Alaska Department of Fish and Game
Division of Wildlife Conservation

Federal Aid in Wildlife Restoration
Research Final Report

Evaluation and Testing of Techniques for Moose Management

by

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and
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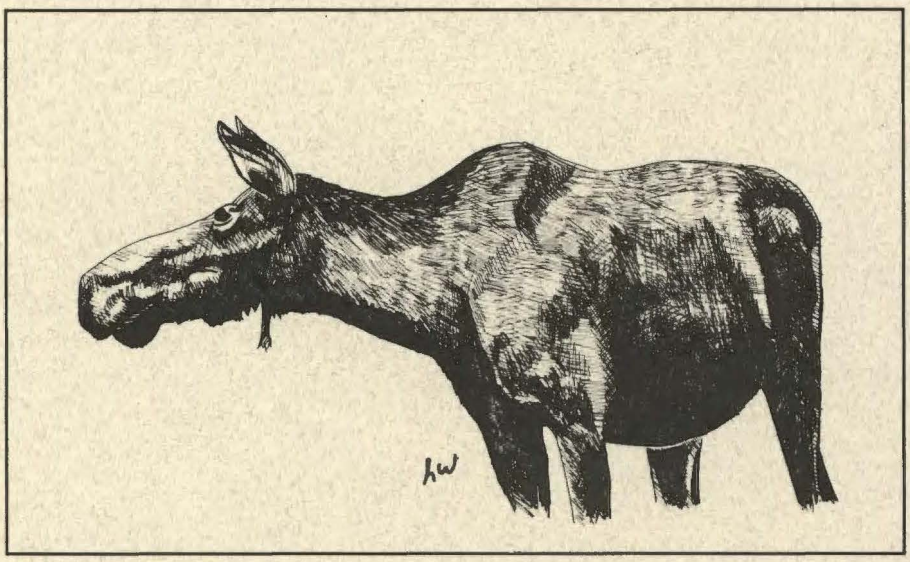

Projects W-22-6, W-23-1, W-23-2,
W-23-3, W-23-4, and W-23-5
Study 1.39
August 1993

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FINAL REPORT (RESEARCH)

State: Alaska

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SUMMARY

The techniques project at the Moose Research Center (MRC) is an open-ended program to test new drugs, equipment, and techniques that have potential application to moose management. Items investigated include new immobilization drugs and techniques, an activity monitoring system, techniques to measure body composition in moose, a broad array of reproductive parameters, moose confinement devices and husbandry techniques, and other miscellaneous programs including spike/fork hunting, genetic diversity, emergency feeding, and feed flavor additives. During this report period, 17 papers were published in professional journals. In addition, 4 book chapters were prepared for the book *North American Moose: Ecology and Management.* Most results are listed as abstracts to technical publications. Reprints are available upon request.

Key Words: *Alces alces*, compensatory growth, estrus length, formulated ration, feed flavorings, gestation, genetics, hay, moose, palatability, reproduction, snow-urine, urine, weight, winter feeding.

CONTENTS

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. Three Federal Aid final reports covering the period from 1968 through 30 June 1986 have been published (Franzmann et al. 1974, Franzmann and Schwartz 1982, Franzmann et al. 1987a). In addition, most research findings accomplished under this study have been published in scientific journals, proceedings of scientific meetings, as book chapters, or popular articles (see Appendix A). These publications covered evaluation and testing of drugs, trapping methods, aerial and pellet-count censuses, radio telemetry, biotelemetry, rumen sampling, marking and collaring, weighing, fertilization of browse, electronic tissue measuring, raising moose calves, developing a moose ration, feeding trials and techniques, developing a respiration chamber, radioisotope markers, a carrying capacity model, many aspects of moose reproduction, body composition studies, and numerous miscellaneous investigations.

OBJECTIVES

Objectives for this study are to test and evaluate techniques that are potentially useful for management of moose.

METHODS

Methods for each job can be found in the published technical report dealing with that subject.

RESULTS AND DISCUSSION

This report covers studies conducted between 1 July 1986 and 30 June 1992. Since virtually all information collected during this report period has been formally published, here we list the information and the technical source where it is available. Abstracts of each publication are in the appendices.

Job 1. MRC Maintenance and Operations

This job includes activities and expenses associated with maintaining and operating the Kenai Moose Research Center. It provides support for all MRC-associated studies and activities. Costs include utilities, maintenance and upkeep of the facilities, basic supplies, repairs not readily attributable to a single research job, salary of a caretaker, drugs, equipment, and food for maintenance of the captive moose herd.

Several major maintenance projects were completed under this job during this report period: (1) metal roofing was installed on 5 buildings; (2) 2.7 km^2 of vegetation was rehabilitated in pens 1, 2, and 3 using Letourneau tree crushers; (3) about 7 miles of wooden-post fence-line was replaced with steel pipe; and (4) one residence cabin was remodeled.

Job 2. Drug Testing

Anesthesia for vasectomy. The protocol for our reproductive studies required vasectomized bull moose. Consequently, we reported on the surgical anesthesia used during the operation (Franzmann et al. 1987b, Appendix B).

R51163. Only one new drug was tested during this report period. R51163 was identified as a useful tranquilizer in domestic cattle and caribou (*Rangifer tarandus*). We therefore tested its usefulness in moose. We concluded that the product was not reliable. Details were published (Schwartz et al. 1991, Appendix C).

Job 3. Activity Monitoring

Information collected under this job was part of a Master of Science project, University of Alaska Fairbanks (Bevins 1989).

Leg-mounted transmitters. As part of long-term studies to develop a carrying capacity model for moose (Schwartz et al. 1988a), we needed refined information on moose activity budgets. Consequently, we designed, tested, and collected information on moose activity patterns. As a result of these studies, we developed a leg-mounted transmitter and a computerized data acquisition system to monitor moose activity patterns (Bevins et al. 1988, Appendix D).

Seasonal activity patterns. Once the telemetry and data acquisition systems were developed, we collected 24-hour activity information on moose populations during summer and winter in good and poor habitat (Bevins et al. 1990, Appendix E).

Job 4. Body Composition Studies

From moose nutrition and physiology studies conducted at the MRC, we concluded that body composition of moose might provide us with an estimate of carrying capacity and population health. Consequently, we tested several techniques which might prove useful in estimating total body fat.

Assessment of condition in moose. As part of the initial review for this job, we completed a literature review of current technologies available to estimate body composition. This literature was presented as a review paper at the XVII International Union of Game Biologists, in Krakow, Poland (Franzmann 1987, Appendix F).

Changes in body composition. Studies with other species suggested that tritiated water might be useful in estimating total body water. Total body fat could then be calculated using standard equations. We tested this technique (Schwartz et al. 1988b, Appendix G), and concluded that the error associated with our estimates was not acceptable.

Bioelectrical impedance. Because we were dissatisfied with the results of studies of body fat using tritiated water, we investigated other techniques that might provide reliable estimates of body composition in moose. Bioelectrical impedance analysis (BIA) provides precise and unbiased estimates of body fat in humans. We investigated BIA and reported preliminary results in annual reports (Hundertmark et al, 1992 a,b). The technique appeared to have promise, so we prepared a study plan, and this segment is now Federal Aid Project W-23-5, Job 1.42. Peliminary study results will be published under this job.

Urinary chemistry. Urine is a medium that contains metabolic by-products and has been used to assess nutritional status of captive animals (Warren et al. 1981, 1982, Waid and Warren 1984, DelGiudice et al. 1987, DelGiudice and Seal 1988). However, obtaining

urine from live free-ranging animals is difficult. Recent reports indicate that assays of snow-urine for urea, sodium, potassium, calcium, and phosphorus, expressed as ratios to creatinine, are potential indicators of nutritional status of populations, particularly the urea:creatinine (U:C) ratio (Mech et al. 1987, DelGiudice et al. 1989). As snow-urine is easily sampled, and assays are relatively inexpensive, this technique has potential to be an effective management tool for moose, as well as other species. A proposal was prepared (Hundertmark et al. 1989) to study the efficacy of urinalysis in moose management, as was a paper summarizing initial findings (Appendix H).

Job 5. Reproductive Studies

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. This entails length of estrus, the receptive period during estrus, the time periods between estruses, the number of estrous periods during the breeding season, gestation length, and behavioral components. At the MRC we conducted late-breeding experiments and were able to demonstrate that calves are subsequently born late (Schwartz et al. 1986). We attribute the consequences of altered or late breeding during the rut to low bull:cow ratios, but with no clear supporting evidence. Nevertheless, the issue remains, and systematic research will be needed to resolve the matter.

Sex pheromones. To better understand the role of male moose in synchronizing the estrous cycle, we performed tests to determine whether bulls produce a sex pheromone. Preliminary findings were promising, and continued studies are planned (Schwartz et al. 1990, Appendix I).

Pregnancy determination. Our reproduction studies would benefit from a technique that would indicate the onset of estrus and whether or not a female was pregnant: such techniques also have management implications. Brundige et al. (1988) were able to detect pregnancy in bighorn sheep (*Ovis canadensis*) from serum progesterone levels. Although blood is difficult to collect from free-ranging animals, it may be possible to detect onset of estrus and pregnancy from progesterone metabolites in urine and feces. We cooperated with Dr. Steve Monfort (National Zoological Park, Smithsonian Institution, Front Royal, Virginia) to determine if moose urine and feces can be assayed for progesterone and estrogen metabolites. Monfort (unpublished data) found that the urinary concentration of the progesterone metabolite pregnanediol-3-glucuronide (PdG) undergoes cyclic fluctuations corresponding to the estrous cycle, and remains elevated during pregnancy in Eld's deer (*Cervus eldi*). Similarly, concentration of an estrogen conjugate (EC) peaked four to five weeks before parturition and declined dramatically immediately before giving birth. We tested the possibility of detecting these metabolites in urine deposited in clean, fresh snow (snow-urine) and feces (Safar-Hermann et al. 1987), which would allow data to be collected from free-ranging moose. We also tested the hypothesis that progesterone and estrogen metabolites in urine are useful to detect estrus and pregnancy and predict parturition dates in moose. We examined the utility of fecal progesterone (P4) and

estradiol (E2) as physiological indicators of reproductive status. Results of these studies can be found in Monfort et al. (1993, Appendix J).

Estrous cycle, gestation length, second estrous breeding. Results of these studies have been published (Schwartz and Hundertmark 1993, Appendix K). A book chapter (Schwartz in press) and an invited review paper covering moose reproduction (Schwartz 1992c, Appendix L) were also prepared under this job. Once data collection is complete, an additional manuscript will be prepared on growth rates of first versus second estrous calves.

Job 6. Moose Containment

One-way gates. We tested a one-way gate design to direct moose off the Glenn Highway following a fencing project. This study was a cooperative program with ADF&G staff in Anchorage. Results were published (McDonald 1991).

Electric fencing. We tested the feasibility of using vertical electric fencing to keep moose off the Alaska railroad tracks during winter. We concluded that although the fence worked, it required considerable maintenance. We also concluded that bulls with antlers, and moose standing on snow in winter may not receive a shock when coming in contact with the electrical wires. Details of the study were reported in Hundertmark et al. (1989).

Husbandry techniques. Maintaining moose in captive and semi-captive conditions is requisite to successful research at the MRC. Over the years, we have gained considerable knowledge about husbandry techniques of moose. Much of this information was combined with data collected in a survey of North American game farms, zoos, and research facilities. We prepared and presented a review paper at the 3rd International Moose Symposium (Schwartz 1992a, Appendix M).

Job 7. Miscellaneous Projects

A very useful aspect of the Techniques Study is the flexibility it provides. Under this study we are able to test and evaluate many new and different techniques that may be useful to moose management. Below we summarize some of those studies.

Spike/fork hunting season evaluation. Concurrent with our moose reproduction studies, we evaluated the potential impacts of selective harvest on moose reproduction. We also evaluated the implications of this season change on bull:cow ratios, total harvest, calf:cow ratios, crippling loss, and hunter participation. Results of this study were presented at the 28th North American Moose Conference (Schwartz et al. 1992, Appendix N).

Genetic diversity of moose. Selective harvest of bull moose targets certain antler types, with the potential of changing the genetic diversity within a population. Genetic diversity in the Kenai Peninsula moose population was measured in a pilot study (Hundertmark et

al. 1992, Appendix O), and a new Federal Aid proposal was prepared (Hundertmark et al. 1993). We also evaluated the genetic implications of selective harvest on moose using computer simulation (Hundertmark et al. 1993, Appendix P).

Hay as an emergency winter food. During winter 1989-90, extreme weather and snowfall resulted in excessive starvation within the moose population in southcentral Alaska. The public demanded a winter feeding program. Disagreement occurred about what should be used as an emergency food. Consequently, we evaluated the potential of locally grown grass hay and a pelleted ration as emergency rations for moose (Schwartz and Hundertmark 1993, Appendix Q).

Flavor additives. To improve the palatability of the pelleted ration evaluated for emergencies, we tested several food flavors to improve attractiveness to wild moose. Results were published along with the hay feeding trials (Schwartz and Hundertmark 1993, Appendix Q).

Other technical publications. During the period covered by this report, we prepared several additional review papers, book chapters, and articles summarizing research results from the MRC. A manuscript covering food passage rates (Schwartz et al. 1988c, Appendix S) was presented at the 24th North American Moose Conference. A review of moose nutrition was presented at the Third International Moose Symposium (Schwartz 1992b, Appendix R). Staff from the MRC prepared 4 draft book chapters for the Wildlife Management Institute Book "Moose of North America". These chapters covered (1) moose reproduction (Schwartz in press), (2) nutrition and energetics (Schwartz and Renecker in press), (3) movements and migration (Hundertmark in press), and (4) food habits and foraging behavior (Renecker and Schwartz in press). Because all chapters are in draft form, they are not included in the appendices at the end of this report. Chuck Schwartz served as the co-editor for the book.

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APPENDIX A. Publication List from the Moose Research Center

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APPENDIX B. Anesthesia of Moose for Vasectomy Using Carfentanil/Xylazine and Reversal with Naloxone/Yohimbine

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ABSTRACT: We report on the use of a mixture of carfentanil hydrochloride and xylazine hydrochloride to anesthetize 2 adult male moose (*Alces alces*) for surgical vasectomy and the subsequent reversal of these drugs with a mixture of naloxone hydrochloride and yohimbine hydrochloride. Induction, relaxation, reversal, and recovery were considered ideal. With minor downward dosage adjustment, we recommend the outlined methodology for surgical procedures in moose.

Alces 23(1987) pp. 211-226.

APPENDIX C. An Evaluation of R51163 as a Tranquilizer in Moose

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Abstract: R51163, a newly synthesized purine alkyl piperidine that produces reliable sedation in cattle, was tested in 6 adult bull moose (*Alces alces*). A single animal dosed at 0.2 mg/kg body weight (BW) responded with violent kicking when handled and was less manageable than when not sedated. Various responses from animals dosed with 0.4 mg/kg BW were noted; some were sedated sufficiently to draw a venous blood sample, while others responded by kicking. Compared with controls, all animals dosed with 0.4 mg/kg BW ate significantly ($P < 0.05$) less dry matter for at least 1 week after treatment. Mean estimates of resting metabolism, measured the day of injection, did not differ between treatment and control groups, although the variation was almost 2 times larger for drugged (C.V. = 14.5%) vs. control (C.V. = 8.2%) individuals.

J. Wildl. Disease 27(1991) pp.119-122.

APPENDIX D. Determining Moose Activity Budgets Using Leg-Mounted Tip-Switch Transmitters and a Compterized Data Acquisition System

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Abstract: Leg-mounted mercury tip-switch radio transmitters and a computerized data acquisition system (Telonics Inc., Mesa, AZ) were tested for the detection of 3 activities in moose (*Alces alces*): lying, standing, and walking. Transmitters were mounted on the lower front legs of 9 study animals with nylon harnesses. Mercury switches were positioned such that signal pulse interval was long during standing, short during lying and variable during movement. The data acquisition system was programmed with frequencies to be sampled, sample period length, number of samples per sample period, and time between samples.

Signal patterns predicted active and resting bouts correctly 99.2% and 89.4% of the time, respectively. Errors resulted when transmitter switches failed to trip when animals laid down, or when animals held their legs at an angle while feeding. Error was reduced by using a sampling design which optimized the detection of movement during active periods (3-minute sample periods) and allowed comparisons of consecutive samples such that samples containing ambiguous data could be re-evaluated (15-minute intervals). The number of steps taken within 808 15-second periods was predicted within 1 step, 95% of the time. Lengths of individual walking bouts lasting over 5 seconds were predicted with a high degree of accuracy.

The system was further tested during a study in which 189, 24-hour activity budgets were obtained. The accuracy of estimating time spent walking, time spent active, and length of individual active and resting bouts are reported.

Alces 24(1988) pp.22-33

APPENDIX E. Seasonal Activity Patterns of Moose on the Kenai Peninsula, Alaska

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[1]Deceased, John was lost at sea north of Barrow, Alaska on a polar bear survey flight on October 11, 1990. This paper was prepared by him prior to his death. John was associated with the Alaska Coop. Wildl. Res. Unit, University of Fairbanks, Alaska, [2]Alaska Department of Fish and Game, Moose Research Center, Soldotna, AK 99669.

Abstract: We obtained monthly estimates of 24-hour activity patterns of moose (*Alces alces*) on the Kenai Peninsula, Alaska, during winter and summer. Activity levels of moose during winter overlapped between areas of high and low deciduous browse availability. Shorter resting periods occurred during summer months (x = 105 min), than during winter months (x = 171 min) resulting in increased activity levels for winter (x = 486 min) to summer (x = 622 min). No consistent pattern was found in the difference in activity period length between summer (x = 80 min) and winter (x = 81 min). Estimates are useful for predicting total energy expenditure of moose. Large variations in activity levels among individual moose point out the importance of obtaining unbiased samples from populations.

Alces 26(1990) pp.14-23

APPENDIX F. Assessment of Condition Status as a Management Tool for Big Game Species

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Abstract: Condition (health, nutrition) status of wildlife populations has long been pursued using the indicator animal concept by applying a variety of techniques measuring form (morphology), function (physiology), and activity (behavior) of animals. At the Moose Research Center (MRC), Alaska, we have in the past focused on measuring blood parameters. However, after an 8-year study on developing a carrying capacity model for moose (*Alces alces*), it became evident that a major driving force in the model was total body fat. Our direction now is toward assessing procedures that can, with a minimum of effort and expense, estimate total body fat in wild animals.

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APPENDIX G. Changes in Body Composition of Moose During Winter

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Abstract: Nine adult moose (*Alces alces*) were assigned to one of 3 treatments in 2 separate trials. In trial 1, 3 treatment groups of 3 moose were fed a pelleted diet ad libitum or at 85% and 70% of ad libitum intake. During trial 2, 3 treatment groups of moose were fed ad libitum intake one of 3 pelleted diets containing a metabolizable energy (ME) content of 2.4, 2.1, and 1.8 kcal/g dry matter. Estimates of body composition were determined with tritiated water. In trial 1, female moose fed restricted quantities (85% or 70% of ad libitum intake) of food lost weight and fat at faster rates than moose fed ad libitum. The percentage change in kg of fat from pretrial measurements in October until the end of the trial in April was 33.0%, 26.8%, and -57.2% for the high-to-low intake treatments, respectively. Male moose were excluded from the analysis because of differences in the dynamics of body composition over time, and reasons are discussed. In trial 2, both male and female moose fed 1.8 and 2.1 kcal ME compensated for lower levels of available energy by increasing dry-matter intake. Fat dynamics were not different ($P > 0.05$) among the treatments but were different ($P < 0.05$) over time. Changes in the energy pool indicated that fat catabolism/metabolism contributed about 94.7-100% of the calories, although the variation was high. Estimates of body composition based on the tritiated water technique were variable, and reasons are discussed.

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APPENDIX H. Urinary Chemistry Profiles of Supplementally Fed Moose

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ABSTRACT: We describe urine chemistry profiles for 4 healthy male moose (*Alces alces*) being fed an ad libitum or moderately restricted high protein-high energy diet, and for 1 male being fed the same diet ad libitum but recovering from severe undernutrition. Urea (U), phosphorus (P), potassium (K), calcium (Ca), and sodium (Na) were expressed as ratios to creatinine (Cr) to account for differences in urine concentrations and to facilitate analysis of urine deposited in snow (snow-urine). Urea:Cr ratios did not differ among animals or over time, although the nitrogen balance of the undernourished moose likely differed from those of the other animals. Profiles of K:Cr, Ca:Cr, and Na:Cr allowed us to differentiate between the undernourished and healthy moose, and Na:Cr differed among animals being fed ad libitum and those on restricted diets. The profiles from the 4 healthy moose can be considered as a baseline for this species. Analysis of urine deposited in snow can be a useful indicator of population condition in moose, but a clear understanding of the physiological processes indicated by these profiles and their inherent limitations is essential to proper implementation.

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APPENDIX I. Are Sex-Pheromones Involved in Moose Breeding Behavior

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ABSTRACT: Evidence is presented that saliva of bull moose (*Alces alces gigas*) contain 16-unsaturated C_{19} steroids. These pheromones have been identified in red deer (*Cervus elaphus hippelaphus*) and wild boar (*Sus scrofa*) and operate in the latter as a potent primer stimulating estrus and copulation readiness in the sow. Saliva samples collected from mature bull moose contained a mean concentration 0.48 ng/ml (n=15, SD=0.17) of 5androst-16-en-3-one. Using thinlayer-chromatography, the musk-scent components were identified as 5a-androst-16-en-3a-ol (3.5 ng/ml) and 5a-androst-16-en-3b-ol (3.5 ng/ml). Bull moose produced signalling pheromones in concentrations 10-20 times lower than those of the boar. Additional research is required to determine the role of the compounds in rut synchronization and induced estrus.

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APPENDIX J. Monitoring Reproduction in Moose Using Urinary and Fecal Steroid Metabolites

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Abstract: Because repeated capture, restraint, and blood sampling generally are impractical strategies for monitoring reproductive status in wildlife species, noninvasive methods for tracking reproductive activity have become increasingly important. Thus, we used radioimmunoassay (RIA) of urinary pregnanediol-3*a*-glucuronide (PdG), estrogen conjugates, and fecal progesterone and estradiol were used to assess estrous cycles and pregnancy in captive moose (*Alces alces*). Using urinary PdG, we identified distinct reproductive cycles that began during October and estrus behavior coincided with nadirs in PdG excretion. Although PdG increased up to 5-fold over cycling levels during pregnancy, hormone concentrations were quite variable making pregnancy diagnosis equivocal using this method. Estrogen conjugates were not useful for monitoring estrous cyclicity; however, during the final month of gestation urinary estrogen conjugate levels increased from <5 ng/mg creatinine (Cr) to >50 ng/mg Cr making this a useful method for definitive pregnancy detection during late pregnancy. To establish a simple pregnancy test, we evaluated estradiol and progesterone in feces (1-6 samples/individual) collected over a 2-year interval from 16 moose of various age, gender and physiological (pregnant vs. nonpregnant) classifications. Using fecal progesterone, blind tests, technicians correctly identified pregnancy status in 22 of 26 (85%) cases with 3 false positive diagnoses; fecal estradiol proved less effective (15/26) (58%) for accurately diagnosing pregnancy. These methods provide the potential to monitor reproductive activity in both captive and free-living moose.

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APPENDIX K. Reproductive Characteristics of Alaskan Moose

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Abstract: Many parameters of moose (*Alces alces*) reproduction are poorly documented. Therefore, we quantified the estrous cycle, estrous length, gestation period, fetal development, and birth mass of calves. We evaluated empirical relationships among maternal age, mass, and previous breeding parity with litter size and neonatal sex ratio. Increased attentiveness by the bull signaled estrous behavior in cows. Estrous females did not increase activity. The estrous cycle ranged from 22 to 28 days ($\underline{x}$= 24.4 days) and did not lengthen with each successive cycle. The cycle of primiparous females was shorter ($\underline{P}$ = 0.05) than pluriparous females. Gestation averaged 231 days (SD = 5.4 days) and did not differ ($\underline{P}$ > 0.05) between primiparous and pluriparous females, litters of 1 or 2 calves, among 5 years of study, or between cows bred their first or second overt estrus. Primiparous yearlings produced fewer ($\underline{P}$ = 0.005) calves (1.07/cow) than primiparous 2-year-old cows (1.60/cow). Calf production was related to body mass at time of breeding in primiparous ($\underline{P}$ = 0.0015) but not pluriparous females (P = 0.38). Fetal counts collected from wild moose on the Kenai Peninsula averaged 0.22, 1.27, and 0.14 for yearlings, cows aged 2-15, and $\geq$16, respectively. Mean corpora lutea counts for the same groups were 1, 1.5, and 2.0 per female suggesting an ova loss of 0, 9.3, and 100% for the three age classes. Mass of single calves ($\underline{x}$ = 16.2 kg) at birth was greater ($\underline{P}$ = 0.001) than twin calves ($\underline{x}$= 13.5 kg), but within single or twin litters, males did not have more mass than females. Change from conception to birth in fetal mass ($\underline{R}^2$ = 0.964) and hind foot length ($\underline{R}^2$ = 0.997) was best described with a von Bertalanffy equation, whereas total ($\underline{R}^2$ = 0.988) and forehead-rump ($\underline{R}^2$ = 0.979) lengths were linear. Using the hind foot length-age relationship, we accurately predicted 19 of 20 known second estrus births. This technique provides a simple means of estimating the incidence of delayed breeding in moose. These statistics defining chronology of the reproductive process, productivity, and fetal growth rates, permit a more refined approach to modeling and management of wild moose populations. These baseline data facilitate analyses of the impacts of harvest of bulls on the reproductive performance of managed moose herds. Continued research needs to quantify the impacts of skewed bull:cow ratios on rut timing and its potential impacts on calf production and survival.

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APPENDIX L. Reproductive Biology of North American Moose

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ABSTRACT: An understanding of the reproductive biology of moose (*Alces alces*) facilitates wise management. Moose are polyestrous cervides with relatively high ovulation rates in adult females. Puberty varies among populations, but no calves are sexually active. In populations on good range or below carrying capacity, yearling ovulation and pregnancy occur. The estrous cycle averages 24 days and ranges from 22-28 days. If not bred, moose have up to 6 recurrent estrous cycles. The period of heat when a female will accept the male is short, lasting from 1-36 hours. Gestation length ranges from 216-240 days with a mean of 230 days. Gestation length is not different for single vs. twin litters. Pregnancy rates in adult moose are remarkably constant averaging about 84%. Twinning rates vary with range quality and may be a good indicator of carrying capacity. Bull moose reach puberty as yearlings. Increasing levels of testosterone initiate antler growth. High levels of testosterone activate Leydig cells which begin spermatogenesis. By fall, bull moose are ready for the breeding season with hardened antlers and fully developed sperm. Breeding season is relatively short, with >85% of all pregnancies occurring in <10 days. Peak rut occurs in late-September and early-October. Rutting season is relatively constant across North America. Out of season births are rare, but have been reported as late as August. Declining levels of testosterone following the rut are responsible for antler drop in bulls, which occurs from early-December through March. Large bulls tent to shed their antlers earlier than young bulls.

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APPENDIX M. Moose Husbandry in North America

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Abstract: Moose (*Alces alces*) have been maintained in captive and semi-captive conditions since the time of fur traders in North America for 3 general purposes: Display in zoological gardens, scientific research, and commercial production. Husbandry techniques summarized are from a survey of the major zoos and game farms in North America; additional data from the Moose Research Center, of the Alaska Department of Fish and Game are presented. Techniques for care, rearing, maintenance, feeding, and housing of moose are reviewed and discussed. Adequately designed facilities are constructed with a minimum of 7 ft (2.13 m) woven wire fence and contain a shelter. Moose are fed fresh cut browse and other green plant material, but the development of a formulated ration which meets the nutrient requirements has simplified feeding and reduced labor costs. With adequate shelter, moose can tolerate extreme cold, but warm temperatures impose stress; adequate shelter and cooling areas are essential. Disease and other illness, particularly in calves, can result in high mortality.

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APPENDIX N. An Evaluation of Selective Bull Moose Harvest on the Kenai Peninsula, Alaska

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ABSTRACT: Intense harvest of bull moose (*Alces alces*) on the Kenai Peninsula in the late 1970's and early 1980's resulted in a low proportion of bulls in the population. Ratios at that time varied from 5 to 12 bulls/100 cows in heavily hunted areas with easy access. Concern for the population's health, stability, and future hunting opportunity coupled with a public desire to increase viewing opportunities of bull moose prompted the Alaska Board of Game to institute a selective harvest system (SHS) for bull moose in 1987. Under the new regulation only males with a spike or forked antler (yearlings) or bulls with antlers ≥50 inches in spread or with three brow tines on one antler were legal to harvest. Here we compare population and harvest statistics for 5 years prior to SHS with the first 5 years of SHS. SHS resulted in a significant ($P < 0.05$) decline in both the total bull harvest (636 vs. 443 moose) and the number of hunters (3602 vs. 2605). Hunter success did not change (18 vs. 17%). Population modeling closely predicted harvest changes with implementation of SHS following both normal and severe winters. Based on harvest statistics, we calculated that under SHS approximately 34, 79, 47, and 19% of yearling, 2-3, 4-5, and ≥6 year old of age, respectively, were protected from harvest. Reported illegal harvest averaged 6.7% of the legal kill during the 5 years of SHS. Most moose killed illegally were mistaken for larger moose. The bull:cow ratio increased from 16 to 29 bulls/100 cows 3 years after SHS was implemented. As the number of bulls in the population increased, we did not detect a change in calf/cow ratios, pregnancy rates, or sex ratio among calves. SHS appeared to be a viable alternative to a general bull moose season. It allowed for unlimited hunter participation, even following a severe winter when hunting seasons were severely restricted or closed in adjacent areas. SHS provided an alternative to more restrictive seasons or permit hunts. Management implications are discussed.

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APPENDIX O. Genetic Diversity of Moose from the Kenai Peninsula, Alaska

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ABSTRACT: Six of 20 loci from liver and muscle tissue from Kenai Peninsula moose (*Alces alces gigas*) were polymorphic. Average heterozygosity was 7.7%, which represents an unprecedented level of genetic diversity for moose. This level of diversity was not expected because empirical evidence from other moose populations, as well as theoretical considerations, indicated that moose exhibited low levels of heterozygosity. We propose that moose populations with low diversity reside in areas that were glaciated during the last Ice Age and that the recolonization process reduced heterozygosity, while high-diversity populations reside in areas in the proximity of glacial refugia.

Alces Vol. 28 (1992) pp. 15-20

APPENDIX P. Genetic Effects of Selective Harvest Systems in Moose: A Modeling Approach

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ABSTRACT: A computer model was constructed to examine genetic changes over a 50-yr period in a population of moose subjected to a variety of selective harvest systems (SHS) based upon antler criteria. Legal bulls in the different SHS were characterized by spike/fork only, ≥36 in., ≥50 in., and spike/fork or ≥50 in., in addition to a system in which all bulls were legal. In SHS in which spreads of a certain size defined legal bulls, an alternative harvest criterion was the existence of a brow palm with ≥3 tines. The model assumed that antler morphology was controlled by 5 loci and that brow palm formation was controlled by a single locus and was independent of antler size. Each locus represented a simple, additive 2-allele system (favorable/unfavorable). Results presented for each SHS include changes in allele frequencies and harvest rates, as well as a sensitivity analysis of model inputs.

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APPENDIX Q. Supplemental Feeding of Moose during Winter: Can Hay Serve as an Emergency Ration?

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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 ($P = 0.004$) 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 ($P = 0.42$) but differed among periods ($P = 0.06$), 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 ($P = 0.82$) or among periods ($P = 0.19$), 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 milky whey when compared to the standard ration and the other 6 flavors tested. Recommendations concerning emergency feeding are discussed.

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APPENDIX R. Food Passage Rate in Moose

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Abstract: Four tame moose (*Alces alces*) were used to measure dry matter digestion and rates of fluid passage of three diets: a pelleted ration, a mixture of pellets and winter clipped aspen (*Populus tremuloides*), and a mixture of winter clipped aspen, willow (*Salix spp.*), and paper birch (*Betula papyrifera*). Dry matter digestion was greatest for the pellets (64.3%) followed by the pellet-aspen mix (58.9%) and the mixed browse (31.1%). Time of first appearance (15.8 h), rumen turnover time (31.2 h), and total mean retention time (53.6 h) of the fluid phase of digesta were longest for the mixed browse diet.

Alces 24 (1988) pp. 97-101.

APPENDIX S. Physiological and Nutritional Adaptations of Moose to Northern Environments

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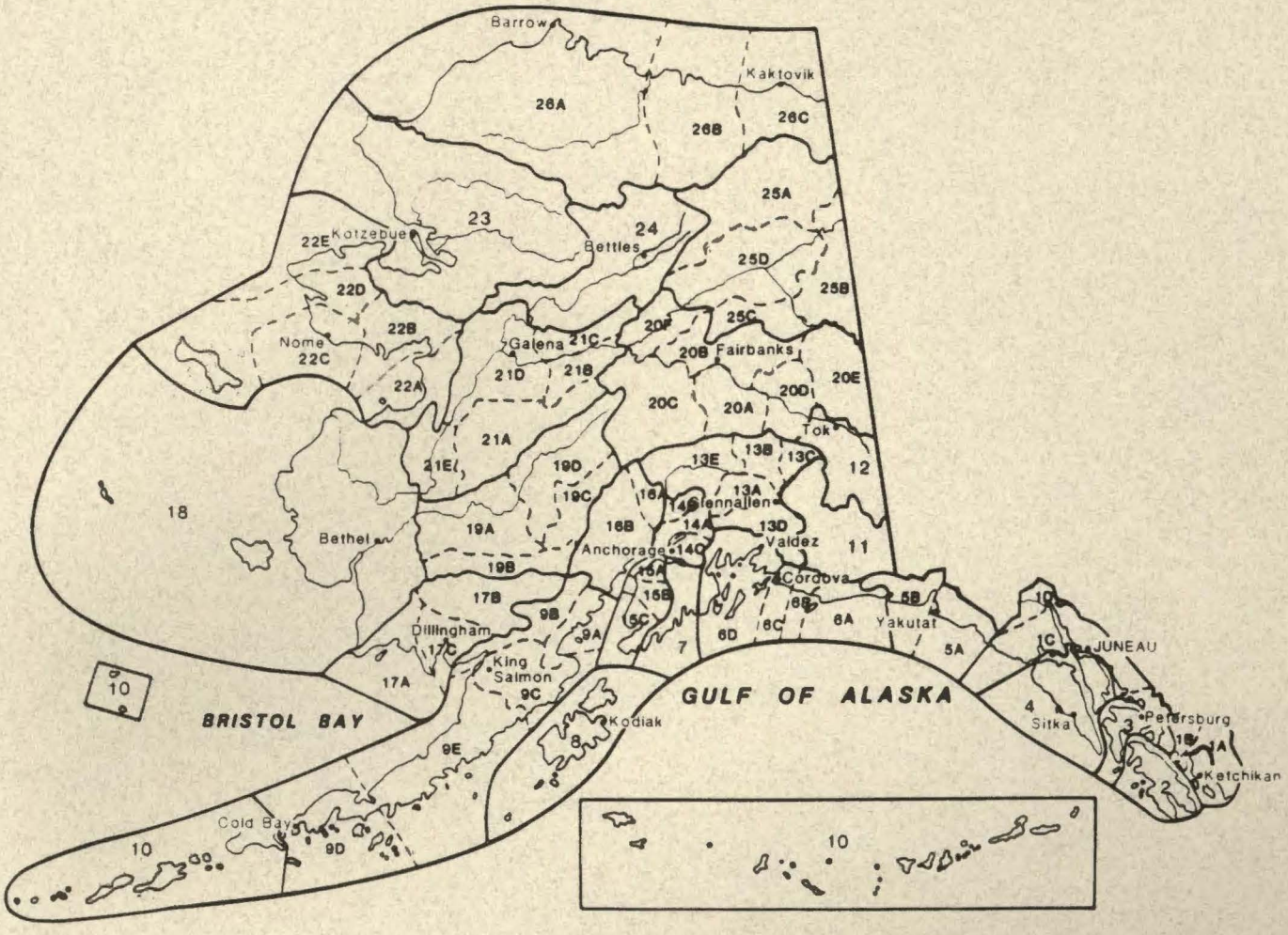
Abstract: Moose (*Alces alces*) exploit the boreal forest where food resources have high nutritive value during brief summers, and low quality and availability during long winters. To accommodate to this fluctuating environment, moose store large quantities of fat during summer and fall which helps to offset their winter energy deficit. Annual rhythms are keyed to this cycle. Intake rates vary seasonally and correspond with nutrient quality and forage availability. Moose are hyperphagic in summer and reduce food intake during winter. Activity budgets vary among environments and seasons with foraging and resting/ruminating occupying most of their time. Metabolism follows a circannual cycle that peaks in mid-summer with a nadir in late-winter; peak metabolism corresponds to maximum energy intake and storage. Moose are classified as seasonally adaptable concentrate selectors that choose a diet primarily of browse foliage and twigs. This diet is high in lignin as well as readily digestible nutrients. Energy and protein requirements are similar to other cervidae. Body composition, like metabolism and intake, is dynamic seasonally. Nutritional adaptations stabilize energy balance and allow moose to withstand energy shortages in a fluctuating environment.

ALCES SUPPL. 1 (1992) pp. 139-155.

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.