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Physiological Ecology of Moose: Nutritional Requirements for Reproduction with Respect to Body Threshold Conditions

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FEDERAL AID FINAL RESEARCH REPORT	ALASKA DEPARTMENT OF FISH AND GAME DIVISION OF WILDLIFE CONSERVATION PO Box 25526 Juneau, AK 99802-5526

PROJECT TITLE: Physiological ecology of moose: nutritional requirements for reproduction with respect to body condition thresholds

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I. PROBLEM OR NEED THAT PROMPTED THIS RESEARCH

Managers increasingly must manage moose populations more intensively within the state. To understand the factors limiting current moose populations and avoid overexploitation, we require a more detailed understanding of the relationship between moose and their environment. Specifically, we need to understand how nutrition, body condition, and reproduction interact to determine population productivity.

Although population size is often dictated by factors including weather and predation, ultimately, the nutritional quality of diets will determine the maximum number of moose that an area can support. Reproductive performance of cow moose is likely related to their body condition. Our intent was to refine the use of an individual animal's condition as an indicator of the nutritional quality of its habitat, as well as a predictor of its potential for reproduction and survival. Furthermore, although body condition and reproductive performance are interrelated, gradual changes in body condition may be more detectable and require smaller sample sizes than fecundity and survival data. The Boolean (yes or no) nature of fecundity and survival data typically requires larger sample sizes to detect significant shifts within populations.

II. REVIEW OF PRIOR RESEARCH AND STUDIES IN PROGRESS ON THE PROBLEM OR NEED

As population density increases, increased competition for resources is coupled with declines in reproduction and recruitment. A density dependent decline in resource availability will result in a reduction in fecundity and survival (McCullough 1979, Clutton-Brock et al. 1983). Our ability to quantify forage quality and quantity has generally been hampered by the extreme variability inherent in natural systems. Recently, methodology for applying the "animal indicator concept" (Franzmann 1985) was validated. Stephenson et al. (1998) developed equations to predict total body fat in moose from ultrasonographic fat measurements. The animal indicator approach assumes that because the animal is a product of its environment, it represents the quality of its environment. Thus, rather than define carrying capacity (K) in numbers of animals, this approach provides a relative indication of the proximity of the population to K. Recently, Grubb (1995) defined nutritional condition as "the state of body components controlled by nutrition and which in turn influence an animal's fitness." Saltz et al. (1995) noted that Grubb's definition clearly identifies the role of nutrition in determining an animal's condition and ultimately its reproductive success. Assessment of body condition provides insight into the ability of individuals in a population to survive and reproduce. However, in order to evaluate the role of body condition in determining an animal's reproductive fitness, we must be able to assess reproductive performance including ovulation, conception, fetal numbers and survival, and natal survival.

Varying emphasis has been placed on the role of summer and winter ungulate ranges in providing for the nutritional requirements of populations. Merrill and Boyce (1991) and Mautz (1978) emphasized the importance of high quality summer habitat in allowing animals to compensate for the nutritional stresses of winter and lactation. Regardless of winter severity, winter ranges in different locations offer different forage species of varying nutritional quality and biomass (Schwartz et al. 1988b; Hubbert 1987; Stephenson 1995). Further complicating matters, Clutton-Brock et al. (1983) proposed the existence of carry-over effects on body condition among years. Debate remains regarding the mechanisms of winter's cumulative effects (Messier 1995, McRoberts et al. 1995). Thus, depending upon the level of stress resulting from reproductive demands and winter severity and habitat quality, the requirements of summer habitats will differ. Post summer and post winter nutritional condition may be used to quantify the respective influences of each season upon the energy balance of individuals.

Although the existence of threshold "set points" of body condition have been hypothesized for ungulates (Schwartz et al. 1988a; Renecker and Samuel 1991; Gerhart 1995), their existence relative to reproduction in moose remains unquantified. Using logistic regression, Albon et al. (1986) determined fertility probabilities in red deer based on body weight, kidney fat, jaw length, reproductive status, and age. The positive relationship between body condition and pregnancy rate in caribou and deer has been well documented (Thomas 1982, Cameron et al. 1993, Cameron and Ver Hoef 1994, Allaye-Chan 1991, Clutton-Brock et al. 1983). In caribou, pregnancy declines with decreasing autumn body mass (Cameron et al. 1993). Furthermore, ovulation rate in reindeer was related to lipid reserves (Leader-Williams and Rosser 1983). In addition, Cameron et al. (1993) predicted perinatal calf survival from the body condition of the female during late gestation. Gerhart (1995) determined that body fat content was the body condition parameter that best explained differences in pregnancy rate in Porcupine Herd caribou. An understanding of thresholds required for ovulation, gestation, and neonatal calf survival will enhance our insight into the importance of different seasonal habitats and the management of these habitats.

Thompson and Peterson (1988) suggested that multifactorial hypotheses should be considered more frequently if we are to enhance our understanding of predator-prey relationships and their interactions with other limiting factors. Captive studies, combined with carefully designed field studies, permit us to individually isolate and test components of complicated models. In particular, we need to quantify threshold "set points" of body condition and their relationship to reproductive parameters in moose. Ultimately, we wish to isolate the importance of habitat quality, predation, weather, and other factors that affect population dynamics.

As a population approaches carrying capacity, increased competition for forage resources should reduce average body condition. Hobbs and Swift (1985) hypothesized that as population density increases, the upper limit on nutritional quality of diets obtainable will decline progressively. A deterioration in the nutritional status of individuals is expected as population density increases and the condition of individuals could be monitored to assess diet quality. Determining the ability of moose to compensate as density changes will enable us to understand the limitations of using the animal condition approach to assess habitat quality and the mechanisms of density dependence. Because thresholds for reproduction and survival likely exist, variation above the thresholds can only be monitored by examining body condition. The ability to precisely monitor condition within a population over an extended time scale may offer the greatest potential to refine monitoring habitat quality.

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III. APPROACHES USED AND FINDINGS RELATED TO THE OBJECTIVES AND TO PROBLEM OR NEED

OBJECTIVE 1: Determine overwinter nutritional requirements for reproductive success in female moose.

H_a: There is a difference in neonatal and in utero calf survival and indices of calf condition with respect to the dam's nutrition during pregnancy.

We conducted feeding trials with adult female moose (Alces alces) on high and low quality diets to assess the influence of nutrition on reproductive success. Ten adult female moose were randomly assigned to 1 of 2 treatment groups (5 per group). Treatment groups consisted of a high quality pelleted moose feed (Schwartz et al. 1985) and a poorer quality sub maintenance ration developed during this study. Known amounts of feed were offered and orts were collected daily to permit calculation of daily energy and protein intake for each animal. Trials were conducted 1 January – 30 April 1998 and 1 January – 30 April 1999. Newborn calves were located by ground surveillance of cows and were captured by hand 24-48 hours following birth. Sex, body mass, total body length, and metatarsus length were recorded at capture. Serum and whole blood was collected for determination of Vitamin E (a-tocopherol), selenium, GGT, Albumin, globulins, and total proteins.

We established a very strong linear relationship between metabolizable energy intake and body condition ($P = 0.001$). Furthermore, we established a curvilinear relationship between maternal condition the mass of neonatal singletons and twins (see appendix). Our sample of cows included animals in optimal body condition which likely led to the asymptote observed in neonatal calf mass. In addition, we also established vitamin E requirements for successful reproduction in cow moose (see Appendix).

OBJECTIVE 2: Determine thresholds in body condition at which reproductive performance declines.

H_a: There is a difference in body condition among female moose relative to reproductive performance (ovulation, pregnancy and twinning, and perinatal and neonatal calf health).

In conjunction with the feeding trials described in objective 1, cow moose were weighed in September and then weekly during feeding trials. We also immobilized these cows during September, November, January, March, and April to measure fat reserves and assess pregnancy using a portable, real-time ultrasound (Aloka 500, Aloka, Inc., Wallingford, CT, USA). In addition, we immobilized cow moose in various field populations and determined in utero fetal numbers and maternal body condition.

We observed a significant increased probability of twinning with increased maternal body condition ($P = 0.01$; see appendix). At maximum body fat (~23%), the probability of twinning approaches 75%.

OBJECTIVE 3: Evaluate the existence of yearly carry-over effects in female moose relative to body condition, reproductive performance, and nutrition.

H_a: Given suboptimal nutrition, reproductive performance of female moose is related to body condition.

We attempted to measure effects of yearly carry-over effects in two groups of 10 animals during the winters of 1998 and 1999. However, we were unable to draw meaningful conclusions or assess these effects because feeding trials were ended after two winters due to unforeseen nutritional deficiencies in the experimental diet which compromised animal health and safety.

OBJECTIVE 4: Refine estimation of moose body composition.

H_a: There is a relationship between ultrasonic fat and muscle measurements and total body fat and muscle mass.

Four captive bull moose on various nutritional planes and during different seasons were used to further evaluate relationships between ultrasonographic and bioelectrical impedance (BIA) measurements and chemical body composition. Animals were euthanized immediately following ultrasonographic and BIA measurements while still chemically immobilized. Chemical analyses of frozen carcass and viscera samples were conducted at Washington State University's Wildlife Habitat Laboratory.

We also demonstrated a relationship between body condition score (BCS) (Franzmann 1977) and chemical body composition in moose. The regression equation percent fat = $1.2779((BCS)^{1.72}$ can be used to predict fat in lean animals with no detectable subcutaneous rump fat ($r^2 = 0.8034$, $P = 0.01$).

OBJECTIVE 5: Develop and refine methodology for diagnosing twinning in moose using ultrasonography and a quantitative serum assay.

H_a: There is a relationship between serum pregnancy-specific B protein (PSPB) concentrations in moose and the number of fetuses in utero.

This was a collaborative effort between the MRC and the University of Idaho, Department of Veterinary Sciences. A graduate student who worked closely with MRC personnel completed a master's thesis (Huang 1998). Huang (1999) isolated, purified and partially characterized PSPB from moose placenta collected by MRC personnel. In addition, serum samples collected from pregnant moose in association with feeding trial immobilizations enabled establishment of gestational PSPB profiles. During the different periods of gestation, the mean amount of PSPB in serum of moose bearing twin fetuses was much higher than that of moose bearing a single fetus. When the moose-specific PSPB radioimmunoassay was used to detect fetal numbers in moose at 10 weeks before parturition, a cut off point at 365 ng/ml PSPB concentration was used as a cut-off value to separate moose bearing single or twin fetuses. The accuracy compared to calving observations was >90% (Huang 2000).

OBJECTIVE 6: Evaluate body condition and reproductive success of moose relative to dietary intake of natural browse.

H_a: There is a decline in moose body condition and reproductive performance as moose per unit area increases.

Foraging habituated moose (n=6) were observed December-April 1999-2002 within each of three 1.0 square mile pens at the MRC to determine how intake parameters (bite size, bite rate, intake rate) and plant nutritional quality (dry matter and protein digestibility) vary among browse-induced architectural plant morphologies of principle winter browse species. In addition, we measured moose body fat via ultrasonography in relation to pen treatment (i.e., early or late successional stage) and winter severity (i.e., snow depth).

Free-ranging moose in 10 Alaskan populations [Nelchina Basin (n = 22), Tanana Flats (n = 89), Denali NPP (n = 38), Copper River Delta (n = 46), Kalgin Island (n = 8), Yukon Flats NWR (n = 12), Togiak NWR (n = 15), Noatak NPP (n = 18), McGrath Management Area (n = 40), and Yakutat Foreland (n = 37)] were handled during collaborative projects (see Appendix). We determined that fat reserves were related to lactation status, diet quality (percent *Salix spp.*), total winter snowfall, and population density (multiple regression, P = 0.01). Post-winter body fat of adult cows ranged between 5 – 17% and enabled ranking of the populations by nutritional status (see Appendix). The magnitude of change both within and among populations corresponds to variation in nutritional carrying capacity and may be used to quantify the relative proximity of populations to K carrying capacity.

IV. MANAGEMENT IMPLICATIONS

We established strong relationships among diet quality, body fat reserves, and reproductive performance in moose. An understanding of these relationships is essential for establishing reasonable expectations for population performance among free-ranging ungulates. Populations that are nutritionally stressed cannot be expected to exhibit high rates of population growth and support sustainable high levels of human harvest.

March estimates of body fat indicate the energy reserves available to individuals to meet energetic demands of reproduction and survival. The magnitude of change both within and among populations corresponds to variation in nutritional carrying capacity and may be used to quantify the relative proximity of populations to K carrying capacity. Quantification of nutritional reserves (e.g., body fat and protein) establishes a mechanism to assess the effects of density dependence (through competition for food) as well as to understand severity of density independent factors (weather, predation) required to manifest effects within populations.

V. SUMMARY OF WORK COMPLETED ON JOBS IDENTIFIED IN ANNUAL PLAN FOR LAST SEGMENT PERIOD ONLY

JOB1: Conduct feeding trials to evaluate the relationship between moose nutrition, body condition, and reproductive performance.

Analysis of feeding trial data was completed during this period.

JOB 2: Evaluate relationship between calf health and the dam's nutrition and body condition.

No work was completed during this period because we did not breed any of our captive animals.

JOB 3: Further validate approaches for determining body fat and body protein in live moose.

We analyzed the relationship between body condition score (BCS) (Franzmann 1977) and chemical body composition in moose. The regression equation percent fat = $1.2779((BCS)^{1.72}$ can be used to predict fat in lean animals with no detectable subcutaneous rump fat ($n = 12$, $r^2 = 0.8034$, $P = 0.01$).

JOB 4: Develop serum assay to detect twinning.

No work was completed during this period.

JOB 5: Monitor body condition and reproductive performance of cow moose feeding on natural browse.

Our efforts to evaluate the relationship between body condition, reproductive performance, diet quality, winter severity, and animal density were focused on free-ranging radiotagged animals rather than tractable animals held at our facility. Natural and predator-caused mortality of adult cow moose at our facility has resulted in too few animals to assess density dependent declines in diet quality. We successfully hand reared 10 moose calves (8 females and 2 males) during this period to facilitate further research.

Fall and spring body condition measurements of female moose on the Yakutat Foreland are indicative of a high nutritional plane. Mean November body fat predicted from ultrasonographic rump fat measurement was 17.0% (n = 22), while March measurements were 10.5% (n = 37). High fat reserves observed in this population result from a combination of excellent summer and winter nutrition provided by abundant willow (*Salix* spp.) forage and reduced lactational costs from high neonatal mortality.

JOB 6: Preparation of reports and publications

We prepared the 1.52 Physiological Ecology of Moose: nutritional requirements for reproduction with respect to body condition thresholds Final Report and 2 manuscripts to be submitted to peer-reviewed journals.

VI. ADDITIONAL FEDERAL AID-FUNDED WORK NOT DESCRIBED ABOVE THAT WAS ACCOMPLISHED ON THIS PROJECT DURING THE LAST SEGMENT PERIOD, IF NOT REPORTED PREVIOUSLY

VII. PUBLICATIONS

HUANG, F., D.C. COCKRELL, T.R. STEPHENSON, J.H. NOYES, AND R.G. SASSER. 1999. Isolation, purification, and characterization of pregnancy-specific protein B from elk and moose placenta. Biology of Reproduction 61:1056-1061.

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STEPHENSON, T.R., J.A.CROUSE, K.J. HUNDERTMARK, AND M.A. KEECH. 2001. Vitamin E, selenium, and reproductive losses in Alaskan moose. Alces 37:201-206.

STEPHENSON, T.R., J.A.CROUSE, ET AL. 2003. Dynamics of body fat in moose and its relationship to nutritional carrying capacity. In preparation.

VIII. RESEARCH EVALUATION AND RECOMMENDATIONS

Additional research needs to be conducted with captive animals to understand the interacting roles of energy and protein relative to nutritional requirements for reproduction. Continued assessment of nutritional status in field populations should incorporate improved collaboration and establishment of protocols for collection of ancillary data.

IX. PROJECT COSTS FROM LAST SEGMENT PERIOD ONLY

FEDERAL AID SHARE $21,326 + STATE SHARE $7,109 = TOTAL $28,435

X. APPENDIX

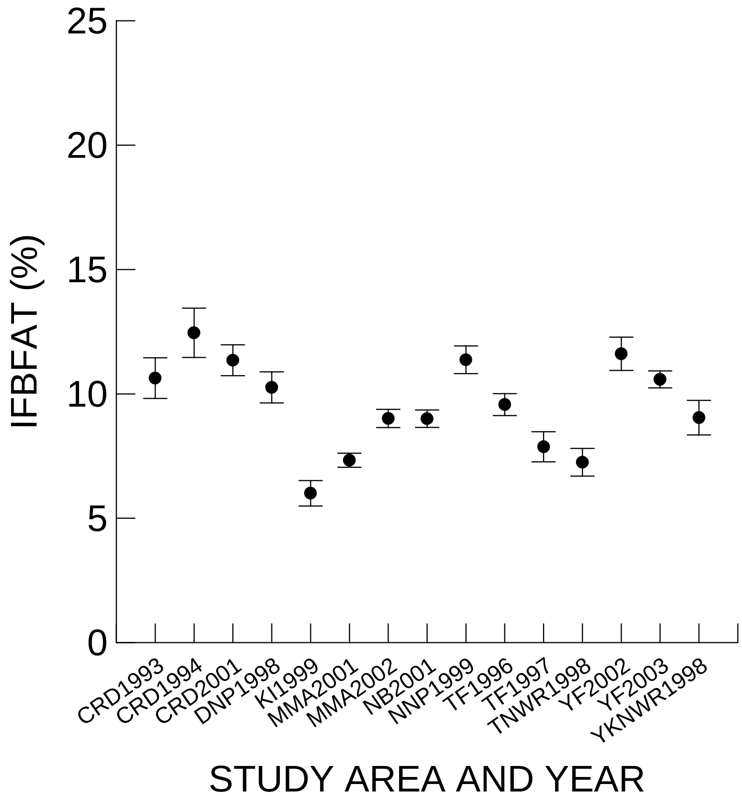

Figure 1. Mean percent ingesta-free body fat of Alaskan moose as predicted from ultrasonographic measurement of subcutaneous rump fat in Spring.
[CRD] Copper River Delta, [DNP] Denali NP, [KI] Kalgin Island, [MMA] McGrath Management Area, [NB] Nelchina Basin, [NNP] Noatak NP, [TF] Tanana Flats, [TNWR] Togiak NWR, [YF] Yakutat Foreland, [YKNWR] Yukon Flats NWR

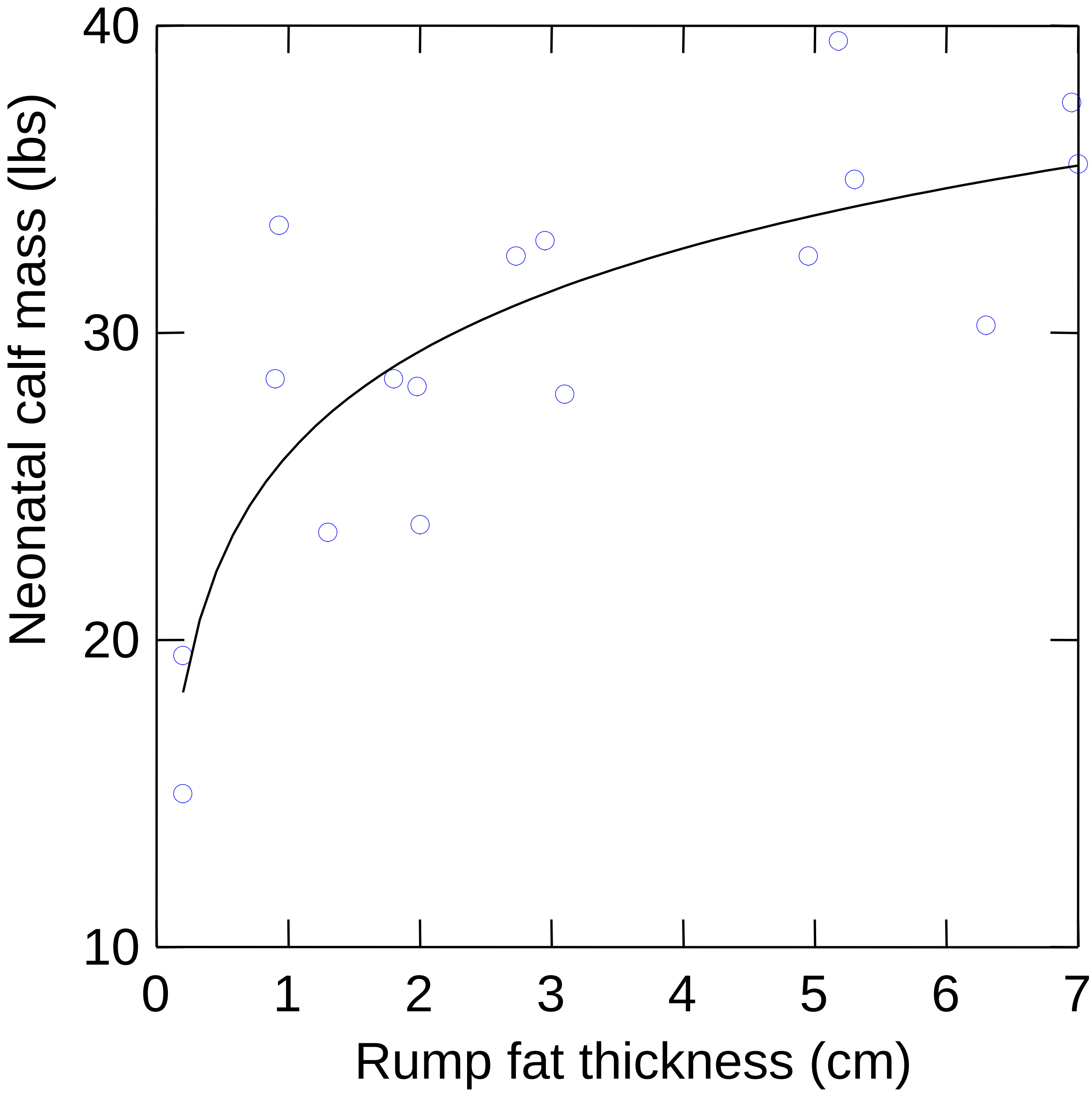

Figure 2. Relationship between neonatal calf mass (twins) and March maternal subcutaneous rump fat measured by ultrasonography.

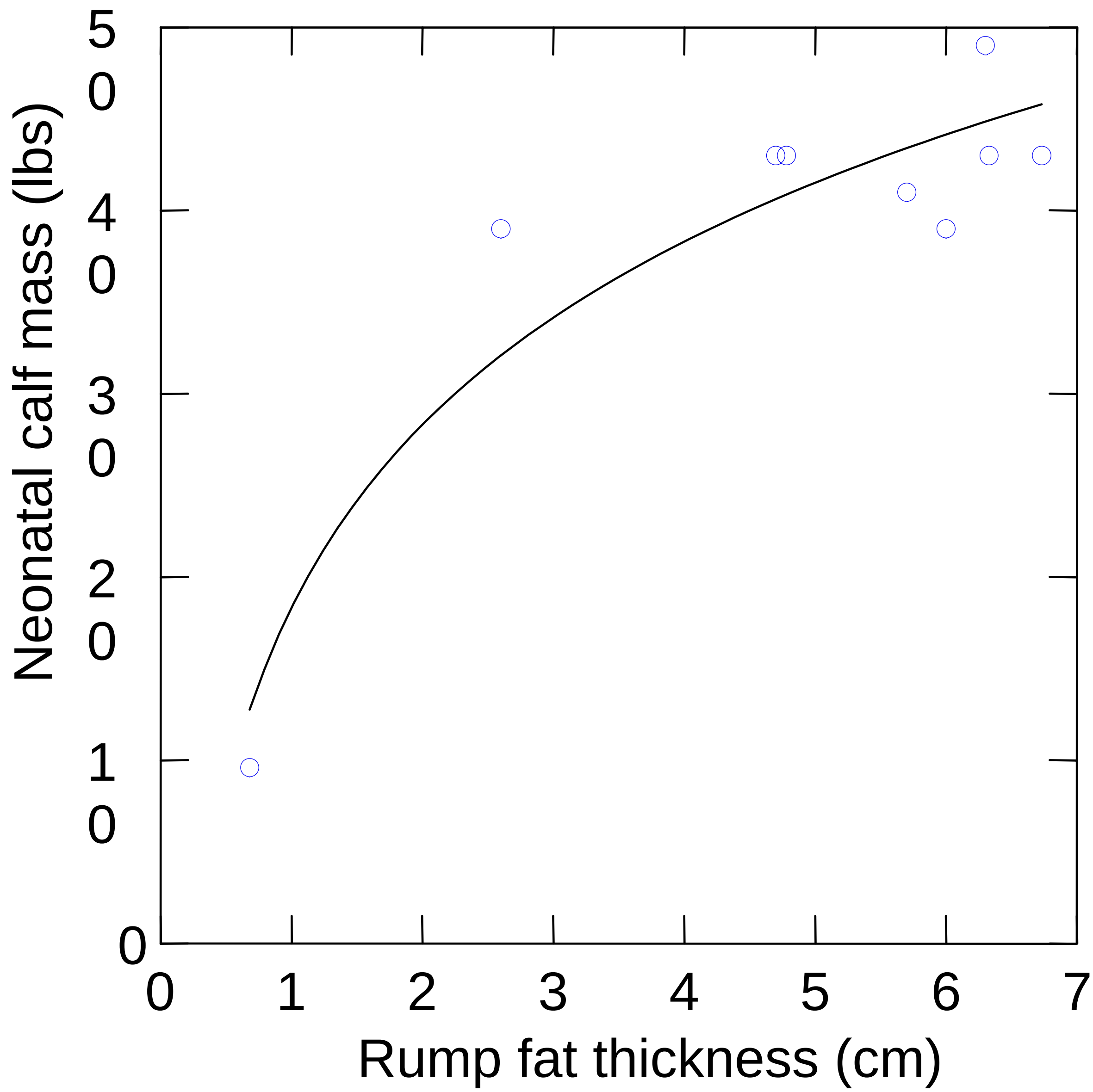

Figure 3. Relationship between neonatal calf mass (singletons) and March maternal subcutaneous rump fat measured by ultrasonography.

ISOLATION, PURIFICATION, AND CHARACTERIZATION OF PREGNANCY – SPECIFIC PROTEIN B FROM ELK AND MOOSE PLACENTA

F. HUANG, D.C. COCKRELL, T.R. STEPHENSON, J.H. NOYES, AND R.G. SASSER

Abstract: Pregnancy-specific protein B (PSPB) has been isolated, purified, and partially characterized from elk and moose placenta. The procedure, which was monitored by bovine PSPB (bPSPB) radioimmunoassay, included homogenization and extraction in aqueous solution, acidic and ammonium sulfate precipitation and ion exchange, gel filtration and affinity chromatographies. The estimated molecular weights of moose PSPB (mPSPB) were 58 kD and 31 kD and of elk PSPB (ePSPB) were 57 kD, 45 kD, and 31 kD by SDS-PAGE. The isoelctric points (pl) of mPSPB were 4.8, 6.6, and 6.7, and of ePSPB were 4.8, 4.9, 6.1, and 6.2 determined by IEF and two-dimensional gel electrophoresis. The carbohydrate content of mPSPB and ePSPB was approximately 3.15% and 4.98%, respectively. Ouchterlony double immunodiffusion test showed when recognized by anti-bPSPB, ePSPB and mPSP B shared identities and both had partial identities compared to the bPSPB. After treatment at different temperatures (20-60°C) for 1 h, the immunoreactives of ePSPB and mPSPB in serum were very stable. Only ePSPB in serum treated at 60°C lost some immunoreactivity. After pH treatment of serum (pH 3-11) for 2 h, the immunoreactivities of ePSPB and mPSPB became lower at acid conditions, remained stable at neutral conditions, and became higher at base conditions. These data demonstrate that moose and elk PSPB have properties similar to those of bovine and ovine PSPB.

A SERUM PREGNANCY TEST WITH A SPECIFIC RADIOIMMUNOASSAY FOR MOOSE AND ELK PREGNANCY-SPECIFIC PROTEIN B

F. HUANG, D.C. COCKRELL, T.R. STEPHENSON, J.H. NOYES, AND R.G. SASSER

Abstract: A double-antibody radioimmunoassay (RIA) specific for elk (Cervus elaphus) and moose (Alces alces) pregnancy-specific protein B (PSPB) was established. Sheep anti-moose PSPB was used for the first antibody and purified placental moose PSPB (mPSPB) was used as a standard. This assay was shown to quantify moose and elk PSPB in serum. When used to detect pregnancy in elk near 40 days after artificial insemination, there was agreement with a bovine RIA at 96%. Accuracy of both RIA's was 93% compared to calving observation. The PSPB concentration in serum of moose increased steadily form 40 to 100-150 days during gestation, but remained steady or decreased slightly between 150 and 190 days. The concentration of PSPB in serum of moose bearing twin fetuses was significantly different and higher than it was in moose bearing single or twin fetuses at approximately 10 weeks before parturition. The accuracy of detection of singles and twins was 90.5%. Based on this RIA, pregnancy can be detected in elk and moose and prediction of single or twin pregnancies in moose is possible.

EVALUATION OF BIOELECTRICAL IMPEDANCE ANALYSIS AS AN ESTIMATOR OF MOOSE BODY COMPOSITION

K.J. HUNDERTMARK AND C.C. SCHWARTZ

***Abstract*:** Estimation of body composition of wild ungulates yields important information regarding nutritional status of individuals and populations, yet there are few suitable field techniques that are nondestructive, unbiased, precise and quick to perform. We tested the suitability of bioelectrical impedance analysis (BIA) as an estimator of body composition of moose (*Alces alces*) for use in the field. A derived BIA variable, impedance volume, was a significant predictor of body fat (mass and percentage) and body water (mass and percentage) when sex was added to models as an indicator variable but explained only 48−57% of variation in composition. Best predictive models included impedance volume, sex, body mass and a body mass × sex interaction. Due to difficulty of measuring body mass of moose in the field, we also generated predictive models when body mass was replaced with a proxy (length × girth^2). Predictive equations for body water were more precise than were those for body fat. Impedance estimates decreased as the subject's hind leg was straightened, indicating that animal positioning must be standardized to minimize bias. Lack of precision made BIA unsuitable for estimating body fat of moose in the field. BIA was a precise and quick estimator of body water in moose, but its limitations made it more suitable for the laboratory than the field.

NITROGEN AND CARBON ISOTOPE FRACTIONATION BETWEEN MOTHERS, NEONATES, AND NURSING OFFSPRING

S.G. JENKINS, S.T. PARTRIDGE, T.R. STEPHENSON, S.D. FARLEY, AND C.T. ROBBINS

***Abstract*:** Stable isotope signatures of lactating females and their nursing offspring were measured on 11 species, including herbivores, carnivores, hibernators, and non-hibernators. We hypothesized that (1) nursing offspring would have stable isotope signatures that were a trophic level higher than their mothers and (2) this pattern would be species-independent. The plasma of adult females had a δ^{15}N enrichment over their diets of 4.1 $\pm$ 0.7 ‰, but offspring plasma had a mean δ^{15}N enrichment over maternal plasma of 0.9 $\pm$ 0.8‰ and no carbon enrichment (0.0 $\pm$ 0.6‰). The trophic-level enrichment did not occur between mother and offspring because milk was depleted in both δ^{15}N (1.0 $\pm$ 0.5‰) and δ^{13}C (2.1 $\pm$ 0.9‰) relative to maternal plasma. Milk to offspring plasma enrichment was relatively small (δ^{15}N enrichment of 1.9 $\pm$ 0.7‰ and δ^{13}C enrichment of 1.9 $\pm$ 0.8‰) compared to the trophic level enrichment between the adults and their diets. While some species did have significant differences between the isotope signatures of mother and offspring, the differences were not related to whether they were hibernators or non-hibernators, carnivores or herbivores. Thus, investigators wanting to use stable isotopes to quantify weaning or other lactation processes or diets of predators when both adults and nursing offspring are consumed must first establish the parameters that apply to a particular species/environment/diet combination.

EFFECTS OF PLANT ARCHITECTURE AND CHEMISTRY ON MOOSE (*ALCES ALCES*) BROWSING BEHAVIOR

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***Abstract*:** We conducted foraging trials with habituated moose inside 2.6 km^2 enclosures to determine how bite size, bite rate, intake rate, and food quality vary with browsing history. Intake was observed on unbrowsed and browsed quaking aspen (*Populus tremuloides*), paper birch (*Betula paperifera*), and Scouler willow (*Salix scouleriana*). Forage quality (dry matter digestibility, digestible protein, tannin binding capacity, and total phenolic content) did not significantly change in response to browsing. However, browse-induced architectural differences greatly affected intake. In species (e.g., aspen and birch) where current annual regrowth was smaller than corresponding unbrowsed twigs, moose selected for larger bites containing both current annual growth and old growth material regardless of browsing history. In species (e.g., willow) where current annual regrowth was of comparable size to unbrowsed twigs, no selection for these bites was observed. Instantaneous intake rates did not differ among architectures in any species. Because unbrowsed stems offered significantly more available biomass than browsed stems however, moose spent more time feeding at each unbrowsed plant and less time traveling than in previously browsed patches. This led to decreased intake when feeding within browsed landscapes as compared to unbrowsed landscapes. Quantification of browse-induced plant architecture is therefore necessary for meaningful assessment of moose habitat quality and nutritional carrying capacity.

VITAMIN E, SELENIUM, AND REPRODUCTIVE LOSSES IN ALASKAN MOOSE

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***Abstract*:** A severe vitamin E deficiency was observed in a captive moose (Alces alces) population that was maintained on a pelleted ration during 9 months per year. During 1998 only 10 of 17 calves identified in utero using ultrasonography at the moose Research center (MRC), Alaska, were born alive. An additional 3 calves exhibited posterior lameness within 3 weeks following birth and 2 of the 3 subsequently died. These symptoms have been previously associated with white muscle disease. White muscle disease results from both vitamin E and selenium deficiencies. While whole blood and liver selenium levels in 3 animals with white muscle disease were above recommended levels, serum vitamin E (α-tocopherol) levels for MRC calves were lower than levels observed in free-ranging neonatal calves in interior Alaska (Tanana Flats). Furthermore, mean serum vitamin E levels in adult cows during March at the MRC (0.08μg/ml were alarmingly lower than free-ranging Tanana Flats moose (2.8μg/ml). We observed vitamin E deficiencies in animals fed diets with 5 IU/kg feed. Our data suggest that clinical symptoms of vitamin E deficiencies in adult moose may be difficult to detect, unless animals are reproducing. Following supplementation of vitamin E to 220 IU/kg in our pelleted ration during 1999, we observed no abortions and only 1 cow had still-born twin calves, but this was attributed to dystocia. Indeed, during 1999 only 2 of 16 calves identified in utero died of

nonpredation causes. Although a vitamin E deficiency in free- ranging moose is unlikely, low selenium levels have been observed in free-ranging ungulate populations. Mean whole blood selenium levels in Tanana Flats moose (0.12μ/g) were significantly lower than MRC adult cows (0.16μ/g) fed a supplemented diet. More importantly, 8 of 10 animals from the Tanana Flats had selenium levels ≤0.085μg/g and were below recommended levels for domestic cattle. Given the lack of data on soil selenium levels in Alaska, deficiency-related neonatal losses may occur that are attributed to other causes of mortality. It will be difficult to quantify in utero and neonatal calf losses resulting from selenium and vitamin E deficiencies if blood or tissue samples from study locations are not examined.

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