# 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 kcals 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. Change 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.

ALCES VOL. 24 (1988) pp.178-187

Use of animals to assess the nutritional status of populations has received increased research attention in recent years. Franzmann (1985:240-259) outlined the steps required to apply the animal-indicator concept to assess nutritional status of large herbivores. He listed the 4 steps required to quantify relative condition: (1) identify boundary conditions, (2) establish baseline values, (3) determine parameter response to perturbation, and (4) determine the resilience of an animal to further perturbation.

Body composition and fat reserves change with animal condition and have been used as indicators of animal condition (Ledger and Smith 1964; Robbins *et al.* 1974; Monro and Skinner 1979; Verme and Ozoga 1980; Torbit 1981; Torbit *et al.* 1985a). Fat metabolism in northern cervids is a dynamic process; large gains and depletions are associated with the summer flush of forage and winter declines in food availability and quality, respectively. Seasonal weight dynamics of northern cervides have been associated with reduced diet quality and forage availability (Severinghaus 1955, 1979; Park and Day 1942). However, numerous studies (McEwan and Whitehead 1970; Ozoga and Verme 1970; Westra and Hudson 1981; Wheaton and Brown 1983; Schwartz *et al.* 1984) have demonstrated a seasonal reduction in intake of dry matter with subsequent weight loss for various deer species maintained on a high-quality diet offered ad libitum throughout the year. Regulation of intake and its subsequent effects on body composition are complex physiological phenomena controlled by the central nervous system (Forbes 1980). Arnold (1985:82) provided an excellent review of these mechanisms and suggested that "long term stability in energy balance is thought to be controlled by the size of the fat reserves."

Torbit *et al.* (1985b) examined the relationships between body composition estimates of mule deer (*Odocoileus hemionus*) using two different procedures. They concluded that body composition could be reliably estimated using dilution techniques to estimate the total body water pool with tritiated water (HTO). This technique provided

estimates of body composition of individuals in a nondestructive manner.

Objectives of this study were to (1) determine if fat dynamics could be measured in moose using indirect estimates of total body water as suggested by Torbit *et al.* (1985b) and (2) evaluate the potential of using these estimates as indicators of animal condition using the criteria outlined by Franzmann (1985).

## METHODS

Experimental protocal was previously described by Schwartz *et al.* (1988), but a brief summary is provided.

### Trial 1: Varied Intake of Same Quality Food.

Nine moose, including 6 adult females and 3 males (2 yearlings, 1 adult) were used as experimental animals. Trials began on 21 November 1983 and continued through 22 April 1984, a period equivalent to winter in Alaska. Animals were alloted into 3 treatment groups on the basis of sex and weight. Treatments were assigned as ad libitum, or 85% and 70% ad libitum intake (high, medium, or low intake) and calculated as dry-matter intake (DMI) expressed per unit of metabolic body weight ($BW^{0.75}$). All moose were fed a pelleted diet (Schwartz *et al.* 1985).

### Trial 2. *Ad libitum* Intake of Varied Quality Food.

Nine adult moose (6 females and 3 males) were used as experimental animals. All moose in trial 1 were used in trial 2, except for a mature bull that was replaced with a 2-year-old male. Animals were maintained prior to studies on the pelleted diet used in trial 1. Feeding trials began on 27 November 1984 and continued through 12 April 1985. Animals were divided into 3 treatment groups on the basis of sex and weight. Treatments were assigned as high-, medium-, and low-quality diets on the basis of a metabolizable energy content of 2.4, 2.1, and 1.8 kcal/g (high, medium, or low quality) of feed (Schwartz *et al.* 1988). Animals were fed ad libitum throughout the experiment. Chemical composition and ingredients used in the ration were reported by Schwartz *et al.* (1988).

During both trial 1 and 2, animals were maintained in individual pens (3.1 X 15.2 m). The only protection from the weather was provided by a small covered shelter (3.1 X 2.4 m) where animals were fed. Water and salt were available ad libitum. Animals were weighed on a counter-balance scale weekly. Intake of dry matter was measured daily from subsamples of food and orts dried at 60 C for 48 hours (Schwartz *et al.* 1984).

At 4-week intervals, each animal was injected with HTO and placed in a digestion cage to collect marked urine for determination of total body water. Body composition was estimated for all moose every month. Because of a limited number of digestion cages, 3 animals were tested weekly. This sampling design was used so that we could estimate total body water in all animals for treatment 1 (high intake or quality) in a single week; the 2nd and 3rd treatments (medium intake or quality) were sampled the 2nd and 3rd weeks, respectively. When body water was estimated, each animal was given a deep-muscle injection of 2 ml of a physiological saline solution containing 1 uCi of HTO per ml. Injections were administered to undrugged animals while they stood on the scale for weighing. After injection, animals were moved to digestion cages for 4 to 6 d. Urine samples were collected prior to injection and at approximately 12-h intervals after injection for 4 days. Collection trays were cleaned with water prior to each trial and lined with new plastic sheeting prior to each sample collection. At the conclusion of a trial, animals were returned to their individual isolation pens. Urine samples were analyzed for HTO, according to methods described by Holleman *et al.* (1982). Estimates of total body water were determined by least-squares analysis

(Neter *et al.* 1985:23-51) of the logarithms of specific concentrations (corrected for background) on time after injection as described by Holleman *et al.* (1982). Total body water was calculated as the injection dosage/intercept. Corrected estimates of total body water, body fat, protein, and ash were obtained with equations presented by Torbit *et al.* (1985b).

Because the data sets lacked homogeneity of variances (Winer 1971:), treatment differences were tested with a multiple comparison Bonferonni t-statistic. Analyses were done on adjusted means (adjusted for initial starting values);i.e. fat, protein, and total calories. Statistical significance was accepted at P = 0.05/3 = 0.0167 (Bonferonni).

## RESULTS

### Trial 1

The experimental design in trial 1 resulted in 3 levels of DMI and subsequent associated weight change (Table 1, Fig. 1). Target intakes of 85% and 70% ad libitum were actually 85.1% and 72.5%, respectively, when averaged over the entire experiment (Schwartz *et al.* 1988). Because there were differences between male and female moose in dynamics of body composition, males were not included in the analysis and comparisons between treatments. Data for males was presented for comparative purposes only.

Two male animals had to be removed from the experiment prior to completion because of extreme weight loss; one was in the medium and the other in the low treatment. Details have been previously reported (Schwartz et al. 1988). Both animals were returned to ad libitum feeding levels in February, and weight change and body composition estimates reflected this change.

Change in body weight (X + SD) for female moose from October through April was 7.0 + 0.6, 3.8 + 0.1, and -0.4 + 0.3 % for the high, medium and low intake groups, respectively (Fig. 1). These data suggest virtually no change in body weight from the beginning to the end of winter. In their review of weight dynamics of moose, Schwartz *et al.* (1987) indicated that weight gains in females during late winter were associated primarily with changes in fetal mass and did not reflect gains in body mass. Female moose in these studies were pregnant, so gains in weight in late winter probably reflect this phenomenon. Changes in body weight were not statistically different among treatments.

Estimates of total body water from the least squares analyses (Table 1) varied among individuals and treatments. Least squares analyses resulted in high correlation coefficients, indicating good estimates of the concentration of HTO at time 0 (Y-intercept). Uncorrected estimates of total body water varied among animals and treatments (Table 1). Total body water determined by the dilution technique is overestimated by approximately 4-15% (Carnegie and Tulloh 1968; Sheng and Huggins 1979; Nagy 1980; Fancy 1986) in mammals.

Regardless of treatment, the dynamics of body composition were markedly different among males and females; these dynamics also reflect differences in seasonal dry-matter intake (Schwartz *et al.* 1984) and weight gain or loss (Schwartz *et al.* 1987) between sexes. Males in trial 1 were probably at peak body condition prior to the September-October rut, while females did not reach their peak until January or February, depending on treatment. We estimated body composition during mid-September for the male moose Charlie in the ad libitum treatment just after the rut began. His total body weight at that time was 317.5 kg; estimates of fat, protein, and ash were 23.4, 59.1, and 11.6 kg, respectively. His monthly body fat, expressed as a percentage of ingesta-free body weight, was 8.3, -5.6, -9.9, 1.1, 7.5, 20.2, 18.8, and, 10.3 in September to April, respectively. We were unable to obtain estimates for the male Chief (85% ad libitum) during September, October, and November because he was not tractable dur-

Table 1. Treatment, date, weight, intake and estimates of body condition for female moose fed a pelleted ration at ad libitum, 85, or 70% of ad libitum intake. Data presented are the mean (SD) of 2 females per treatment.

| Treatment | Injection Date (mo-d) | Injection Weight (kg) | Intake[1] $g/kgW^{0.75}$ | Body Water (kg) | Fat (kg) | Protein (kg) | Ash (kg) | Energy (kcal X $10^3$ |
|---|---|---|---|---|---|---|---|---|
| Ad libitum | 10-09 | 436(20) | -- | 284(32) | 63(17) | 79( 5) | 16(1) | 1014(134) |
| | 11-21 | 458(30) | -- | 297(33) | 69(10) | 83( 6) | 16(1) | 1090( 57) |
| | 12-19 | 471(30) | 62(9) | 308(34) | 68(11) | 85( 6) | 17(1) | 1089( 72) |
| | 1-16 | 480(16) | 67(4) | 296(16) | 88( 4) | 86( 3) | 17(1) | 1282( 18) |
| | 2-13 | 482(13) | 60(4) | 291(13) | 95( 3) | 86( 3) | 17(0) | 1353( 16) |
| | 3-12 | 483(17) | 57(0) | 295(30) | 92(18) | 86( 4) | 17(1) | 1320(141) |
| | 4-09 | 466(18) | 39(2) | 290(27) | 83(14) | 84( 4) | 17(1) | 1223(112) |
| 85% of ad libitum | 10-09 | 437( 3) | -- | 292( 2) | 56( 0) | 80( 1) | 16(0) | 953( 4) |
| | 11-28 | 467( 1) | 75(6) | 272(56) | 67(10) | 85( 1) | 17(0) | 1079( 94) |
| | 12-26 | 471( 7) | 64(1) | 279(56) | 72(16) | 85( 2) | 17(0) | 1130(139) |
| | 1-23 | 478(15) | 56(0) | 275(48) | 83( 2) | 86( 3) | 17(0) | 1236( 1) |
| | 2-20 | 468(11) | 52(3) | 269(55) | 74( 2) | 84( 2) | 17(0) | 1143( 3) |
| | 3-19 | 463( 1) | 49(0) | 271(55) | 68(11) | 84( 1) | 16(0) | 1085(102) |
| | 4-16 | 453( 2) | 41(0) | 252(46) | 72( 8) | 82( 1) | 16(0) | 1106( 70) |
| 70% of ad libitum | 10-09 | 401(35) | -- | 278( 9) | 40(20) | 74( 5) | 14(1) | 768(219) |
| | 12-05 | 424(50) | 63(1) | 313(11) | 22(31) | 80( 7) | 15(2) | 626(326) |
| | 1-02 | 419)56) | 50(0) | 283(45) | 51( 1) | 77(11) | 15(2) | 887( 52) |
| | 1-30 | 416(55) | 45(0) | 294(26) | 36(19) | 77( 9) | 14(2) | 746(229) |
| | 2-27 | 407(56) | 44(0) | 292(27) | 30(19) | 76(10) | 15(2) | 683(226) |
| | 3-26 | 389(65) | 38(0) | 277(28) | 32(25) | 72(11) | 14(2) | 683(290) |
| | 4-23 | 379(62) | 36(0) | 284(47) | 16( 3) | 71(12) | 14(2) | 525( 87) |

[1]Intake represents the mean consumption of dry matter for the previous 28 days except for 12-05 and 11-28 which represent 2 and 1 week(s) of intake, respectively.

ing the rut. We likewise failed to obtain an estimate of body condition for the male Joker (70% ad libitum) in September because of a partial but unknown loss of the HTO and, consequently, no accurate estimate of total injected HTO. Estimates of body fat as a percent of ingesta-free body weight for Joker followed a pattern similar to that of Charlie, except the losses were greater and reflect restricted intake; while gains reflect the change from 70% ad libitum feeding to ad libitum feeding in February. Estimates of percent body fat were -1.8, 7.8, 3.7, -3.5, 0.9, 7.4, and 10.4 for the months of October through April, respectively. Because of this marked difference between males and females and because we had to drop both males from the medium and low treatments, we excluded males from all data analyses and discussions when comparisons among treatments were made.

Females in the high-treatment group actually gained fat until February and then lost it through April (Fig. 1). Females in the medium group gained weight and fat until January and then lost it through April, while animals in the low group lost both weight and fat during the entire trial (Fig. 1). The percentage change (X + SD) in fat from the pretrial estimate of body composition (Oct 9) until April was 33.0 + 9.4, 26.8 + 10.2, and *f*57.3 + 10.6% for the high, medium, and low treatments, respectively. Based on analysis of co-

variance, changes in body fat during the trial were not statistically different among treatments. Lack of differences were due to (1) females in the low treatment had different body sizes and lost fat at different rates and (2) the estimate of body composition for 1 female in the 70% ad libitum group in Dec. was incorrect, adding error to the effects of the treatment.

Although changes in body protein for females (Table 1, Fig. 1) were similar to changes in body fat and weight, they were much less dramatic. Animals in the high and medium treatments gained body protein (X + SD) from October to April (5.7 + 0.8% and 2.6 + 0.4%), while animals in the low group lost body protein (-3.7 + 6.0%) during the same time period. Changes in body protein were not statistically different among treatments.

To evaluate changes in the total energy pool for female moose attributable to changes

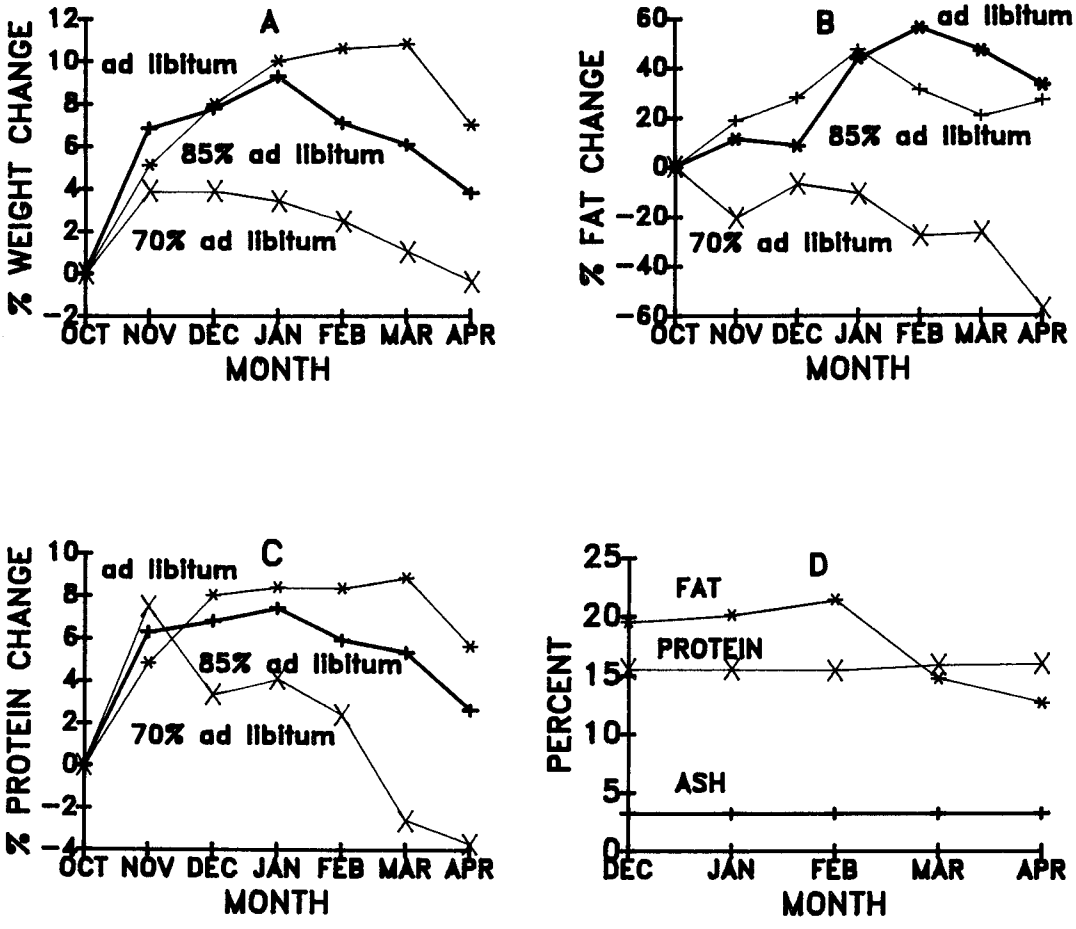


Fig. 1. Weight change (A), fat change (B), and protein change (C) with time for female moose fed a pelleted ration at 3 levels of intake during the winter of 1983-84, at the Moose Research Center, Soldotna, Alaska. Change was calculated as current variable (ie., weight, fat, or protein) - initial variable (October) /initial variable x 100. Monthly fat, protein, and ash (D) expressed as a percent of total body weight for 3 treatment groups of moose pooled. Animals were fed a pelleted ration containing 2.44, 2.07, or 1.81 kcal/g of metabolizable energy at ad libitum intake during winter, 1984-85 at the Moose Research Center, Soldotna, Alaska.

in the fat and protein pools, we converted these pools to kilocalories using 9.4 and 5.3 kcal/g for fat and protein, respectively (Panaretto 1964). Animals gained or lost total calories. Caloric gains represented gains in both the fat and protein pools or a gain in one pool that exceeded the caloric losses in the other pool. Caloric losses occurred when fat and protein pools were catabolized or one pool was depleted at a rate greater than a gain in the other pool. Energy changes from the beginning of the trial (Oct) to the end (April) were positive for the high- and medium-intake treatments and negative for the low-intake treatment (Table 1), but these changes were not significantly different. Fat contributed approximately 94.7% + 32.2 SD (range -22.7 to 215.6%) of the total calories gained or lossed, while protein contributed 5.3% + 32.2 SD. Changes among monthly periods in energy were quite variable; there was no relationship between gain or loss in total energy and the proportion of the change contributed by calories of fat or protein.

Trial 2

Intake and digestion of dry matter were significantly different among treatments, and results have been reported elsewhere (Schwartz *et al.* 1988). In general, moose on the low quality diet compensated by increasing intake, so there was no difference among treatments in intake of digestible energy. Actual metabolizable energy intakes were 2.44, 2.07, and 1.81 kcal/g (Schwartz *et al.* 1988). One female in the low-quality treatment went off feed in March, was put back on high-quality food, and removed from the trial.

Because of the vast differences in body composition between males and females by month in trial 1, we delayed the start of trial 2 until December, well after the rut. We tested treatment effects for trial 2 both with and without males; the results were similar, so all discussion includes males.

Weight change among treatments and over time (Tables 2) was not significantly different. Animals gained weight through January and then lost weight gradually through April.

Estimates of total body water from the least squares analyses (Table 2) varied among individuals. Least squares analyses resulted high correlation coefficients, indicating good estimates of the concentration of HTO at time 0 (intercept).

Total body fat and energy were similar in their dynamics and changes in energy reflected the proportion of calories contributed by fat (Table 2). Treatment effects were not significant. A significant month effect resulted because there were differences in fat and energy content of animals from the start of the trial, rather than a difference attributable to treatment (diet). This was further confirmed by a non-significant treatment-by-month interaction.

Gain and loss of total calories from the body were similar to trial 1. The mean percentage change in fat calories expressed as a percent of the total caloric change was 108.6% + 38.7 SD (range 58.3 to 322.5%) when considered on a monthly basis. Protein and ash levels (Table 1, Fig. 1) did not vary between treatments and months.

## DISCUSSION

Estimates of body composition measured in this study are, to our knowledge, the first presented for moose. Estimates of body composition for our moose were slightly higher than those reported for white-tailed deer (*Odocoileus virginianus*) but lower than those for cattle and sheep (Reid *et al.* 1955, 1968) and the Svalbard reindeer (*Rangifer tarandus platyrhynchus*) (Reimers *et al.* 1983).

Changes in body constituents in trial 1 and 2 were consistent with our expectations, however, absolute measures of fat, protein, and ash may have been inaccurate. For example, the negative estimates of fat for bulls

Table 2. Treatment, date, weight, intake and estimates of body condition for moose fed a pelleted ration containing 2.44, 2.07, or 1.81 kcal/g metabolizable energy at ad libitum. Data presented are the mean (SD) of 3 (2 females, 1 male) moose per treatment.

| Treatment | Injection Date (mo-d) | Injection Weight (kg) | Intake[1] g/kgW$^{0.75}$ | Body water (kg) | Fat (kg) | Protein (kg) | Ash (kg) | Energy (kcal X 103) |
|---|---|---|---|---|---|---|---|---|
| 2.44 kcal/g | 12-17 | 427(31) | 57(10) | 264(23) | 77( 4) | 76(6) | 15(1) | 1131(59) |
| | 1-14 | 433(26) | 54( 9) | 250(11) | 98(12) | 76(4) | 16(1) | 1326(131) |
| | 2-11 | 428(29) | 64( 8) | 249( 9) | 95(19) | 75(4) | 15(1) | 1290(197) |
| | 3-11 | 434(31) | 54(16) | 304(26) | 41(11) | 80(6) | 16(1) | 815(105) |
| | 4-08 | 438(35) | 54( 8) | 279(59) | 72(40) | 79(9) | 16(1) | 1091(330) |
| 2.07 kcal/g | 12-10 | 430(45) | 52(21) | 243( 9) | 103(35) | 75(6) | 15(1) | 1367(360) |
| | 1-07 | 431(40) | 62( 7) | 249(13) | 98(38) | 76(5) | 15(1) | 1318(379) |
| | 2-04 | 426(43) | 65( 3) | 231(11) | 112(26) | 74(6) | 15(1) | 1452(278) |
| | 3-05 | 421(44) | 59( 9) | 245(11) | 94(26) | 74(7) | 15(1) | 1271(279) |
| | 4-01 | 423(47) | 61(10) | 286( 7) | 50(38) | 77(6) | 15(2) | 881(394) |
| 2.07 kcal/g | 12-03 | 441(24) | --- | 252(15) | 103(26) | 77(3) | 16(1) | 1378(251) |
| | 12-31 | 442(28) | 81( 2) | 263( 6) | 92(23) | 78(4) | 16(1) | 1278(240) |
| | 1-28 | 441(14) | 82(10) | 250(22) | 105(30) | 77(2) | 16(1) | 1400(289) |
| | 2-25 | 423(10) | 69(18) | 258(14) | 81(23) | 75(0) | 15(1) | 1165(221) |
| | 3-25 | 428(11) | 87( 3) | 288(32) | 52(28) | 78(4) | 15(1) | 912(250) |

[1]Intake represents the mean consumption of dry matter for the previous 28 days except for 12-05 and 11-28 which represent 2 and 1 week(s) of intake, respectively.

were obviously incorrect. Similarly, the rapid increase in fat content for the two bulls (Chief and Joker) when they were refed in trial 1 were probably overestimated. These problems could have been minimized if detailed knowledge of the relationships between body composition and the HTO technique had existed for moose. Data for whitetailed (Robbins *et al.* 1974) and mule deer (Torbit *et al.* 1985a, 1985b) appear inadequate to predict body composition in moose. Similarly, we were unable to accurately predict the effect of variability of gut water on the total body-water estimate. Animals in trial 1 were on different levels of intake, and unlike Torbit (1981), we did not equilibrate food intake among treatments prior to HTO estimation.

Because the HTO technique is a dilution estimation, the amount and concentration of the HTO injected into the animal must be accurately known. Errors in HTO estimation can occur if (1) an unknown amount of marker is lost during injection, (2) the concentration of the injected material is calculated incorrectly, or (3) there is great variation in water content of individuals. We attempted to minimize the first 2 sources of error. Each dosage was individually weighted prior to injection. Animals were injected while they stood on a scale, and the material was dispensed from the syringe only after the needle had penetrated the muscle. On those occasions where there was a question about complete injection, we noted it; but those few instances did not account for all the variations. To minimize errors with the standard, we used material from the same dilution

for animals in all treatments. We did use different dilutions over time, but review of the data indicated that there was no relationship between material used and subsequent estimates in body water (i.e., obvious trends between batches did not exist).

The source of energy lost or gained (kcals) for moose in trial 1 and 2, respectively averaged 94.7 and 108.6% for fat and 5.3 and -8.6% for protein. When the two trials were averaged together, the mean energy lost/gained from fat was 100%. The variation about this estimate was large, particularly as the energy change approached zero. This error appeared to be associated with the variation in our ability to accurately predict fat and protein levels in the moose. Torbit *et al.*(1985a) measured fat and protein catabolism in mule deer. Their studies showed that when total energy losses were considered, protein contributed 23-29%, depending on treatment. The variation of their estimates appeared to be quite small relative to ours (Torbit 1981:62).

Body-composition estimates determined from this study can serve as crude approximations of the criteria outlined by Franzmann (1985). We used the HTO-dilution technique because it provided an inexpensive and non-destructive measure of the dynamics of body composition in moose. Correction equations developed for deer may be useful for moose, but varification of the technique must require whole-body measurements of body constituents using chemical analysis. We were unable to verify our data because (1) a whole-body grinder capable of processing a moose carcass does not exist in Alaska and (2) the considerable value of our study animals.

At the Moose Research Center, we are currently evaluating several new methods of determining body compositon in moose using non-destructive techniques (Schwartz *et al.* 1988). Recently, Hout and Picard (1988) have developed a technique to determine body composition from a carcass using a bandsaw sample. The technique still requires destructive sampling, but before we can accurately determine body composition based on HTO or other techniques, these data suggest that validation is imperative. We plan to validate the new techniques.

## ACKNOWLEDGEMENTS

We wish to thank all those people who assisted in various phases of this research. We appreciate the help of D. C. Johnson, J. S. Bevins, R. W. Bale, C. Lodge, C. A. Bando, D. M. Waring, and D. J. Groves for animal care and sample collection. E. F. Becker helped with statistical analysis, while K. B. Schneider, S. R. Peterson, and S. Morgan reviewed the manuscript. This study is a contribution of Fed. Aid Wild. Restor., Proj. W-17 and W-21.

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