Alaska Department of Fish and Game
Division of Wildlife Conservation
Federal Aid in Wildlife Restoration
Research Progress Report

EVALUATION AND TESTING OF TECHNIQUES FOR MOOSE MANAGEMENT

by
Kris J. Hundertmark
Charles C. Schwartz
and David C. Johnson
Project W-23-3
Study 1.39
September 1990

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SUMMARY

We used 4 moose to test a body composition estimation technique involving the urea dilution in blood serum. The dilution of infused urea technique underestimated total body water at equilibration, because of a probable measurement error in blood urea nitrogen (BUN) values and a bias introduced with the technique used to remove gut contents. The ability of bioelectrical impedance anlysis (BIA) to predict total body water (TBW) of moose was compared with predictions of urea dilution and was found to be a promising technique for estimation of body composition. Five adult cow moose were bred on either their 1st (n = 1) or 2nd (n = 4) estrus. Mean length of gestation (n = 3) was 230.7 $\pm$ 4.0 (SD) days. Calves born in 1989 to cows bred on their 1st or 2nd estrus exhibited similar mean growth rates over the summer (1.32 and 1.25 kg/d, respectively), indicating that calves born later in the summer did not exhibit compensatory growth and entered the winter at a lower body weight. Onset of estrus in 3 adult cows corresponded with the nadir point of the concentration of pregnanediol-3-glucuronide (PdG), a progesterone metabolite, in urine; but concentration of PdG throughout gestation did not conform to a pattern typical of ungulates. The concentration of estrogen conjugates (EC) in the urine prior to parturition was determined to be a reliable indicator of the onset of birth. Urinary urea:creatinine (U:C) ratios were unrelated to BUN values and general physical condition of 5 bulls, indicating that analysis of snow-urine may not be an appropriate technique for determination of condition of moose populations. Electrophoretic analysis of liver and skeletal muscle samples from 38 road-killed cow moose and fetuses revealed 5 polymorphic loci, a level of genetic variability heretofore unreported for moose. A manuscript was submitted dealing with energy expenditure of moose calves.

Key Words: Alces alces, bioelectrical impedance analysis, BIA, body composition, breeding, estrous cycle, genetic diversity, gestation length, moose, snow-urine, urine.

CONTENTS

BACKGROUND

Because the Moose Research Center (MRC) has known numbers of confined animals and facilities to handle them, it 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 to 1986 have been published (Franzmann et al. 1974, Franzmann and Schwartz 1982, Franzmann et al. 1987), in addition to more than 30 journal publications (see Schwartz 1987). These publications covered (1) evaluating and testing drugs, (2) trapping methods, (3) aerial and pellet-count censuses, (4) telemetry, (5) biotelemetry, (6) rumen sampling, (7) marking and collaring, (8) weighing, (9) fertilizing browse, (10) electronic tissue measuring, (11) raising moose calves, and (12) developing a moose ration, feeding trial and digestion crates, respiratory chamber, radioisotope digestion markers, and carrying capacity model.

Active jobs include total body fat estimation (Job 4), reproduction studies (Job 5), and miscellaneous techniques (Job 7). Body condition is a critical variable within the moose carrying capacity model (Hubbert 1987, Schwartz et al. 1988a,

1988b), and body fat is a major driver of the moose submodel. This critical parameter (i.e., total body fat) must be accurately measured in moose. A proposal was prepared to test methods for estimating body composition of moose (Schwartz et al. 1988c), focusing primarily on measurements of urea space (Preston and Kock 1973) as an in vivo technique and composition of the peroneus muscle group (peroneus tertius, extensor digitorum longus, and extensor digiti III proprius, Huot and Goodreault 1985) as a technique for use on dead animals.

Over the last decade a body composition estimation technique known as bioelectrical impedance analysis (BIA) has been demonstrated to be a precise and unbiased predictor of human body composition (Lukaski 1987), and it is being investigated for potential use in animal applications (Hall et al. 1989, Jenkins et al. 1988). This technique works on the principle of measuring the impedance (resistince to alternating current) of hydrated body tissues to an alternating current of a known frequency. Nyboer et al. (1943) demonstrated that

$$V = rL^2/R$$

where V = body water volume, r = volume resistivity and is constant for a given conductor, L = conductor length, and R = resistance. [Impedance (Z) actually equals $(R^2 + Xc^2)^{0.5}$ where Xc is reactance, but as reactance is small in relation to R the equation can be reduced to Z = R.]

This technique was tested as a potential indicator of moose body composition.

The need to obtain information for better assessment of "optimum" bull:cow ratios in Alaska moose populations hinges on a thorough understanding of the estrous cycle. This entails the length of estrus, the receptive period during estrus, the time periods between estruses, and the number of estrous periods during the breeding season. Markgren (1969) identified the time between estruses at 25-30 days, but the other needed data have been speculative. At the MRC we conducted late-breeding experiments and were able to demonstrate that calves were subsequently born late (Schwartz et al. 1986a). Although the consequences of altered or nonoptimum breeding during the rut has been attributed to low bull:cow ratios, there is no clear supporting evidence. Nevertheless, the issue remains, and systematic research needs to be implemented to help resolve the matter. Past research at the MRC has documented the length of estrus in moose (Schwartz 1987). During the past 2 years we looked at the effects of 1st- and 2nd-estrous breeding on growth and development of calves; we also measured gestation lengths (Schwartz et al. 1988c, Hundertmark et al. 1989). During this reporting period we continued the breeding studies.

Our reproduction studies would benefit from a technique that would indicate the onset of estrus and whether or not a female was pregnant; such a technique would 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 are cooperating with 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 4-5 weeks prior to parturition and declined dramatically immediately prior to birth. It may be possible to detect these metabolites in urine deposited in clean, fresh snow (snow-urine) and feces (S. Monfort, pers. commun.; Safar-Hermann et al. 1987), which would allow data to be collected from free-ranging moose. We plan to test the hypothesis that progesterone and estrogen metabolites in urine and feces can be used to detect estrus and pregnancy and predict parturition dates in moose.

Urine is a medium containing metabolic by-products that 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 the potential to be an effective management tool for moose as well as other species. A proposal was prepared to study the efficacy of urine analysis in moose management (Hundertmark et al. 1989).

Although the population genetics theory has played a negligible role in management of wildlife populations in North America (Smith et al. 1976), it is emphasized in Europe, particularly in Germany (Leopold 1936) where sportsmen and managers believe that antler size is determined largely by genetics. Studies of white-tailed deer (Odocoileus virginianus) have indicated a relationship between antler development and genetic variability (heterozygosity) (Scribner et al. 1984, 1989). Additionally, the ability to maintain body condition during times of nutritional stress was associated with heterozygosity in white-tailed deer (Cothran et al. 1987) and old-field mice (Peromyscus polionotus, Teska et al. In Press). High levels of heterozygosity also have

been associated with superior reproductive performance in white-tailed deer (Johns et al. 1977) and moose (Ryman et al. 1980).

Management policies can potentially reduce or improve heterogeneity of populations and, therefore, the fitness of individuals (Chesser et al. 1982, Ryman et al. 1977, 1981, Smith et al. 1976). For instance, recent changes in moose hunting regulations for the Kenai Peninsula, based on antler size restrictions, may improve heterogeneity. Knowledge of the degree of heterogeneity in wildlife populations, as well as the effects of management practices on this parameter, would aid in the formulation of management policies that conserve or enhance genetic variability. Before this can be confirmed we must determine if enough polymorphic loci can be detected in tissue samples from the population to allow us to examine the heterogeneity of local populations. To determine this, a study in cooperation with M. Smith (Savannah River Ecology Lab, University of Georgia) was initiated.

OBJECTIVES

To test and evaluate techniques that are potentially useful for management of moose.

To investigate physiological parameters that may provide an index to total body fat in moose.

To investigate the basic parameters of moose reproduction.

To test miscellaneous techniques.

METHODS

Job 4. Total Body Fat Estimation

Four bulls (three calves and one 3.5-yr-old) were confined separately in 3.1- x 15.2-m enclosures at the MRC from January through June 1989. These animals were provided a formulated ration (Schwartz et al. 1985), water, and a mineral lick ad libitum. Beginning on 7 March, 3 bulls were put on limited feed rations based on ad libitum consumption; i.e., the 3.5-yr-old bull was put on a diet of 85% ad libitum, one of the calves was given 85%, and another calf was given 75%. Dry matter of food consumed was calculated to determine actual intake.

Animals were sampled for body composition on a monthly basis beginning in January. Animals were weighed and immobilized with xylazine hydrochloride (Rompun, Hauer-Lockhart, Shawnee, KS). Two blood samples were obtained via jugular venipuncture, one for serum analysis and one for whole blood analysis. A 20% urea solution was prepared and administered via a catheter at a rate of 66 ml/kg live weight (130 mg U/kg), following the technique

described by Preston and Kock (1973). Blood samples were collected at 5.0, 7.5, 10.0, 12.5, 15.0, 22.5, 30.0, and 60.0 minutes after infusion. These samples were centrifuged at the MRC, and the serum was extracted, placed in vials, and frozen prior to analysis. Whole blood was analyzed at the MRC for hemoglobin (Hb) and packed cell volume (PCV). Serum was analyzed for blood urea nitrogen (BUN) and electrolytes. One animal was euthanized on 12 April, 1 June, and 21 November 1989. The 4th animal died on 21 January 1990, 5 days after sampling, from complications associated with immobilization, compounded by a previously undetected internal infection and associated toxemia; this animal was included in this study because of the short period between estimation of body water and death. Euthanized moose were skinned and eviscerated, and the empty carcasses were weighed and cut longitudinally along the centerline of the bodies. Up to 6 patches of shaved skin measuring approximately 10 x 10 cm were cut from each hide, and the peroneus muscle groups were dissected from one leg. The viscera were weighed, emptied of gastro-intestinal contents, weighed again, and frozen along with both halves of the carcass and the skin and peroneus samples. The frozen items (with the exception of the skin and peroneus muscle) were cut into 2.54-cm slices on a commercial band saw; the sawdust accumulated at the base of the saw blade was collected separately for each carcass half and viscera and refrozen (Huot and Picard 1988). The peroneus and skin samples of the first 2 animals were ground with dry ice in a Wiley Mill; however, this became too labor intensive. Samples from the 3rd and 4th animals were freeze-dried before grinding.

Body composition analysis was conducted at the Wildlife Habitat Laboratory, Department of Natural Resource Sciences, Washington State University. The percentage of organic dry matter was determined by drying samples in a 100°C oven for 12-16 h. Crude fat was determined by ether extraction, crude protein by the Kjelldahl procedure, and ash by burning in a muffle furnace at 550°C for 2 h. A minimum of 3 replicates was used to determine each constituent for the following: right carcass, left carcass, viscera, peroneus, and skin.

Equilibration of infused urea solution with body water was estimated in 2 ways. BUN concentration for each animal was plotted against time collected to determine visually the time at which the infused urea equilibrated in the blood. The equilibration point (S_e) derived from this method was at time (t) = 15 min (Hundertmark et al. 1989). The 2nd method involved a least squares estimate of the concentration of BUN at equilibration:

$$S_0 = (S_t/e^{-kt})$$

where S_0 = the extrapolated specific concentration of BUN, which approximates S_e; and S_t = BUN at time t, provided t occurs after equilibration (Holleman et al. 1982). S_0 was then compared to S_{15}.

Total body water space (TBWS) was calculated as:

$$TBWS = D*(S_e-S_b)^{-1}-V_d$$

where D = dose of UN administered; S_b = background BUN naturally occurring in the animal (from the sample taken at t=0); and V_d = the volume of urea solution infused.

Four moose (3 male calves and 1 nonpregnant adult cow) were added to the study in the winter of 1990. These animals were sampled with urea dilution and BIA. Total body water was estimated by BIA after the urea dilution procedure was concluded. Electrodes were constructed from trocars obtained from 10.2-cm, 14-ga spinal needles. The trocar was bent to 90° at 1.27 cm from the tip and was inserted under, but parallel to, the skin with the subdermal tip of the electrode pointing distally. Sender electrodes were placed ipsilaterally (on the same side of the body) on the dorsal surface of the front and hind legs at the joint immediately proximal to the hoof. Detector electrodes were placed 5.1 cm proximal to the senders. Animals were sampled while sternally recumbent. Resistance (R) and reactance (Xc) measurements were obtained from a plethysmograph (model BIA-101, RJL Inc., Detroit, MI), and the total length of the animal was measured to the nearest cm.

Job 5. Reproduction Studies

Five adult and 3 yearling female moose and 2 adult male moose (ages >2.5 years) were used in studies to determine the length of estrus (i.e., the period of sexual receptivity), the length of the estrous cycle (i.e., number of days between each estrus), and gestation length. All animals were semitame and maintained at the MRC. Animals were held in two 4-ha enclosures during the study and fed a pelleted ration (Schwartz et al. 1985). We divided the adult cows into 2 groups. Two cows that had been bred during their 1st estrus (control group) were maintained in one of the holding pens with an intact (i.e., not vasectomized) mature bull. The 2nd group of 3 adult cows was maintained in the 2nd pen with a surgically vasectomized bull. All animals were observed daily beginning in the 1st week of September and continuing through mid-November. Dates of breeding (determined by a cow being mounted by the bull) were noted for each female.

Females that were housed with the vasectomized bull were put with the intact bull about 2 weeks after they were observed mating with the vasectomized bull. These cows were again observed to determine the date of breeding with the intact bull. In 1989 the treatment order was reversed for each female; cows bred on their 1st estrus in 1988 were placed initially with the vasectomized bull in 1989, and cows bred on their 2nd estrus in 1988 were placed initially with the intact bull in 1989. Three yearling females were mistakenly allowed to associate with a

reproductively intact male. Two of these females were observed being mounted.

Following breeding, each female (both groups) was observed when suspected to be cycling into another estrus (19-26 days after 1st estrus) to determine if they recycled (indicating they were not pregnant) or exhibited no signs of a subsequent estrus (indicating they were pregnant). Following the breeding season, all moose were maintained together and fed a pelleted ration throughout the winter.

During the calving season, each cow was checked several times daily to record time and date of calving. Calves were weighed the day of birth using a spring scale (Salter No. 235, London, England), ear tagged, and fitted with a calf mortality transmitter (Telonics Inc., Mesa Arizona). When the calves were approximately 2 weeks of age, they were released with their cows into Pen 1 of the MRC, which contained regrowth vegetation from the 1947 burn and recently crushed vegetation from our crushing program in 1977 and 1986-87. Radio signals from each calf were checked daily for mortality mode, and the calves were observed every 3-5 days during the summer. Growth and development were measured as weight gain/day from time of birth to fall; values in parentheses following means are SD.

Job 7. Miscellaneous Projects

Pregnancy Determination:

Urine was collected from adult cows housed at the MRC by maneuvering a 10-cc vial attached to the end of a pole into the urine stream. Samples from 3 cows (Janie, Oly, and Betsy) were collected daily from mid-October through mid-November 1988, periodically through February, weekly through March and April, and daily in May and June 1989. Urine samples from other adult females, calves, and bulls were collected periodically. Samples were frozen and shipped to the National Zoological Park for spectrophometric analysis of PdG and EC.

Urinary U:C Ratios:

Urine samples were collected from the 4 bulls used in the body composition study every 2-3 days during the winter and spring of 1989. Samples were obtained from a 5th bull, a 10-yr-old, when it became apparent that his physical condition was deteriorating, despite being fed ad libitum. These samples were frozen and shipped to G. DelGiudice (Veterans Administration Hospital, Minneapolis, MN) for analysis of urea nitrogen, sodium, potassium, phosphorus, calcium and creatinine content. Urea:creatinine (U:C) ratios were computed for all samples, excepting those collected within 48 hrs after urea dilution procedures because administered urea was voided in the urine during that period.

Analysis of Genetic Variability:

Samples of skeletal muscle and liver were obtained from 38 road-killed cow moose or fetuses during the winter of 1990. These samples (approximately 3-6 cc in size) were frozen fresh and sent to M. Smith for electrophoretic analysis of genetic composition.

Energy Expenditure in Moose Calves:

Estimation of resting heat production of moose was reported previously (Schwartz et al. 1986b). We summarized resting heat production data for 10 moose calves and made comparisons with data from adult moose.

RESULTS AND DISCUSSION

Job 4. Total Body Fat Estimation

Body fat content of the 4 bulls determined from the band-sawn samples (wet weight basis) ranged from 1.3-7.5% (Table 1). The value for Butch was below 3%, which is widely considered to be the minimum fat level necessary to sustain life (C. Robbins, pers. commun.); however, the ether extract technique may not detect "non-recoverable" fats such as lipoproteins, and this value may represent "surplus" fat rather than total body fat (C. Robbins, pers. commun.). We plan to analyze the body fat samples again using a methanol-chloroform technique that extracts all lipids. Body water content ranged from 65.9-72.8% (Table 1). As urea dilution and BIA are actually measures of body water, these values are of greater interest than fat values.

Estimates of total body water (TBW) via urea dilution for the 4 euthanized animals were related to measured body water (Fig. 1) but not in the way we expected. Theoretically, S_0 should predict TBWS, but these estimates were too low for the 2 leaner animals, as were the S_{15} estimates for all 4 animals. Estimates using the 30-min BUN values (S_{30}) predicted TBWS fairly well, although theoretically these should have overestimated TBWS as they represented postequilibration values. One possible explanation for this anomaly was the variation in the observed water content of the viscera. The GI tract was flushed with water to remove ingesta and allowed to dry to approximately its original water content. This, of course, had the potential for providing biased estimates of visceral water, and examination of our data (Table 1) indicates extreme variation in these estimates. We are considering alternative methods for emptying GI tracts in the future.

The observed relationship between measured body fat (BF) and TBW conformed loosely to the theoretical relationship

$$BF = LW-(TBW/0.732)$$

where LW = live weight less weight of ingesta, and 0.732 = the interspecific mean value of the proportion of water in fat-free mass (Pace and Rathbun 1945, Fig. 2).

Again, the potential bias associated with our visceral water values could have influenced these data, but the differences between the observed and expected values were more likely associated with the difference between the water content of fat-free moose tissue and the interspecific mean used to derive the expected response. Another potential source of error was the BUN values. These were expressed to the nearest mg/dl, and a difference of only 1 mg/dl changed the estimate of TBWS dramatically. Submission of duplicate samples to the veterinary lab often yielded results that differed by 1 or 2 mg/dl.

Estimates of TBWS via BIA were not available for the 4 euthanized animals, because we were not familiar enough with this technique at the time these animals were slaughtered. Comparisons between urea dilution and BIA were limited to the 4 moose added to the study in 1990. The predictor of TBWS by BIA (TL^2/R) was linearly related to the TBWS estimates generated by urea dilution (Fig. 3) and seemed to show potential as an estimator of body composition; however, our sample size was small, and we will not attempt to determine the statistical validity of this relationship until we have more data.

Fat content of the peroneus muscle group was related to total body fat for the 4 moose sampled (Fig. 4), but once again, we refrained from reporting statistical significance because of the small sample size. The general form of the relationship was similar to that reported for caribou by Huot and Goodreault (1985). These observations indicated that this muscle group may indeed be a useful predictor of total body fat; we intend to pursue this.

Job 5. Reproduction Studies

Three cows (Trixie, Angel, and Zumu) were bred on their 2nd estrus in 1989. One (Trixie) exhibited typical estrous cycling, with 24 days between estruses (Table 2). This interval is consistent with normal intervals observed in the 3 prior breeding seasons (Schwartz 1987, Schwartz et al. 1988c, Hundertmark et al. 1989). Although these 3 females were observed daily, we apparently missed the 1st estrus of both Angel and Zumu; they were first observed being mounted during the typical 2nd-estrus period (late October). One yearling female was observed breeding on 5 October (vasectomized bull) and again on 19 November, an interval of 45 days. This interval likely represented the time between her 1st and 3rd estrus periods and conformed to the shorter estrus cycle in yearlings (Schwartz 1987).

Only 1 cow (Trixie) that had bred on her 2nd estrus calved. Zumu aborted her calf on 14 May, and Angel apparently was not

pregnant. The reason for Zumu's spontaneous abortion was unknown; however, it may have been related to a shipment of unpalatable feed we received last winter that the moose refused to eat. Mean gestation length for the 3 cows that gave birth to healthy calves in 1990 was 230.7 (4.0) days. The mean gestation length of 5 cows in 1987-88, five in 1988-89, and one in 1984-85 was 230.6 (4.7) days (Schwartz et al. 1988c, Hundertmark et al. 1989). Mean gestation length for all cows from all years was 230.6 (4.4) days. This gestation length is longer than that reported by Stewart et al. (1987) of 216-218 days for yearling moose in Saskatchewan, within the range reported by Markgren (1969) of 226-244 days for moose in Sweden and the Soviet Union, but shorter than that reported for North America by Peterson (1974) of 240-246 days.

Weight gain per day was nearly identical for 1st- and 2nd-estrus calves (Table 3) to those for the previous year (Hundertmark et al. 1989). Rates of increase for 1st- and 2nd-estrus calves, respectively, were 1.32 (0.08) and 1.25 (0.10) kg/day from birth to late summer and 0.50 (0.06) and 0.51 (0.07) kg/day from late summer to early winter. Respective rates of increase overall were 1.04 (0.07) and 0.99 (0.06) kg/day. One calf was born at an extremely low birth weight, and it likely would not have survived had we not intervened on occasion. Data from this calf are reported in Table 3, but they were not included in calculations of means.

This apparent lack of compensatory growth by 2nd-estrus calves resulted in lower winter weights among this cohort. Mean weight of 1st-estrus calves entering October was 19% greater than that of 2nd-estrus calves. Such a weight difference among moose coming off summer range may result in differential winter mortalities.

Job 7. Miscellaneous Projects

Pregnancy Determination:

Previously (Hundertmark et al. 1989), we reported PdG concentrations from urine collected through January 1989 from cows bred in 1988 and discussed their utility. Methodological problems with these assays necessitated reanalysis of these data along with samples from the remaining duration of gestation; corrected values are listed in Table 4. PdG values fluctuated throughout gestation with a peak immediately prior to parturition (Figs. 5-7). This type of profile is different from that observed with other cervids where PdG levels rise throughout gestation (S. Monfort, pers. commun.). While the profiles were qualitatively similar, the mean values of PdG concentration varied among females, making it difficult to draw conclusions from single samples. Nonetheless, the status (pregnant or non-pregnant) of females for which we collected more than 3 samples was predicted accurately by Monfort, who had no prior information. Zumu was incorrectly classified as nonpregnant

based on 3 urine samples, all of which contained PdG concentrations lower than the maximum value exhibited by Lily, a female calf (Table 4).

Urinary EC levels (Figs. 5-7) conformed to a pattern typical of ungulates in general--remaining low or undetectable until approximately 40 days prior to parturition, increasing and reaching a peak just prior to parturition, and dropping sharply thereafter. This index, therefore, is useful in indicating impending parturition as well as fetal viability, as estrogen precursors are believed to derive from fetal biosynthesis (S. Monfort, pers. commun.). However, additional samples from non-pregnant cows during traditional calving periods would be useful in verifying this technique.

Urinary U:C Ratios:

The 3 yearlings continued to gain weight throughout the study, despite the restricted diets for two of them. The 3-yr-old bull (on 85% ad libitum diet) lost 5% of his body weight and the 10-yr old lost 12%. Therefore, we had moose at various levels of body condition; however, mean urinary U:C ratios did not differ among bulls, nor did monthly mean ratios differ greatly within or among individual animals (Table 5). Warren et al. (1982) and DelGiudice et al. (1987) reported that the U:C ratio (or urinary urea nitrogen) was correlated directly with BUN; however, U:C ratios from the 4 original bulls (we had no blood samples from the 10-yr-old animal) were unrelated to BUN values obtained within no more than 5 days of the urine sample (Fig. 8).

Urinary U:C ratios were ineffective as indices of physical condition of these bulls, based on weight changes. Our conclusion is similar to the findings of Franzmann and LeResche (1978), who reported that BUN was not a suitable indicator of physical condition in moose, but was more an indicator of recent dietary quality. As all animals were fed the same high-protein ration, albeit at different levels, our data supported this conclusion. Published reports of snow-urine as an effective indicator of condition in white-tailed deer (DelGiudice and Seal 1988) and wolves (Mech et al. 1987) may have been valid under the conditions studied, but they have limited application to other situations. Even when applicable, snow-urine assays categorized condition of white-tailed deer only in the broadest of terms (DelGiudice et al. 1989). The degree of interpretation necessary, the lack of precision in classifying condition, as well as the factors that confound this index (DelGiudice et al. 1988) render this technique no more valuable than traditional methods of assessing winter condition (e.g., visually appraising habitat, monitoring winter mortality, monitoring recruitment).

Analysis of Genetic Variability:

Analysis of liver and skeletal muscle samples indicated at least 5 detectable heterozygous loci in the local moose population.

Although all of these loci have been found to be heterozygous in various populations in Scandinavia, no population had been found in which all 5 loci were heterozygous (P. Johns, pers. commun.). This indicates a high level of diversity in our sample and offers the potential to study the genetics of Alaska moose in more detail to determine how heterogeneity relates to population parameters and morphology. The gene frequency data were not available for inclusion in this report, because personnel at the Savannah River Ecology Lab were continuing the examination of our samples.

Energy Expenditure in Moose Calves:

A manuscript concerning resting heat production of moose calves was prepared and submitted to the Journal of Wildlife Management for publication (Appendix A).

RECOMMENDATIONS

We plan to continue to evaluate new drugs and related products as they become available for use. We plan to investigate the potential of using labelled urea for more precise estimations of TBWS. In addition, we are working with the Limnology Lab of FRED Division in Soldotna to develop a more precise urea estimation technique for analysis of body composition serum samples as well as snow-urine. The existing urine samples used for pregnancy determination will be assayed for an additional progesterone metabolite (20 alpha dihydroprogesterone) to determine if a hormone profile more indicative of pregnancy can be established.

LITERATURE CITED

Brundige, G. C., L. J. Layne, and T. R. McCabe. 1988. Early pregnancy determination using serum progesterone concentration in bighorn sheep. J. Wildl. Manage. 52:610-612.

Chesser, R. K., C. Reuterwall, and N. Ryman. 1982. Genetic differentiation of Scandinavian moose Alces alces populations over short geographic distances. Oikos 39:125-130.

Cothran, E. G., R. K. Chesser, M. H. Smith, and P. E. Johns. 1987. Fat levels in female white-tailed deer during the breeding season and pregnancy. J. Mammal. 68:111-118.

DelGiudice, G. D., and U. S. Seal. 1988. Classifying winter undernutrition in deer via serum and urinary urea nitrogen. Wildl. Soc. Bull. 16:27-32.

_____, L. D. Mech, and U. S. Seal. 1989. Physiological assessment of deer populations by analysis of urine in snow. J. Wildl. Manage. 53:284-291.

_____, _____, _____, and P. D. Karns. 1987. Winter fasting and refeeding effects on urine characteristics in white-tailed deer. J. Wildl. Manage. 51:860-864.

Franzmann, A. W., and R. E. LeResche. 1978. Alaskan moose blood studies with emphasis on condition evaluation. J. Wildl. Manage. 42:334-351.

_____, P. D. Arneson, R. E. LeResche, and J. L. Davis. 1974. Developing and testing of new techniques for moose management. Alaska Dept. Fish and Game, Fed. Aid in Wildl. Rest. Final Rep. Juneau. 54pp.

_____, and C. C. Schwartz. 1982. Evaluating and testing techniques for moose management. Alaska Dept. Fish and Game Fed. Aid in Wildl. Rest. Final Rep. 45pp.

_____, _____, and D. C. Johnson. 1987. Evaluation and testing of techniques for moose management. Alaska Dept. Fish and Game, Fed. Aid. in Wildl. Rest. Final Rep. 16pp.

Hall, C. B., H. C. Lukaski, and M. J. Marchello. 1989. Estimation of rat body composition using tetrapolar bioelectrical impedance analysis. Nutr. Rept. Int. 39:627-633.

Holleman, D. F., R. G. White, and J. R. Luick. 1982. Application of the isotopic water method for measuring total body water, body composition and body water turnover. Pp. 9-32 In Studies of production and adaptation in ruminants. Int. Atomic Energy Agency, Vienna.

Hubbert, M. E. 1987. The effect of diet energy partitioning in moose. Ph.D. Thesis. University of Alaska, Fairbanks, 158pp.

Hundertmark, K. J., C. C. Schwartz, and D. C. Johnson. 1989. Evaluation and testing of techniques for moose management. Alaska Dept. Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rept. Juneau.

Huot, J., and F. Goodreault. 1985. Evaluation of several indices for predicting total body fat of caribou. Pp. 157-175 in T.C. Merideth, and A.M. Martell (eds.). Caribou management, census techniques, and status in eastern Canada. McGill Subarctic Res. Pap. 40.

_____, and G. Picard. 1988. A simplified method for assessment of caribou body composition. J. Wildl. Manage. 52:606-609.

Jenkins, T. G., K. A. Leymaster, and L. M. Turkington. 1988. Estimation of fat-free soft tissue in lamb carcasses by use of carcass and resistive impedance measurements. J. Anim. Sci. 66:2174-2179.

Johns, P. E., R. Baccus, M. N. Manlove, J. E. Pinder III, and M. E. Smith. 1977. Reproductive patterns, productivity and genetic variability in adjacent white-tailed deer populations. Proc. Ann. Conf. S.E. Assoc. Fish Wildl. Agencies 31:167-172.

Leopold, A. 1936. Deer and dauerwald in Germany. II. Ecology and policies. J. Forestry 34:460-466.

Lukaski, H. C. 1987. Methods for the assessment of human body composition: traditional and new. Amer. J. Clin. Nutr. 46:537-556.

Nyboer, J., S. Bagno, and L. F. Nims. 1943. The electrical impedance plethysmograph an electrical volume recorder. Nat. Res. Council, Comm. on Aviation, Rept. No. 149. Washington DC.

Markgren, G. 1969. Reproduction of moose in Sweden. Viltrevy 6:127-285.

Mech, L. D., U. S. Seal, and G. D. DelGiudice. 1987. Use of urine in snow to indicate condition of wolves. J. Wildl. Manage. 51:10-13.

Pace, N., and E. N. Rathbun. 1945. Studies on body composition. III. The body water and chemically combined nitrogen content in relation to fat content. J. Biol. Chem. 158:685-691.

Peterson, R. L. 1974. A review of the general life history of moose. Le Naturaliste can. 101:9-21.

Preston, R. L., and S. W. Kock. 1973. In vivo prediction of body composition in cattle from urea space measurements. Proc. Soc. Exp. Biol. Med. 143:1057-1061.

Ryman, N., G. Beckman, G. Jruun-Petersen, and C. Reuterwall. 1977. Variability of red cell enzymes and genetic implications of management policies in Scandinavian moose (Alces alces). Hereditas 85:157-162.

_____, C. Reuterwall, K. Nygren, and T. Nygren. 1980. Genetic variation and differentiation in Scandinavian moose (Alces alces): are large mammals monomorphic? Evolution 34:1037-1049.

_____, R. Baccus, C. Reuterwall, and M. H. Smith. 1981. Effective population size, generation interval, and potential loss of genetic variability in gime species under different hunting regimes. Oikos 36:257-266.

Safar-Hermann, N., M. N. Ismail, H. S. Choi, E. Mostl, and E. Bamberg. 1987. Pregnancy diagnosis in zoo animals by estrogen determination in feces. Zoo Biol. 6:189-193.

Schwartz, C. C. 1987. Evaluating and testing techniques for moose management. Alaska Dept. of Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Juneau. 36pp.

_____, W. L. Regelin, and A. W. Franzmann. 1985. Suitability of a formulated ration for moose. J. Wildl. Manage. 49:137-141.

_____, A. W. Franzmann, and D. C. Johnson. 1986a. Moose Research Center report. Alaska Dept. of Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Juneau.

_____, M. E. Hubbert, and A. W. Franzmann. 1988a. Energy requirements for winter maintenance of moose. J. Wildl. Manage. 52:26-33.

_____, _____, and _____. 1988b. Changes in body composition of moose during winter. Alces 24(in press).

_____, K. J. Hundertmark, and D. C. Johnson. 1988c. Evaluation and testing of techniques for moose management. Moose Research Center report. Alaska Lept. of Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Juneau.

_____, A. W. Franzmann, M. E. Hubbert, and D. C. Johnson. 1986b. Moose Research Center Report. Alaska Dept. of Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Juneau.

Scribner, K. T., M. H. Smith, and P. E. Johns. 1984. Age, condition and genetic effects on incidence of spike bucks. Proc. Annual Conf. S.E. Fish Wildl. Agencies 38:23-32.

_____, _____, _____. 1989. Environmental and genetic effects of antler growth in white-tailed deer. J. Mammal. 70:284-291.

Smith, M. H., H. O. Hillestad, M. N. Manlove, and R. L. Marchington. 1976. Use of population genetics data for the management of fish and wildlife populations. Trans. N. Amer. Wildl. Nat. Res. Conf. 41:119-133.

Stewart, R. R., L. C. Stewart, and J. C. Haigh. 1987. Gestation periods in two yearling captive moose, Alces alces, in Saskatchewan. The Canadian Field-Naturalist. 101:103-104.

Teska, W. R., M. H. Smith, and J. M. Novak. In Press. Food quality, heterozygosity, and fitness correlates in Peromyscus polionotus. Evolution.

Waid, W. D., and R. J. Warren. 1984. Seasonal variations in physiological indices of adult female white-tailed deer in Texas. J. Wildl. Dis. 20:212-219.

Warren, R. J., R. L. Kirkpatrick, A. Oelschaeger, P. F. Scanlon, and F. C. Gwazdauskas. 1981. Dietary and seasonal influences on nutritional indices of adult male white-tailed deer. J. Wildl. Manage. 45:926-936.

_____, _____, _____, _____, K. Webb, Jr., and J. B. Whelan. 1982. Energy, protein, and seasonal influences on white-tailed deer fawn nutritional indices. J. Wildl. Manage. 46:302-312.

PREPARED BY:

Kris J. Hundertmark
Wildlife Biologist II

APPROVED BY:

W. Lewis Pamplin, Jr.
W. Lewis Pamplin, Jr., Director
Division of Wildlife Conservation

SUBMITTED BY:

Karl B. Schneider
Research Coordinator

Wayne L. Regelin
Wayne L. Regelin, Deputy Director
Division of Wildlife Conservation

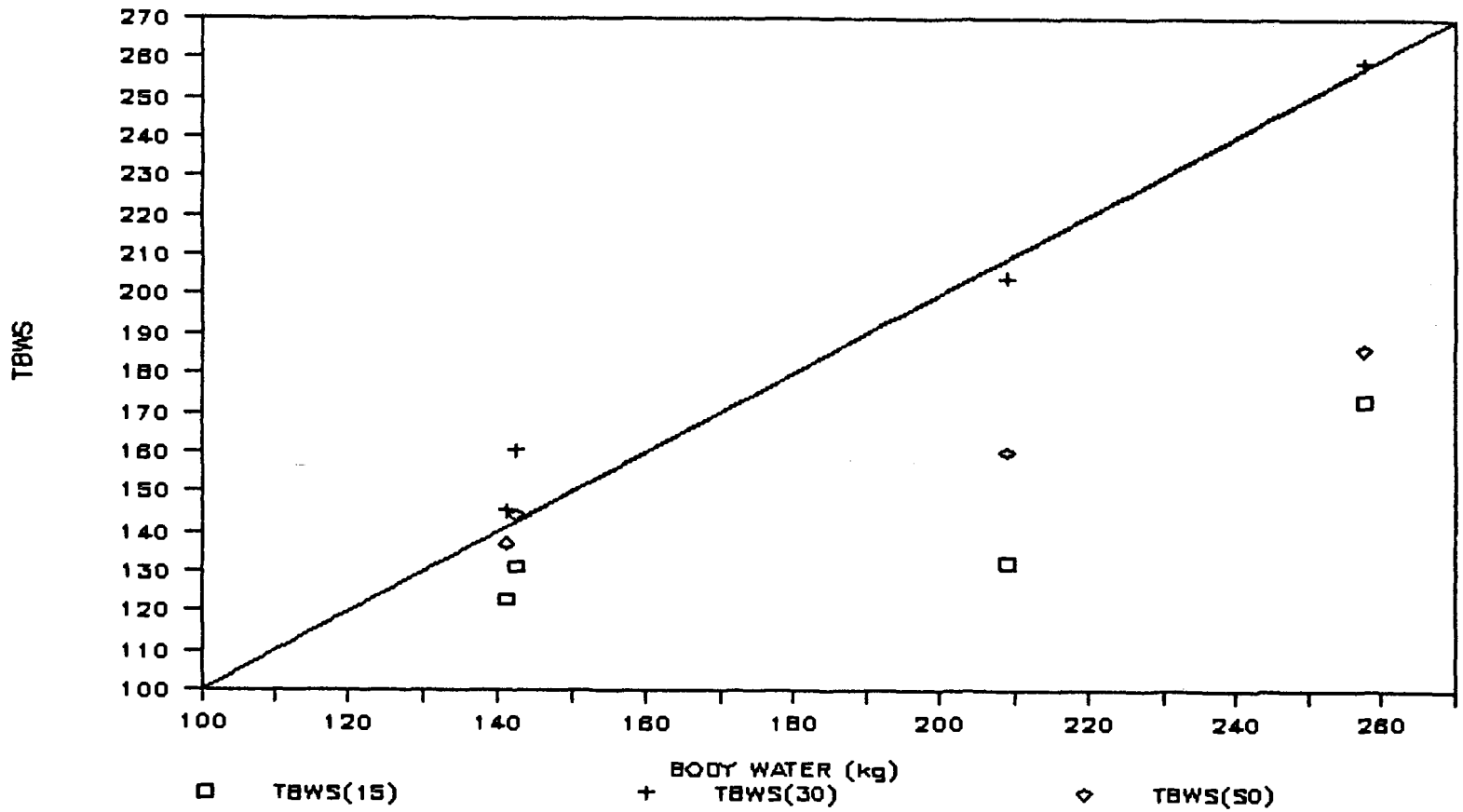

Figure 1. Estimates of total body water space (TBWS) via urea dilution using blood samples taken at 15 and 30 min post-infusion, and with the least squares estimate of equilibration (S0) compared with chemically determined body water for 4 male moose, Moose Research Center, Alaksa. Line of identity is shown.

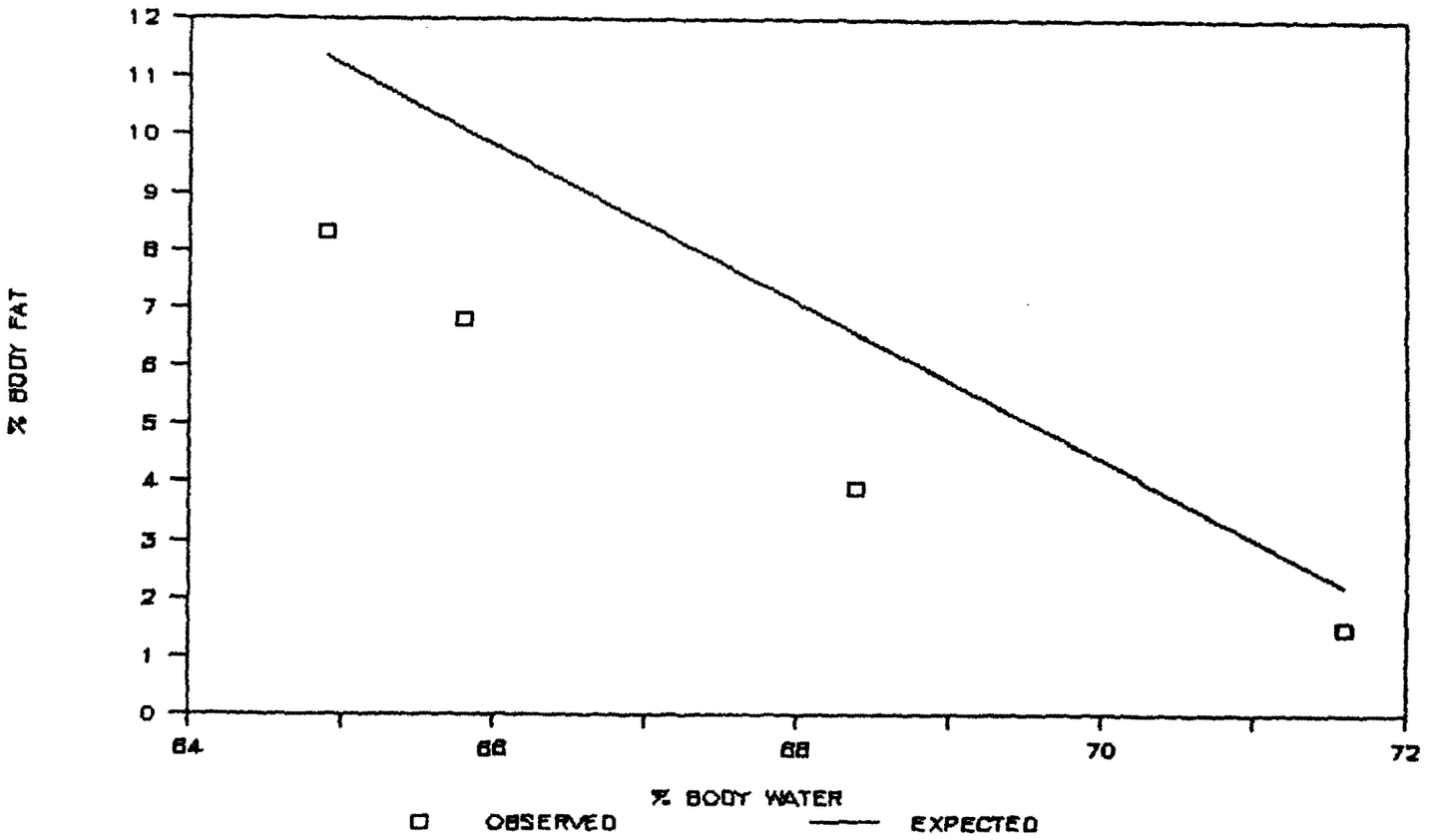

Figure 2. Observed relationship between chemically determined body water and body fat in 4 male moose, Moose Research Center, Alaska. Line represents the theoretical relationshop between these components.

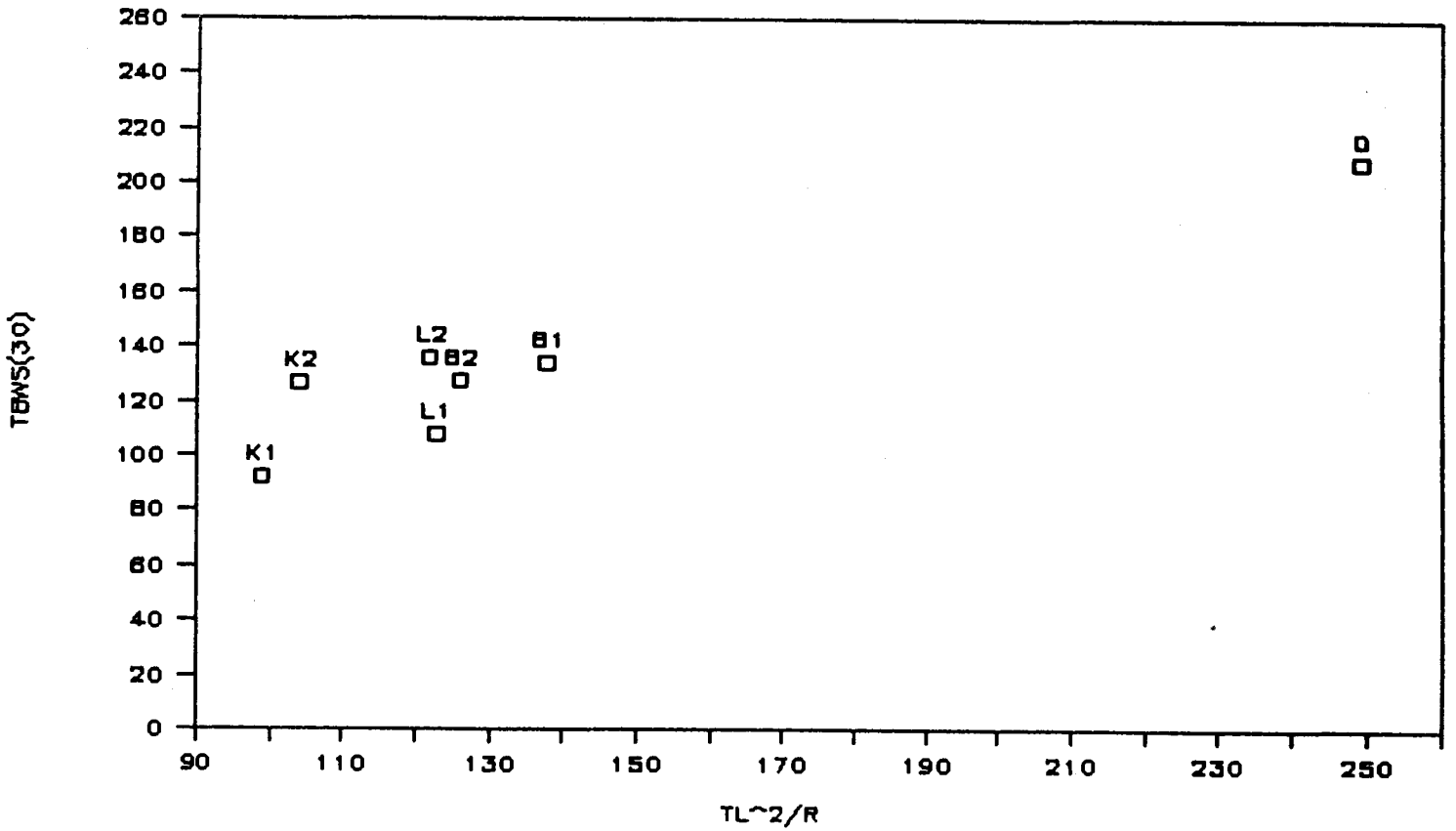

Figure 3. The relationship between impedance-generated predictor of TBWS (TL^2/R) and that estimated by urea dilution [TBWS(30)] for 3 yearling male (K, L and B) and 1 non-pregnant adult female moose (D) at the Moose Research Center, Alaska. Numerals next to animal initials indicate 1st (1) and 2nd (2) estimates, taken approximately 2 wks apart, for the yearlings.

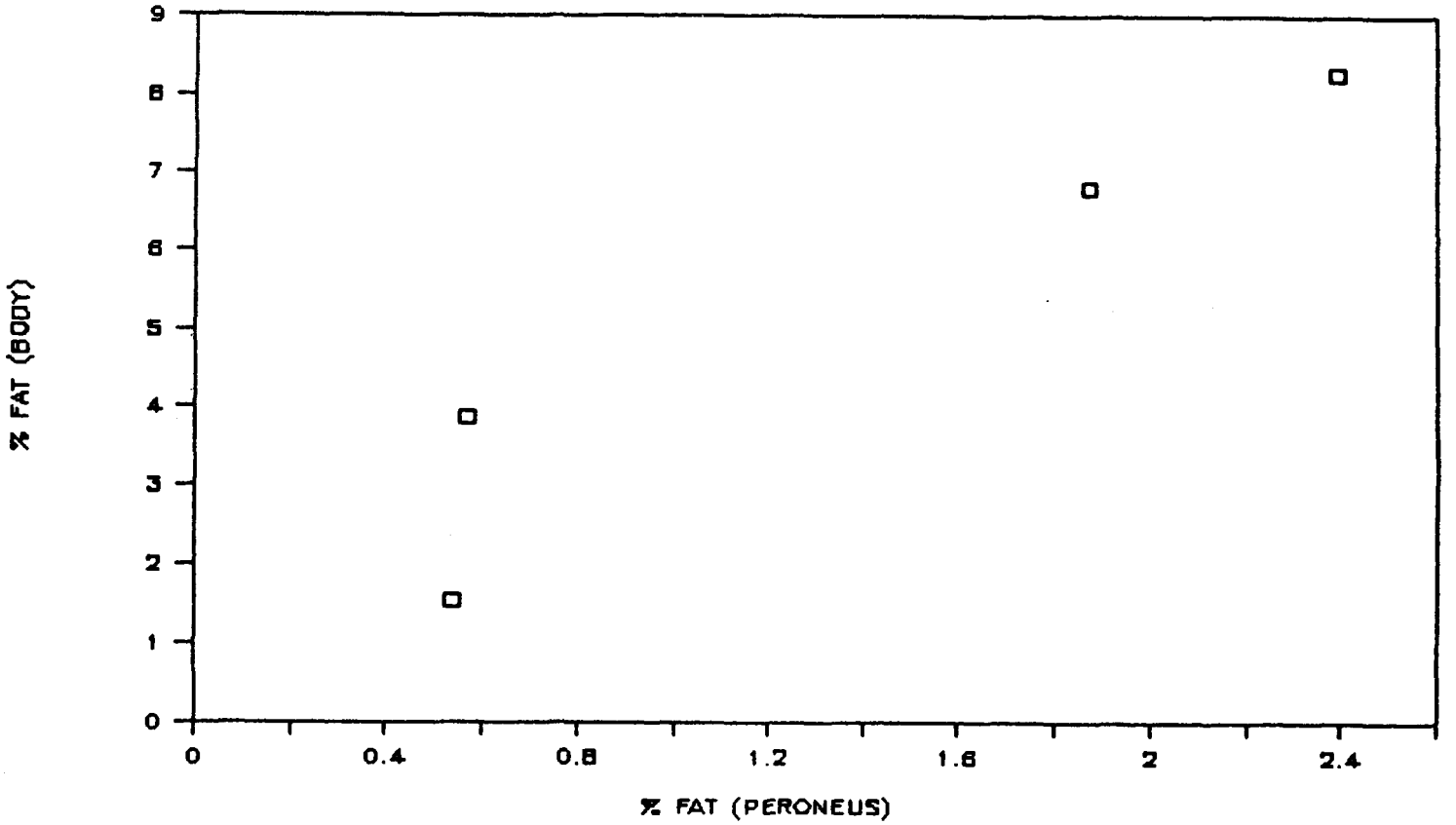

Figure 4. Observed relationship between the chemically determined fat contents of the peroneus muscle group and total body fat for 4 male moose at the Moose Research Center, 1989-90.

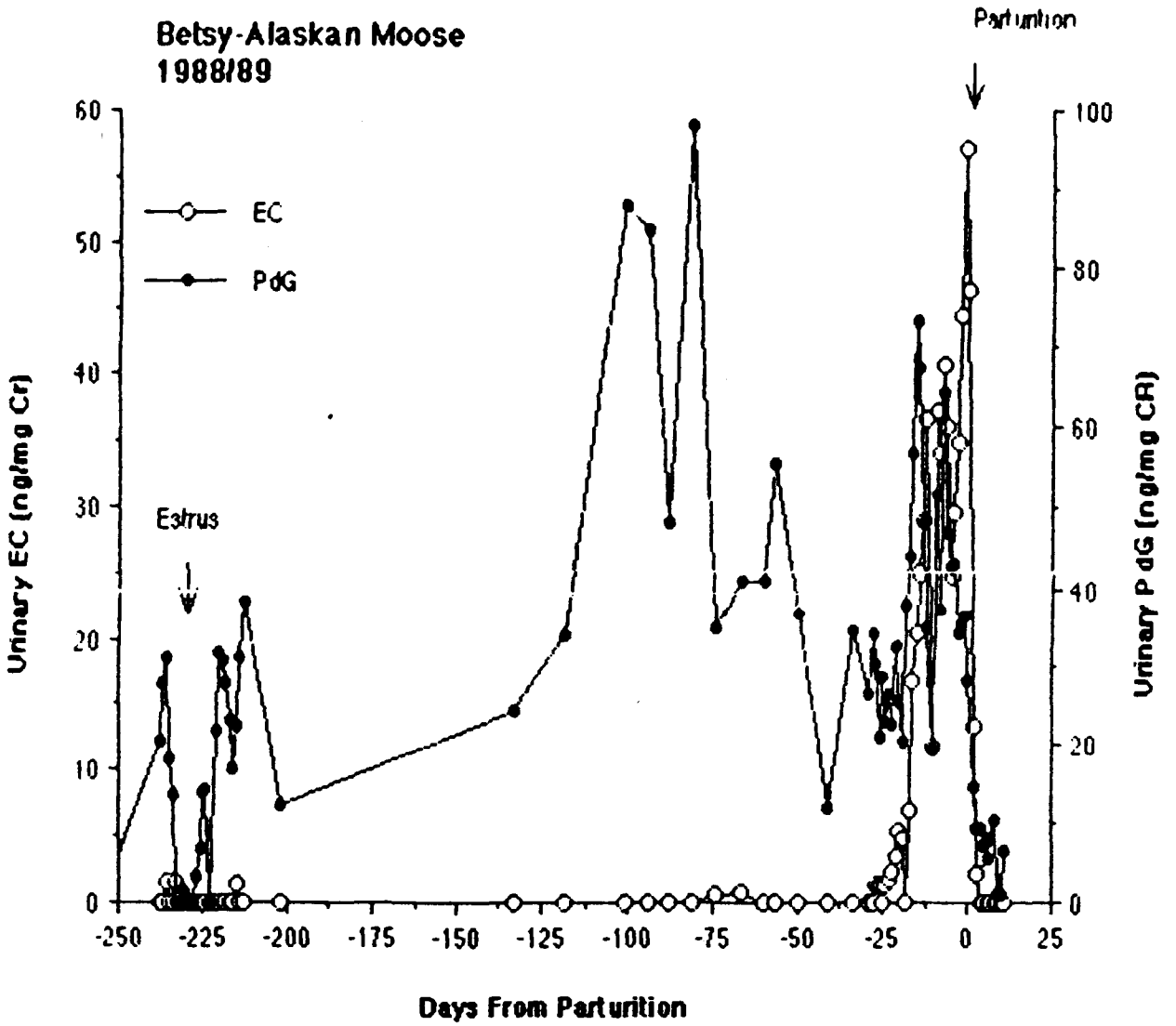

Figure 5. Urinary profiles of PdG and EC for Betsy, a pregnant adult moose at the Moose Research Center, Alaska.

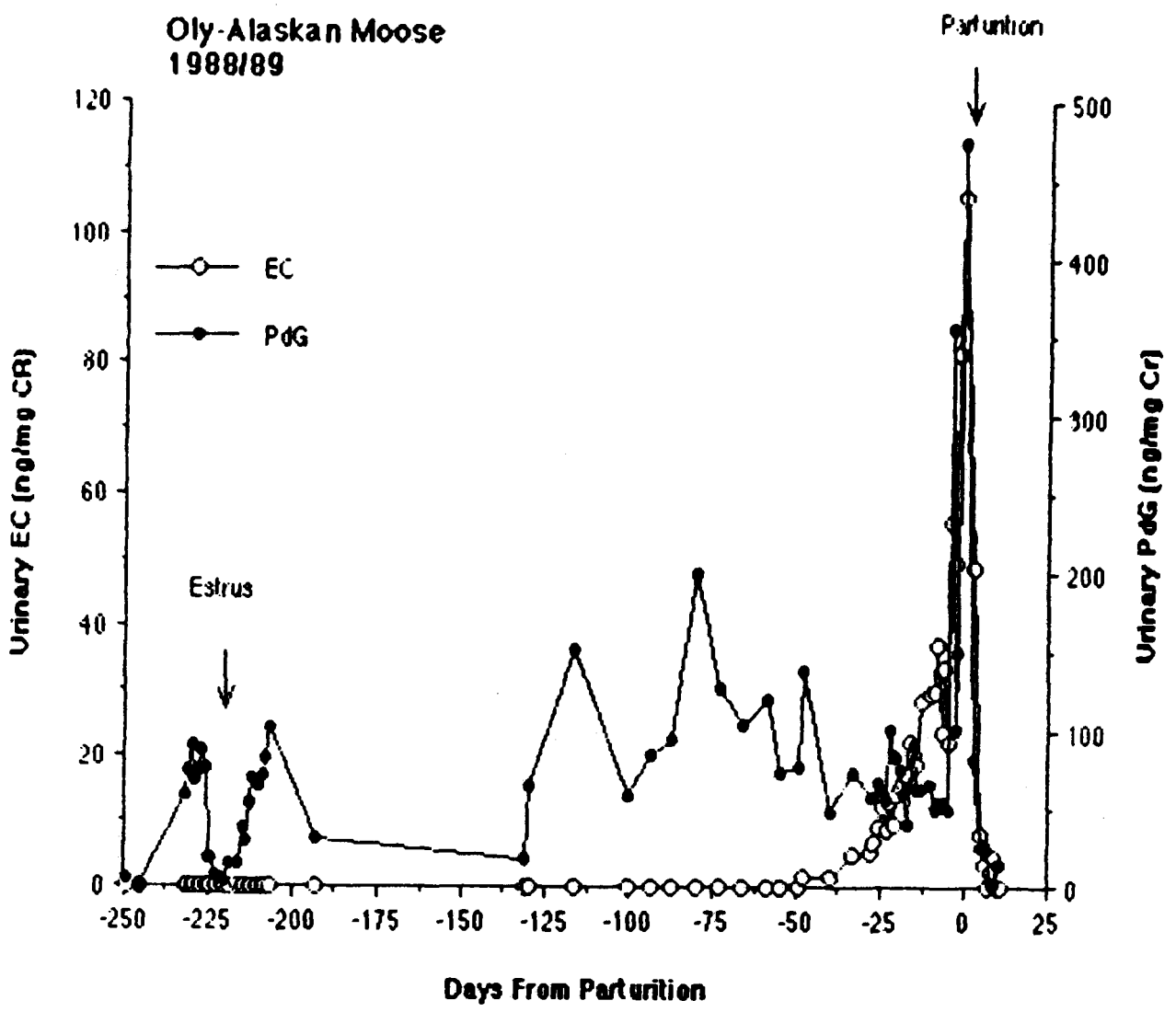

Figure 6. Urinary profiles of PdG and EC for Oly, a pregnant adult moose at the Moose Research Center, Alaska.

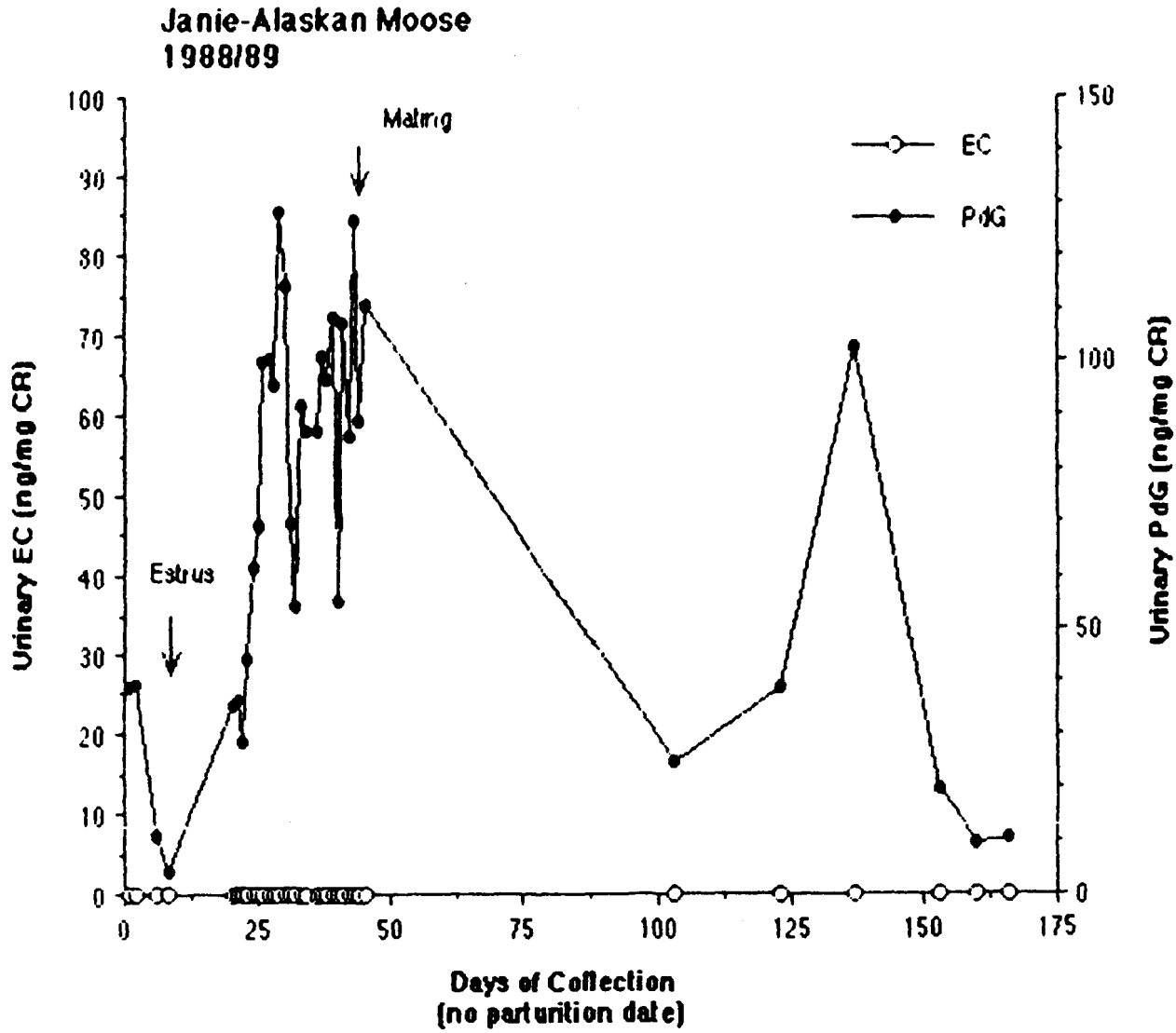

Figure 7. Urinary profiles of PdG and EC for Janie, an adult female moose at the Moose Research Center, Alaska. Janie died before parturition and it was not possible to determine her pregnancy status.

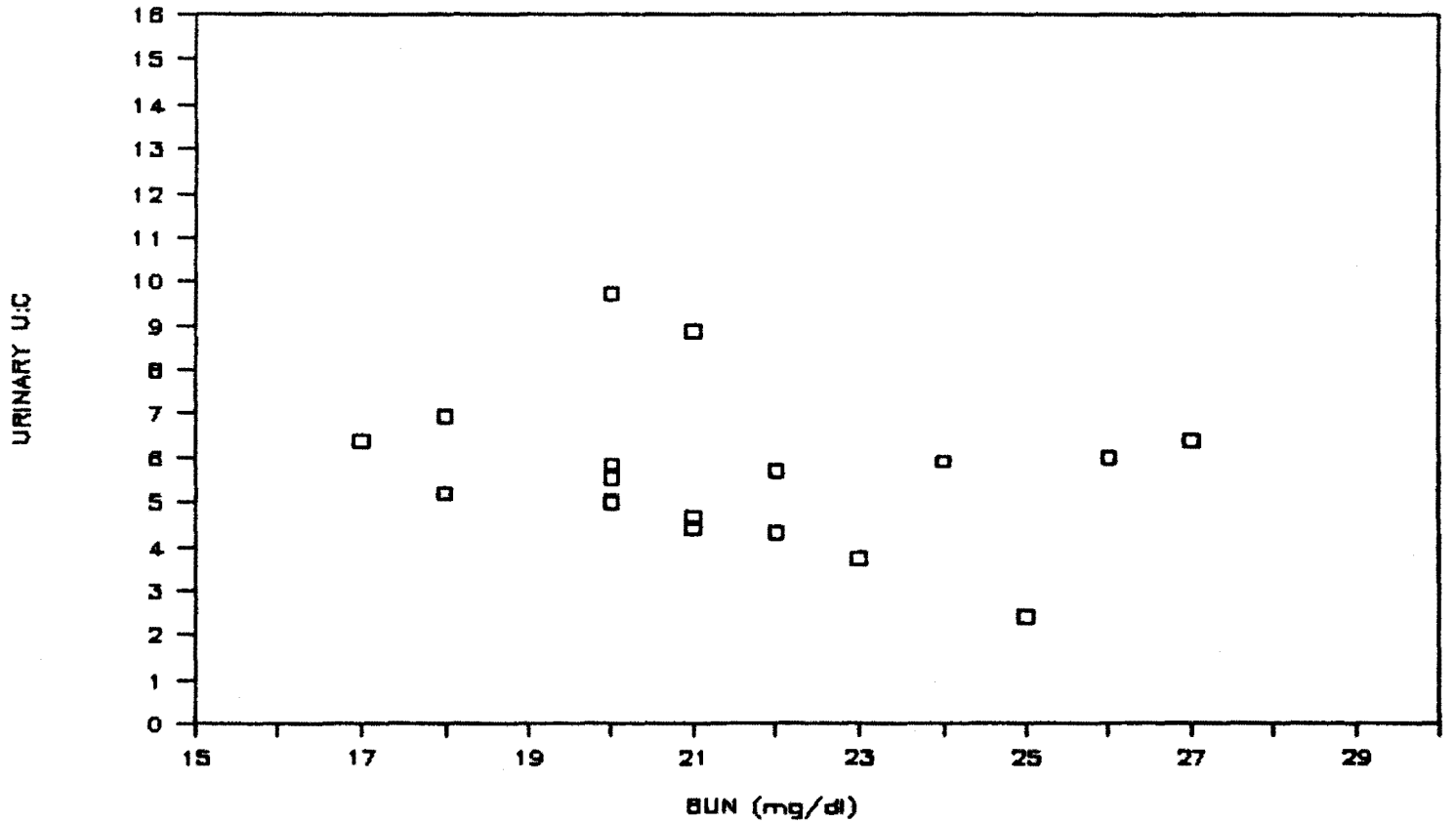

Figure 8. Relationship between urinary U:C ratios and BUN for 4 male moose during winter 1989 at the Moose Research Center, Alaska.

Table 1. Body composition of 4 male moose from the Moose Research Center, Alaska, 1989-90.

Animal	Sample	Wt (kg)	% Fat	% Water	% Crude protein	% Ash
Butch	Left carcass	109	1.8	70.4	19.7	7.5
	Right carcass	109	1.6	71.7	20.4	6.8
	Viscera	32	1.1	81.2	14.4	0.6
	Hide	41	0.4	66.8	33.1	0.4
	Peroneus	0.8	0.5	75.5	21.1	1.5
	Total	291.8	1.5	71.6	21.3	5.5
Bill	Left carcass	130	4.5	65.3	22.2	7.4
	Right carcass	130	4.0	68.1	20.5	6.1
	Viscera	62	5.3	78.0	16.0	0.7
	Hide	54	0.4	65.4	34.1	0.5
	Peroneus	0.8	0.6	74.9	21.9	1.0
	Total	376.8	3.9	68.4	22.3	4.9
Rex	Left Carcass	84	6.7	65.1	20.7	5.7
	Right carcass	84	7.4	63.6	21.8	6.4
	Viscera	28	21.7	63.9	12.3	0.8
	Hide	23	0.8	69.6	29.7	0.7
	Peroneus	0.6	2.4	72.8	22.7	1.1
	Total	219.6	8.3	64.9	21.0	4.8
Yogi	Left carcass	85	6.9	63.5	20.3	7.5
	Right carcass	85	7.2	66.2	19.6	7.2
	Viscera	23	10.5	72.4	13.9	1.0
	Hide	21	0.9	66.5	32.6	0.6
	Peroneus	0.6	1.9	74.8	19.8	1.1
	Total	214.6	6.8	65.8	20.5	6.0

Table 2. Reproductive observations of seven captive female moose at the Kenai Moose Research Center from September to November 1989, and subsequent parturition data, 1989-90.

Moose	Date of estrus	Type of data[a]	Time between estrus periods (days)[b]	Date of parturition	Length of gestation (days)	Calf or Calves Sex	Wt.(kgs.)
Trixie	1 Oct	O				M	15.6
Trixie	25 Oct	O	24	8 June	226	F	14.3
Betsy	2 Oct	O		23 May	233	M	15.6
						F	12.9
Oly	3 Oct	O		24 May	233	F	17.9
Amelia[c]	5 Oct	O					
	19 Nov	O	45				
Zumu	23 Oct	O		14-16 May[d]			
Angel	23 Oct	O		not pregnant			
Sony[c]	22 Nov	O		29 Jun	216	F	15.4
Lily[c]	--	N		4 Jul	--	M	--
						F	--

[a] O = Observed breeding, N = not observed.

[b] Time between first observed mounting of each estrus period.

[c] Yearling

[d] Spontaneous abortion

Table 3. Birth weights and selected subsequent weights of moose calves born at the Moose Research Center in 1989 and their corresponding rates of increase.

Animal name	Birth Weight (kg)	Birth Date	Late summer Weight (kg)	Late summer Date	Early winter Weight (kg)	Early winter Date	Rate of increase (kg/d) Birth - late summer	Late summer - early winter	Birth- early winter
First estrus calves									
Sinuk	15.4	23 May	175	27 Sep	205	1 Dec	1.26	0.46	0.99
Kobuk[a]	5.9	24 May	117	27 Sep	145	2 Dec	0.88	0.42	0.72
Brooks	15.0	26 May	188	29 Sep	224	3 Dec	1.37	0.55	1.09
Mean	15.2						1.32	0.50	1.04
Second estrus calves									
Lara	14.5	13 Jun	137	29 Sep	174	2 Dec	1.13	0.58	0.93
Deshka	14.1	14 Jun	160	4 Oct	189	1 Dec	1.30	0.50	1.03
Luke	13.8	14 Jun	161	4 Oct	187	1 Dec	1.31	0.45	1.02
Mean	14.1						1.25	0.51	0.99

[a] Calf would not have survived without human intervention. Values not included in means.

Table 4. Concentration of pregnanediol-3-glucuronide (PdG), expressed as a ratio to creatinine (C), in the urine of moose of various sex and age classes, Moose Research Center, 1988-89.

Animal	Sex	Age	Date of collection	PdG (ng/ml C)
Lily	F	Calf	14 Nov 1988	38.37
			2 Feb 1989	7.02
Zumu[a]	F	Adult	11 Nov 1988	12.75
			12 Nov 1988	14.83
			3 Feb 1989	24.91
Angel[a]	F	Adult	28 Sep 1988	--
			2 Oct 1988	--
			23 Nov 1988	114.47
			4 Feb 1989	103.20
Trixie[a]	F	Adult	11 Oct 1988	5.41
			23 Nov 1988	230.28
Deneki	F	Adult	21 Nov 1988	9.45
Tutka	M	Calf	10 Nov 1988	2.79
			1 Feb 1989	4.91
Bando	M	Adult	10 Nov 1988	4.37
			2 Feb 1989	3.40

[a] Indicates an animal that was pregnant.

Table 5. Urinary U:C ratios of 5 male moose on various dietary restriction at the Moose Research Center, Alaska, 1989-90.

Animal	Diet level (% ad libitum)		Mean U:C ratio (SD) Overall	Jan	Feb	Mar	Apr	May
Yogi	75		5.5(2.4)	3.8(--)	4.7(1.0)	5.9(0.8)	4.8(2.3)	6.9(1.6)
		n	29	1	7	11	5	5
Chief	100		5.5(1.4)	--	--	5.4(--)	5.2(1.6)	5.7(1.4)
		n	12				5	6
Rex	85		5.5(1.9)	6.8(--)	5.0(3.1)	5.7(0.7)	5.8(0.2)	--
		n	22	1	8	11	2	
Butch	100		5.4(1.9)	5.2(--)	4.6(0.8)	6.1(2.8)	5.7(0.7)	--
		n	24	1	9	10	4	
Bill	85		5.5(1.4)	4.9(1.5)	5.8(2.1)	5.5(0.8)	4.9(0.9)	--
		n	25	2	9	10	4	

Appendix A.

ENERGY EXPENDITURE IN MOOSE CALVES

CHARLES C. SCHWARTZ, Moose Research Center, Alaska Department of Fish and Game, 34828 Kalifornsky Beach Road #B, Soldotna, AK 99669

MICHAEL E. HUBBERT, Institute of Arctic Biology, University of Alaska, Fairbanks 99701[1]

ALBERT W. FRANZMANN, Moose Research Center, Alaska Department of Fish and Game, 34828 Kalifornsky Beach Road #B, Soldotna, AK 99669

Abstract: Resting heat production was estimated in an open circuit respiration chamber for 10 moose (Alces alces) calves during the summer and late winter. Heat production measurements did not differ ($P = 0.3097$) between sexes, but summer measurements (172 kcal/kgBW$^{0.75}$/d) were significantly higher ($P = 0.0001$) than those from late winter (117 kcal/kgBW$^{0.75}$/d). Resting heat production estimates for calves were higher than those reported for adult moose.

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Key Words: Alces alces, energy requirements, heat production, metabolism, moose.

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