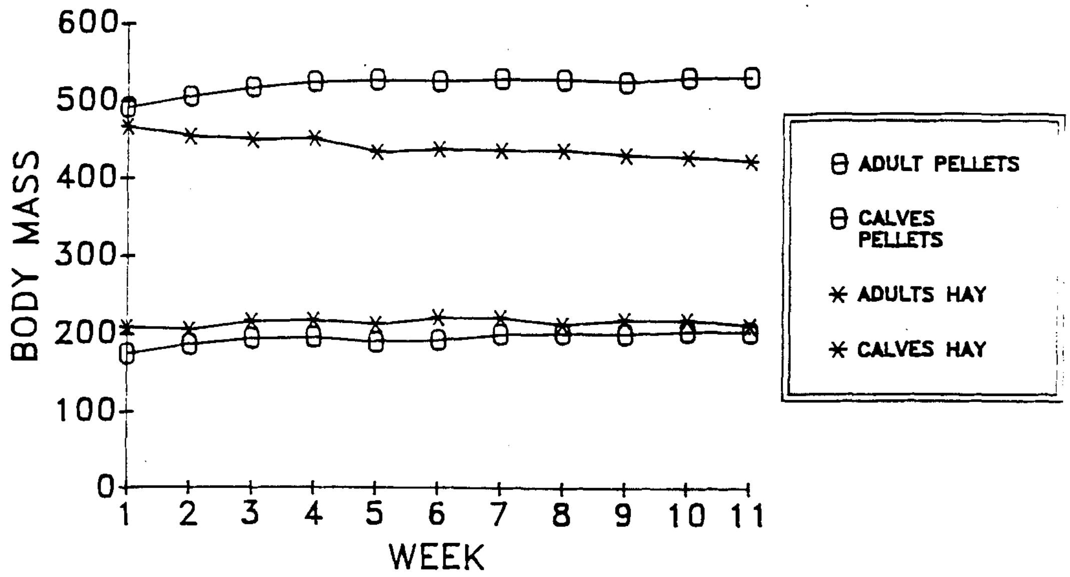


Figure 1. Body mass of cow and calf moose fed either hay or a pelleted ration during winter. The trial began on 17 January (week 1) and continued through early April 1992.

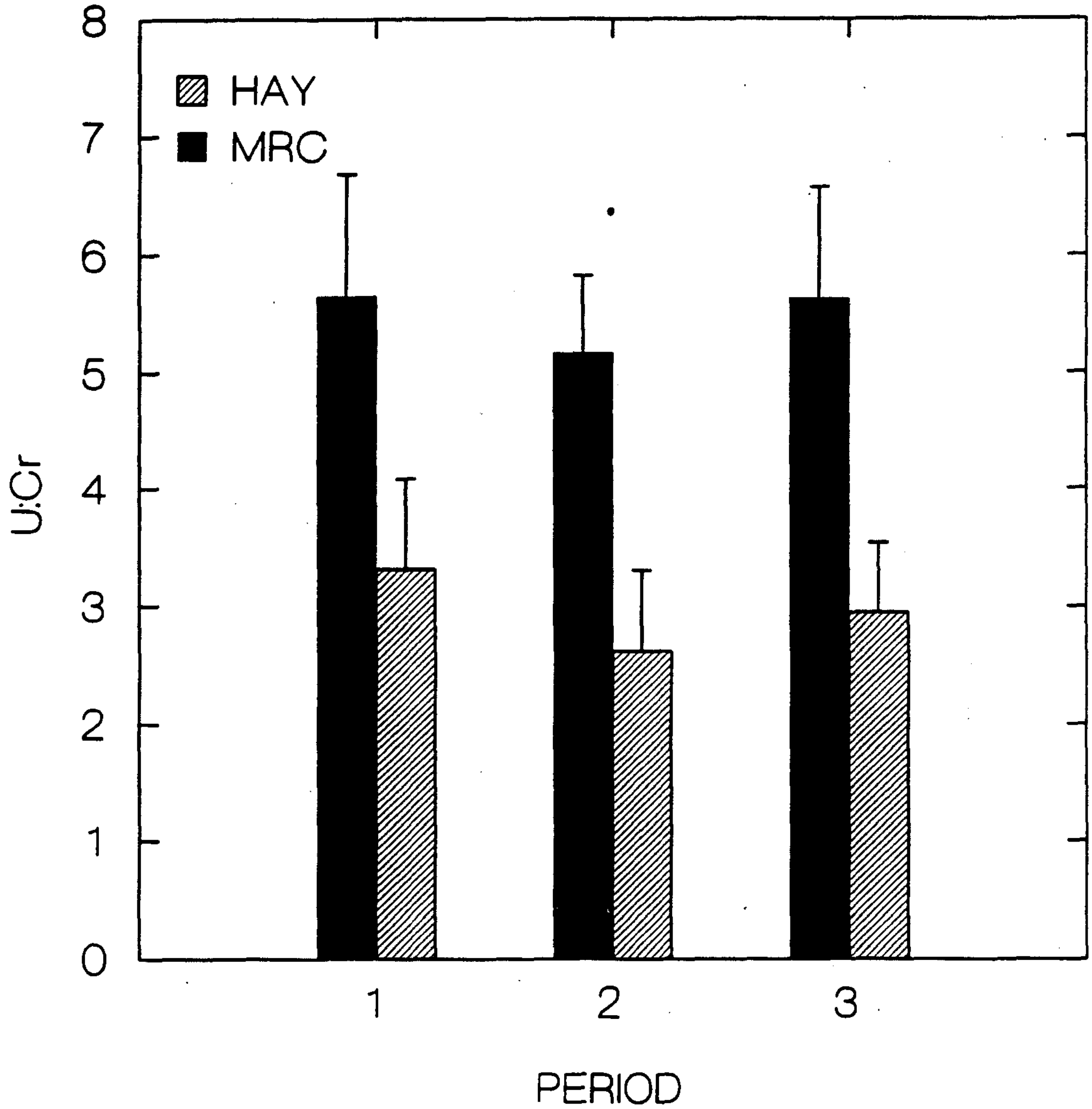


Figure 2. Mean U:Cr ratios of moose on 2 different diets, for each of 3 periods (see text) during an 11-week feeding study. Error bars represent 1 SE.

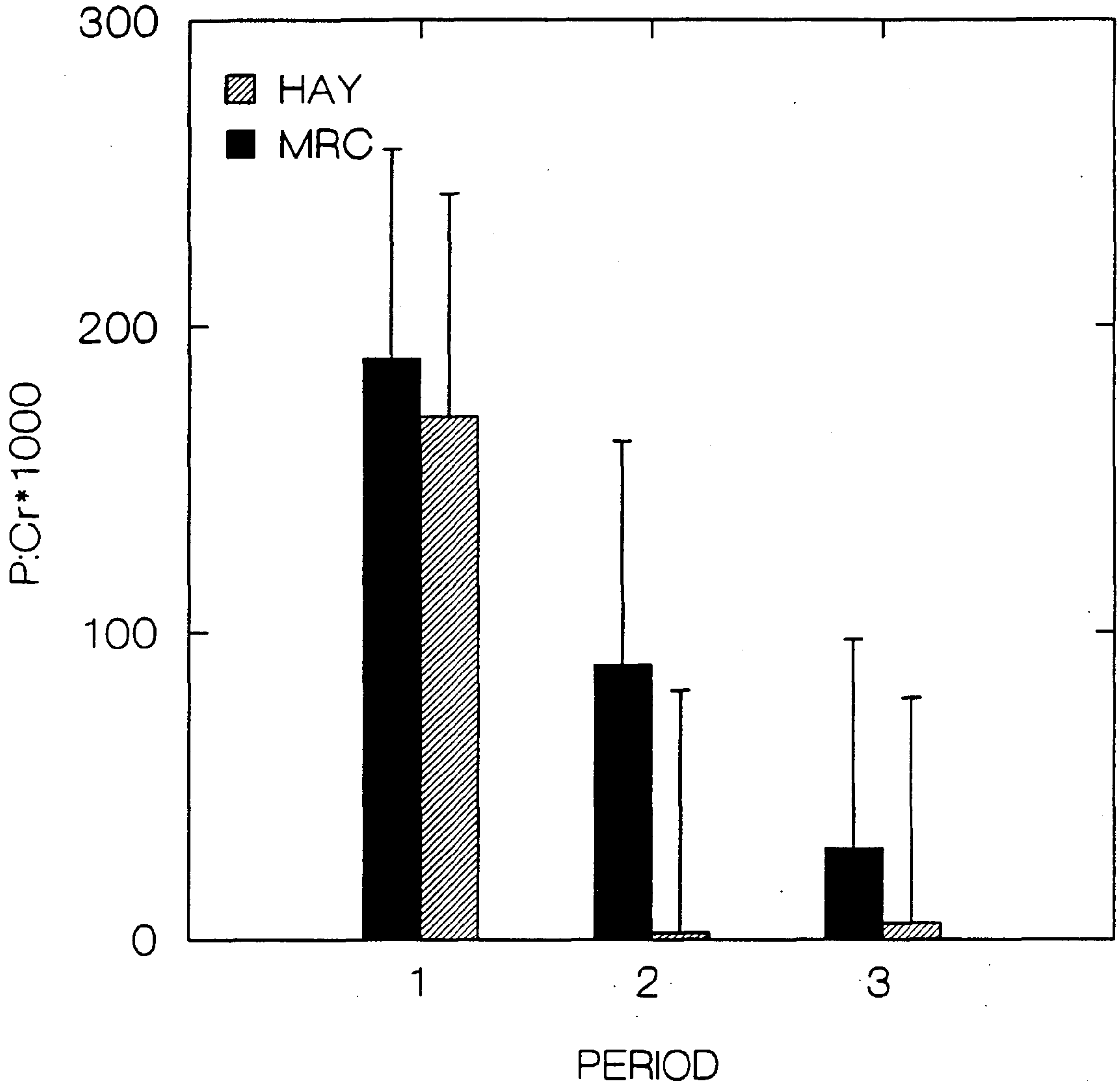


Figure 3. Mean P:Cr*1000 ratios of moose on 2 different diets, for each of 3 periods (see text) during an 11-week feeding study. Error bars represent 1 SE.

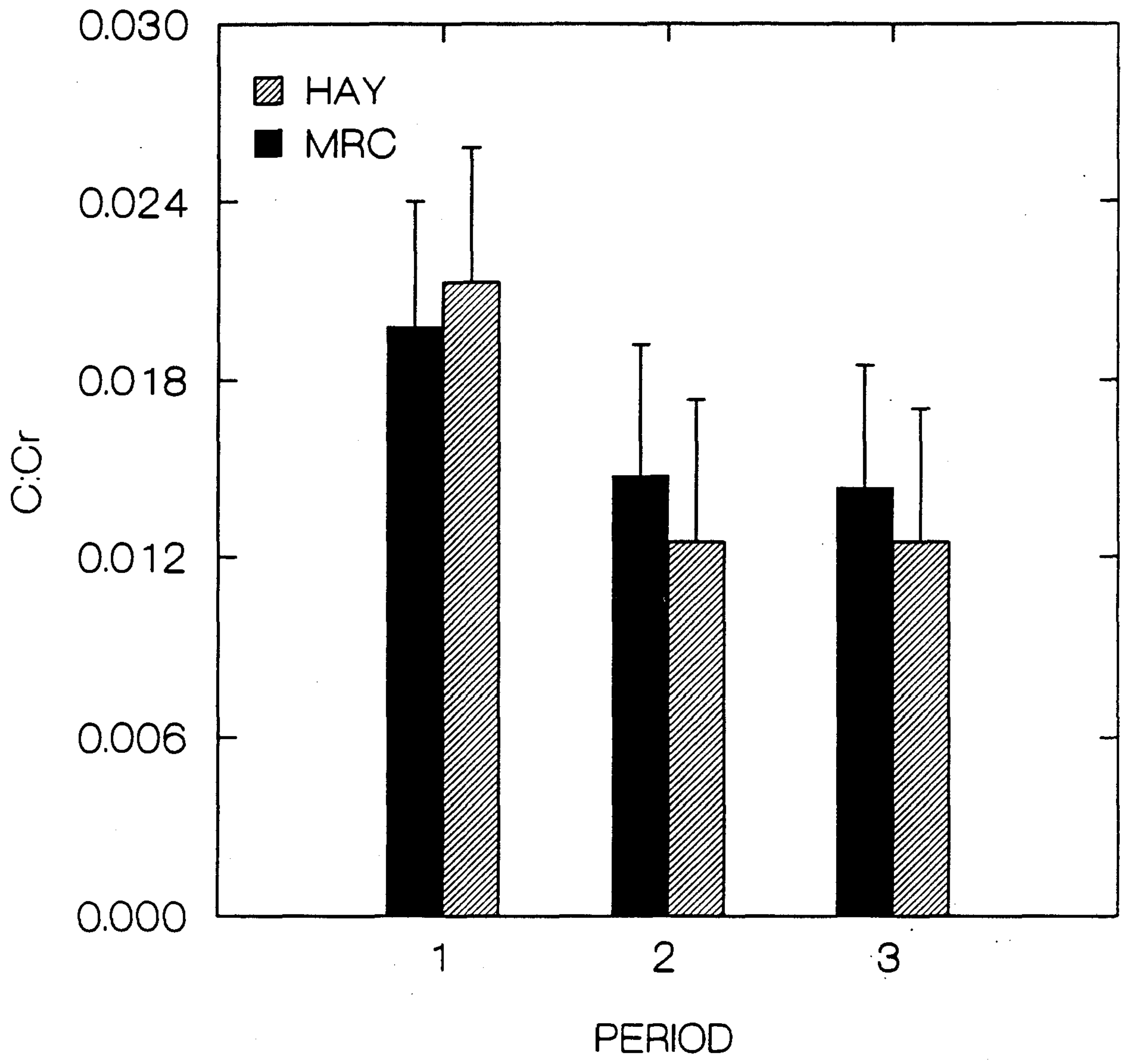


Figure 4. Mean C:Cr ratios of moose on 2 different diets, for each of 3 periods (see text) during an 11-week feeding study. Error bars represent 1 SE.

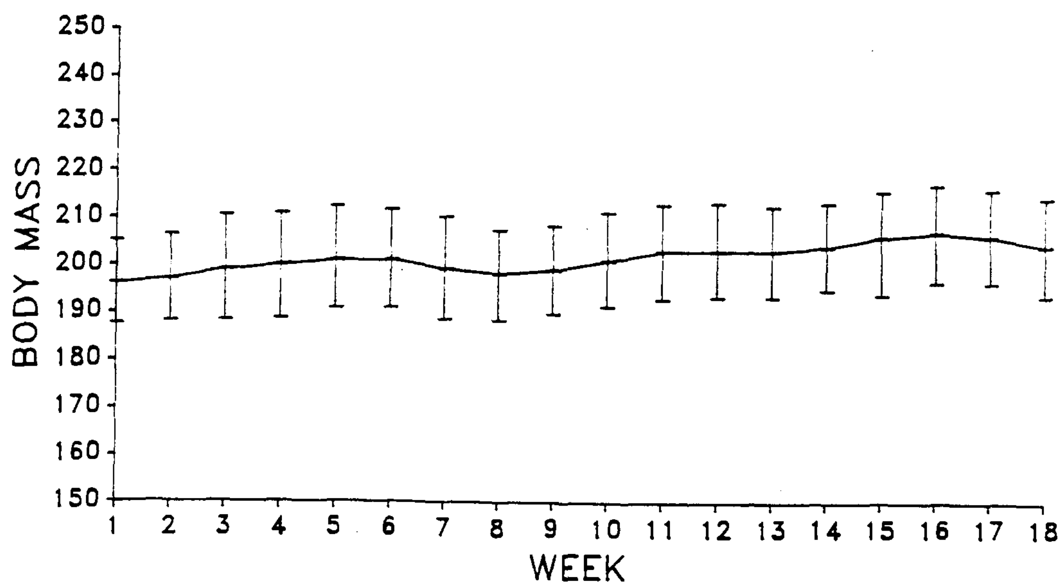


Figure 5. Body mass of calf moose fed hay during winter. The trial began on 25 December (week 1) and continued through early May, 1993.

Table 1. Chemical composition (%) of the pelleted ration and grass hay fed to moose at the Moose Research Center, Alaska. Moose were fed during the winters of 1991-92 and 1992-93.

	Hay		
Nutrrient	1991-92	1992-92	Pellets
Dry matter	84.0-86.3	84.0	92.7
Gross energy (kcal/g)	4.4- 4.5	4.6	4.5
Dry matter digestion	59.0	65.7	59.0
Neutral-detergent fiber	65.1-67.0	57.8	33.8
Acid-detergent fiber	36.9-39.7	30.4	18.1
Lignin	4.8- 4.9	4.0	2.8
Crude protein	7.9- 9.5	9.5	10.5
Ash	4.5- 4.7	6.6	7.4
In vitro digestion	57.6-59.8	65.7	67.9

Table 2. Dry matter intake of hay and a pelleted ration fed to adult cow and calf moose during winter 1991-92 at the Moose Research Center, Alaska.

Treatment	Mass (BM)		Intake (SD)			
Age	(kg)	SD	g/kg $BM^{0.75}$/d		%BM	
Pellets						
Cows	529	44	70.5	12.2	1.5	0.2
Calves	196	24	76.1	17.2	2.0	0.5
Hay						
Cows	430	44	36.6	9.8	0.8	0.2
Calves	215	26	63.4	5.7	1.6	0.1

Table 3. Mean ranks of feed flavorings used in a test of flavor preference by moose. Higher mean ranks indicate a greater amount of feed was consumed.

Number	Mean Rank	Flavor	Manufacturer
1	43.75[b]	Milkey Whay	Crest Flavor Co.
2	38.69[a]	Apple	Crest Flavor Co.
3	34.75[a]	Carmel	Far-Mor
4	34.31[a]	Anise-molasses	Crest Flavor Co.
5	29.88[a]	Dairy Krave	Feed Flavors, Inc.
6	22.94[a]	Horse	Crest Flavor Co.
7	14.56[a]	Mineral	Crest Flavor Co.
8	41.13	MRC CONTROL	Don Chemical

[a,b] Means with different superscripts are significantly different ($\underline{P} < 0.05$); the mean for the control ration was not included in the comparison.

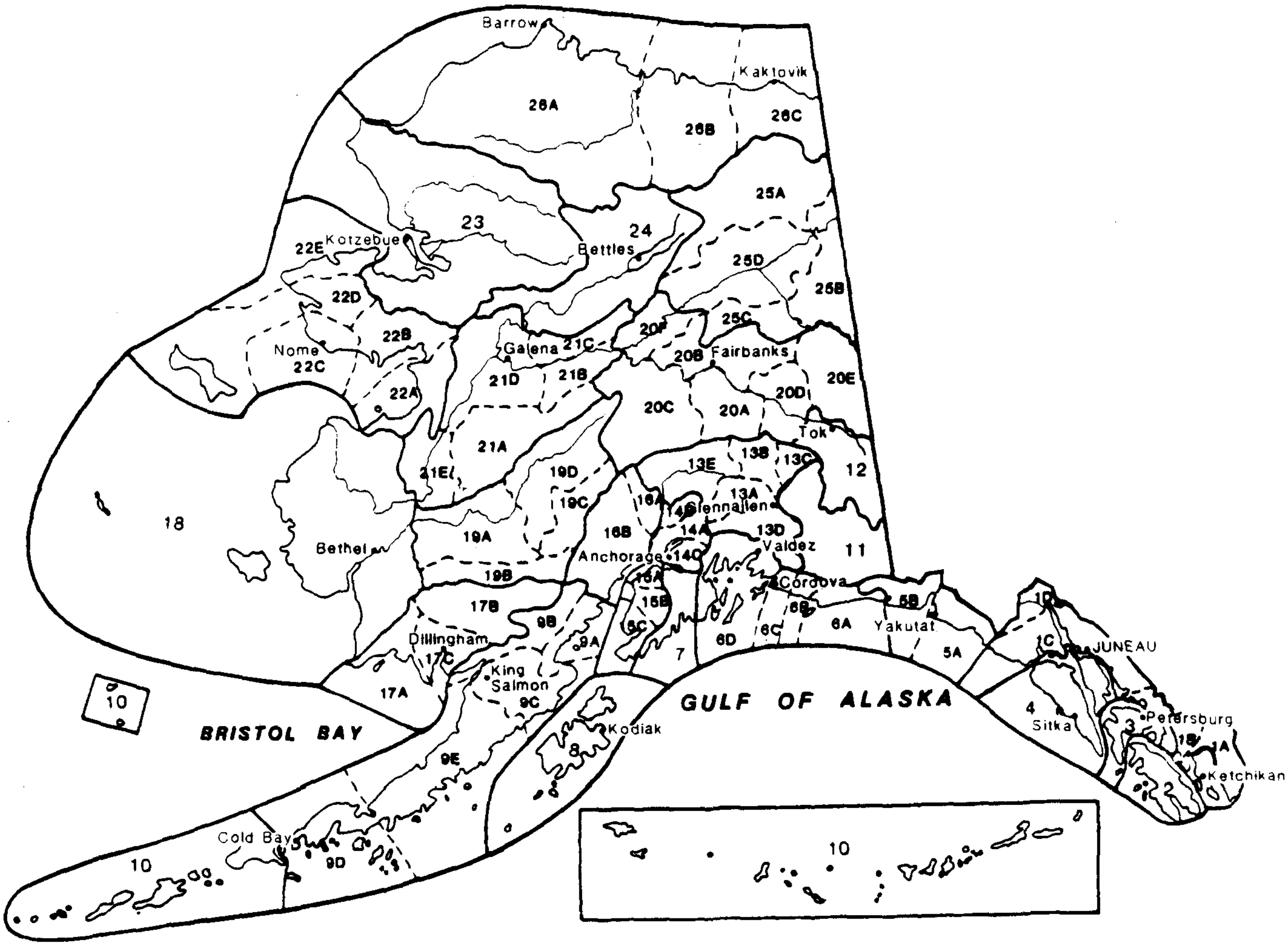
Table 4. Estimated cost of emergency feeding an adult cow and calf moose during winter either hay or a pelleted ration.

	Diet	
Assumptions	Hay	Pellets
Intake of feed (% body mass)		
Cow	1.0	1.0
Calf	2.0	2.0
Feed dry matter (%)	85	93
Efficiency of feed use (%)	50	80
Cost of feed (cents/kg)	0.39	0.53
Feeding costs (cents/d)	0.35[a]	0.35[a]
Feed time (days)		
Cow	105	105
Calf	135	135
Body mass (kg)		
Cow	480	480
Calf	200	200
Cost/day ($)		
Cow	4.75[b]	3.77[b]
Calf	4.02[b]	3.20[b]
Cost/winter ($)		
Cow	499.24	395.78
Calf	542.78	431.93

[a] Estimate from Baker and Hobbs (1985).

[b] Cost of feeding per day was calculated as follows: (body mass X daily intake / feed dry matter / efficiency of usage X cost of feed) + feeding costs.

Alaska's Game Management Units



Federal Aid in Wildlife Restoration

The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sales of handguns, sporting rifles, shotguns, ammunition, and archery equipment. The Federal Aid program then allots the funds back to states through a formula based on each state's geographic area and the number of paid hunting license holders in the state. Alaska receives 5% of the revenues collected each year, the maximum allowed. The Alaska Department of Fish and Game uses the funds to help restore, conserve, manage, and enhance wild birds and mammals for the public benefit. These funds are also used to educate hunters to develop the skills, knowledge, and attitudes necessary to be reponsible hunters. Seventy-five percent of the funds for this project are from Federal Aid.