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

Moose Research Center Reports

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Study 1.45 Evaluation and Testing of Techniques for Moose Management
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ESTIMATION OF BODY COMPOSITION IN MOOSE (STUDY 1.42)

Kris J. Hundertmark
Charles C. Schwartz
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RESEARCH PROGRESS REPORT

State: Alaska

Cooperator: Kenai National Wildlife Refuge, Soldotna, Alaska

Grant No.: W-24-2 Project Title: Wildlife Research and Management

Study No.: 1.42 Study Title: Estimation of body composition in moose

Period Covered: 1 July 1993-30 June 1994

SUMMARY

We evaluated techniques for estimation of body composition in moose under field conditions. Body water was estimated via bioelectrical impedance analysis (BIA) for 5 moose. These animals were slaughtered and tissue samples were analyzed for protein, water, fat, and ash content. Additionally, the peroneus muscle group was dissected from 4 of these individuals and submitted to the same analyses. Percentage fat in each of 3 depots (hide, carcass, and viscera) declined linearly with declines in percentage body fat (ingesta-free body), indicating that fat from all depots is mobilized simultaneously during periods of energy deficit. Fat in each depot was expressed as percentage of total fat in the body (rather than percent of total depot mass) and was plotted against percentage body fat. Curvilinear relationships were evident indicating as body fat declines below 10%, visceral fat is used at a relatively higher rate. At extremely low fat levels (2-3% body fat) the animal relies more on carcass fat, perhaps in conjunction with mobilization of muscle protein, and the percentage of body fat comprised of carcass fat declines precipitously. Our data indicate 2 divergent relationships between percentage body fat and percentage fat in the peroneus muscle. We cannot provide an explanation of this observation at this time. Estimates of impedance via bioelectrical impedance analysis (BIA) displayed relatively high intra-animal variation during this reporting period. We believe this variation was caused by animals lying on a wet substrate. Of all models of body composition generated using BIA estimates in multiple stepwise regression, percentage body water was estimated most precisely ($R^2 = 0.82$, SEE = 2.87%).

Key Words: *Alces alces*, BIA, bioelectrical impedance analysis, body composition, body fat, body water, moose, urea dilution, weight

CONTENTS

BACKGROUND

Body condition was identified as a critical variable within the moose carrying capacity model (Hubbert 1987, Schwartz et al. 1988*a*, 1988*b*), and body fat is a major driver of the moose submodel. Body fat must be accurately measured in moose. A proposal was prepared to test methods for estimating body composition of moose (Schwartz et al. 1988*c*), focusing primarily on measurement of urea space (Preston and Kock 1973), as an in vivo technique, and measurement of 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 is being investigated for potential use in animal applications (Hall et al. 1989, Jenkins et al. 1988, Swantek et al. 1991). This technique works on the principle of measuring the impedance (resistance to alternating current) of hydrated body tissues to an alternating current of known frequency. Nyboer et al. (1943) demonstrated that

$$V = rL^2/I$$

where V = body water volume, r = volume resistivity and is constant for a given conductor, L = conductor length, and I = impedance. Impedance is computed by $(R_S^2 + Xc^2)\ 0.5$ where R_S = resistance and Xc = reactance, but as Xc is small in relation to R_S, the equation can be reduced to $I = R_S$; however, as R_S and Xc are both easily measured, we decided to use I as an estimator. This technique was tested as a potential indicator of moose body composition.

Implicit in the estimation of body composition by these techniques is an accurate measurement of body weight. Obtaining weights of free-ranging moose is difficult because they are often too heavy to be lifted by helicopter and weighed. Franzmann et al. (1978) and Haigh et al. (1980) reported high correlations between certain body measurements and body weight of moose; however, body measurements are insensitive to changes in the fat depots of moose. Franzmann et al. (1976) developed a subjective 11-point scale for assessing condition class (CC) of moose based on physical appearance that may, when combined with body length, more precisely predict body weight.

OBJECTIVES

To determine the relationship between urea space measurements, impedance measurements, chemically determined composition of the peroneus muscle group, and chemically determined body composition in moose.

To determine if moose body weight can be predicted accurately from measurement of body length and heart girth, and appraisal of physical appearance.

To determine if these techniques have potential to estimate moose body composition in field applications.

METHODS

Job 1. Acquire and maintain experimental animals

Experimental animals were from the pool of surplus animals of the Kenai Moose Research Center (MRC) herd, and included 4 adult females and 1 male calf. These animals were kept in captivity at the MRC and were fed a controlled ration (Schwartz et al. 1985). All animals were sampled and slaughtered between 11-25 January 1994.

Job 2. Determine the body water content of experimental animals via urea dilution

Work on this aspect of the project was halted in 1993.

Job 3. Determine the body water content of experimental animals via BIA

A plethysmograph (Model BIA-101, RJL Systems, Inc. Detroit, MI) was used to estimate electrical impedance of moose. The animals were allowed to assume a sternally recumbent position after immobilization. Any variation in positioning of animals was corrected so that all animals were tested in similar positions. Electrodes were constructed from trocars removed from 18ga spinal needles and were bent to an angle of 90 degrees 13mm from the

tip. A "source" electrode was inserted subdermally at the carpal joint on the foreleg and at the joint between the metatarsus and hoof on the hind leg on the body side most exposed while the moose was sternally recumbent. A "detector" electrode was placed 7.5 cm proximal to each source electrode. The tips of the electrodes were oriented distally. Electrodes were connected to the plethysmograph via alligator clips on the end of 10-ft cables. Resistance and Xc were recorded as well as total body length (TL) and heart girth (HG). Electrodes were removed and reinserted, and R_S and Xc measured, a minimum of 3 times per animal to ascertain variation associated with electrode placement.

Job 4. Determine body composition of experimental animals

The animals were killed immediately after we completed BIA measurements. The animals were eviscerated and skinned (with as much fat as possible left on the carcass). The empty carcasses were bisected along the spinal column, with one half of the carcass frozen for analysis. The peroneus muscle groups were dissected from the carcass halves that were not used in the analysis and were frozen. The digestive tract was emptied, and the ingesta and viscera were weighed separately. Entire viscera and samples of ingesta and shaved hide were frozen. The frozen side of the carcass and the visceral mass were cut into 51- and 25-mm slices, respectively, on a commercial band saw. The sawdust that accumulated at the base of the blade was collected for each component, thoroughly mixed and refrozen, and shipped along with ingesta, hide and peroneus samples to the Wildlife Habitat Laboratory of Washington State University for determination of crude fat, crude protein, ash, and water content (Huot and Picard 1988). We determined crude fat by methanol-chloroform extraction, crude protein content by the Kjeldahl procedure (AOAC 1975), ash content by burning in a muffle furnace at 550C for 2h, and percent organic dry matter (1.00-moisture content) by drying samples in a 100C oven for 12-16h and subtracting ash content. Three replicates of each sample were analyzed. Peroneus and hide samples were freeze-dried and ground in a Wiley mill before being subject to chemical analysis.

Job 5 Determine if body weight of moose can be predicted accurately from total body length and visual appraisal

Moose at the MRC immobilized and weighed during this reporting period were subject to visual appraisal of CC (Franzmann 1977). Total body length (TL), HG and CC were used in a multiple regression analysis to predict live weight (LW).

Job 6 Examine the relationship between urea space, impedance values, peroneus fat, and body composition estimates

Peroneus composition and BIA values (TL^2/I and I) were compared to body composition estimates by simple linear and/or stepwise multiple regression with LW and TL as additional predictors. In this report references to "body" composition refer to the ingesta-free body, which is the entire body less contents of the gastrointestinal tract. Swantek et al. (1991) demonstrated that R_s and/or Xc (and by extension their product I) were occasionally better predictors of body fat and water than the traditional parameter TL^2/I. Nyboer (pers. commun.) suggested that conductance (C) and susceptance (S), which are the reciprocals of R_s and Xc,

respectively, were truly the parameters of interest. Packed cell volume (PCV) was also used as a predictor because it served as an index of dehydration, which accompanies malnutrition and would have an effect on BIA measurements (Brodie et al. 1991). We constrained the stepwise regression procedure to minimize multicollinearity by instructing the software not to enter predictors that were highly correlated with predictors already in the model (Wilkinson 1990). Adjusted coefficients of multiple determination (R_a^2) were reported for multiple regressions rather than raw R^2 values because, unlike R^2, R_a^2 is not influenced by the number of independent variables in the model (Neter and Wasserman 1974:229).

RESULTS AND DISCUSSION

Job 2. Determine the body water content of experimental animals via urea dilution

We discontinued this part of the research program when it became apparent that urea dilution was not a practical technique for monitoring condition of animals in captivity or in the field (Hundertmark et al. 1993).

Job 3. Determine the body water content of experimental animals via BIA

Measurement of R_s and Xc yielded higher intra-animal variability than in previous years (Table 1). We believe this can be attributed to the substrate upon which the subjects were lying when measured. All animals were immobilized and allowed to lie down in a part of the facility with a frozen soil surface. Ambient air temperature was high enough to allow this soil to thaw partially after the moose lay down, yielding a wet substrate. This substrate likely allowed current to leave the subjects body, resulting in higher estimates of impedance. One animal (Terra) was measured on this substrate and was then placed on a dry substrate by placing multilayered paper under her. The impedance measurements from this second trial were less than those from the "wet" measurements and displayed much lower variability (Table 1).

During the last two years we have been concerned about the variability in positioning of the hind leg and its effect on impedance measurements. We quantified the position of the leg by measuring the straight-line distance between the knee and carpal joints with the leg in at least three different positions. Moose with the hind leg extended, as is observed in some subjects during immobilization, have a larger distance between these joints than an animal with the leg pulled in to the body, as is normal for sternally recumbent moose. Although these data have not been analyzed formally, there is an observed trend toward greater impedance estimates as the hind leg is straightened.

Job 4. Determine body composition of experimental animals

Percentage of body fat of all animals ranged between 1.4% and 19.7% (Table 2), and based upon weight and CC of these animals, we believe this represents the entire range of fatness likely to be encountered in wild moose. We observed linear relationships between body fat, visceral fat, empty carcass (skinned and eviscerated) fat, and shaved skin fat expressed as percentages of weight (Fig. 1). This illustrated that mobile fat depots (with the likely

exception of marrow fat, which was not measured in this study) were used simultaneously and that the sequence of fat mobilization described by Harris (1945) referred only to the sequence of disappearance of these depots based upon visual appraisal, which was dependent upon their original size.

When weight of depot fat was expressed as a percentage of the weight of body fat (g depot fat/100 g total fat) we found carcass fat represented the largest fat depot available to the animal, followed by visceral fat. Skin fat was a minor component of body fat. Previously (Hundertmark et al. 1992, 1993) we reported the percentage of body fat comprised of each depot was constant over the observed range of body fat. With the addition of new data, we detected curvilinear relationships (Fig. 2). Carcass fat contributes a greater percentage to body fat at low body fat concentrations and declines as the animal fattens; the opposite relationship exists for visceral fat. These relationships did not hold for 2 of our subjects, both of which were in very poor body condition when they were killed. In these 2 cases, carcass fat composed a smaller percentage of body fat than was expected and visceral fat composed a greater percentage. We believe these animals were in such poor condition they were catabolizing muscle protein to produce energy. Thus, the carcass contributed a relatively smaller portion to the ingesta-free body compared to the viscera.

Job 5 Determine if body weight of moose can be predicted accurately from total body length and visual appraisal

The animals we sampled this year were added to this analysis and the regression parameters (SEE and R^2) indicated variation among animals increased (Table 3). The best predictive equation for live weight (LW), based upon these parameters, included TL and CC, and accounted for 88% of the variation in LW. It is not surprising that HG was not included in the best model as this measurement has a high level of variability because it is difficult to measure on an immobilized moose.

There were some notable differences between our results and those reported elsewhere for weight-length relationships (Franzmann et al. 1978, Haigh et al. 1980). The correlation (r) between TL and LW for our data was 0.83, which was not as high as that reported by Franzmann et al. (1978) (0.94) but was higher than that reported by Haigh et al. (1980) (0.71). These differences may be attributable to the considerably greater sample size reported by Franzmann et al. (1978) and the fact that Haigh et al. (1980) measured weight by suspending moose from a helicopter and recording weight only to the nearest 5 kg. Haigh et al. (1980) also subtracted a subjective estimate of antler weight from LW of males, which would increase the variation of the estimate.

Regression equations presented by Franzmann et al. (1978) and Haigh et al. (1980) for predicting LW as a function of TL do not describe the variation in our data (Fig. 3). A major difference between our study and theirs is that we have only one animal less than 1.5 years old in our sample. Also, Haigh et al. studied a smaller subspecies (*A. a. andersoni*) than that studied by Franzmann et al. (1978) and this study (*A. a. gigas*). The relative positions of the regression lines (Fig. 3) indicated that representatives of *A. a. andersoni* are shorter than representatives of *A. a. gigas* of the same weight. This is an important consideration when

choosing a model for predicting weight for different subspecies. Nonetheless, we expected better agreement between our data and the relationship described by Franzmann et al. (1978) because both studies dealt with the same subspecies. We attribute the difference to condition of animals at the time of sampling. Franzmann et al. (1978) sampled wild animals, free-living or enclosed by fences at the MRC, during winter; therefore, their sample likely contained mostly animals on the lower end of the CC scale, indicating moderate to poor body condition. Our sample included animals held in captivity that represented what was likely a wider array of body condition. The distribution of our data in Fig. 3 with respect to CC supports this explanation.

During this reporting period we assisted T. Stephenson (Univ. of Idaho) in additional testing of the effectiveness of a portable ultrasound unit in measuring subcutaneous rump fat depths. Data collected this year will supplement those collected previously (Stephenson et al. 1993). This technique measured fat depths accurately and delineated the size of the rump fat depot. This exercise demonstrated to us that rump fat can exist on an animal even though visual appraisal and/or palpation did not detect it. As the presence/absence of rump fat is a criterion in determining CC, use of this technique may provide a less biased alternative to CC in appraising animal condition.

Job 6 Examine the relationship between urea space, impedance values, peroneus fat, and body composition estimates

The peroneus muscle group was collected from four of the five moose sampled this year. Adding these observations to those collected in previous years, we determined two distinct trends were apparent in the relationship between peroneus fat and body fat (Fig. 3). Hout and Goodreault (1985) reported a high correlation between percent peroneus fat and percent body fat ($r = 0.96$) for caribou (*Rangifer tarandus*). Their model, represented by the line in Fig. 3, describes variation in one group of our data. A second group, however, is distinct from this model, and we cannot explain why these data would diverge so dramatically.

Multiple linear regression models derived by stepwise regression were computed to describe variation in body water and fat (volume and percentage)(Table 4). Live weight was included in all 4 models, which indicated that variation in LW accounted for the greatest proportion of variation in the dependent variable. Similar results were reported for caribou and reindeer (Gerhart et al. 1992). In the model estimating percent body water, the BIA parameter C (conductance) also was included. Percentage of body water was modeled most precisely, with 85% of the variation being explained by the independent variables and a standard error of the estimate of 2.5. Live weight was the only independent variable included in the fat models and the standard errors were high in relation to estimates. Estimation of body composition components for all animals without using LW as an independent variable (see Job 6) resulted in TL being entered into all models. Once again, BIA parameters were entered in the water models but not the fat models. Packed cell volume was a significant independent variable in all models except body water weight.

We realize our sample sizes are extremely small for this type of analysis and regression parameters could change significantly with the addition of more animals. We present these

data as preliminary and caution against drawing conclusions from the information presented here. Indeed, Gerhart et al. (1992) concluded that BIA was inferior to traditional body composition indices in estimation of body composition in caribou and reindeer. However, we believe our data indicate that further research is warranted.

RECOMMENDATIONS

This study should continue for one year. During the coming year we will complete our analysis with the addition of 4-6 animals to our sample. Historic records of moose measurements from the MRC will be analyzed for relationships to predict weight.

LITERATURE CITED

AOAC. 1975. Official methods of analysis of the Association of Official Analytical Chemists. 12th ed. Assoc. Off. Anal. Chem. Washington D. C.

Brodie, D. A., T. G. Eston, A. Y. Coxon, S. N. Kreitzman, H. R. Stockdale, and A. N. Howard. 1991. Effect of changes of water and electrolytes on the validity of conventional methods of measuring fat-free mass. *Ann. Nutr. Metab.* 35:89-97.

Franzmann, A. W., R. E. LeResche, P. D. Arneson, and J. L. Davis. 1976. Moose productivity and physiology. Fed. Aid in Wildl. Rest. Final Rep., Alaska Dep. of Fish and Game, Juneau, AK.

_____. 1977. Condition assessment of Alaskan moose. Proc. N. Am. Moose Conf. Workshop. 13:119-127.

_____, _____, R. A. Rausch, and J. L. Oldemeyer. 1978. Alaskan moose measurements and weights and measurement-weight relationships. *Can. J. Zool.* 56:298-306.

Gerhart, K. L., R. G. White, and R. D. Cameron. 1992. Estimating body composition of caribou and reindeer using bioelectrical impedance analysis and body condition scores. Unpubl. manuscript. Univ. Alaska Fairbanks.

Haigh, J. C., R. R. Stewart, and W. Mitton. 1980. Relations among linear measurements and weights for moose (*Alces alces*). *Alces* 16:1-10.

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

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 C. C. Shuey. 1992. Moose Research Center Rept.: estimation of body composition in moose. Fed. Aid in Wildl. Rest. Prog. Rep. Alaska Dept. of Fish and Game. Juneau.

_____, _____, _____. 1993. Estimation of body composition in moose. Fed. Aid in Wildl. Rest. Prog. Rep. Alaska Dept. of Fish and Game. 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.

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

Neter, J., and W. Wasserman. 1974. Applied linear statistical models. Richard D. Irwin, Inc. Homewood, IL.

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

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.

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

_____, 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* 24:178-187.

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

Stephenson, T. R., K. J. Hundertmark, C. C. Schwartz, and V. Van Ballenberghe. 1993. Ultrasonic fat measurement of captive yearling bull moose. *Alces* 29:115-123.

Swantek, P. M., J. D. Crenshaw, M. J. Marchello, and H. C. Lukaski. 1991. Bioelectrical impedance: a nondestructive method to detemine fat-free mass of live market swine and pork carcasses. *J. Anim. Sci.* 70:169-177.

Wilkinson, L. 1990. SYSTAT: the system for statistics. SYSTAT, Inc., Evanston, IL.

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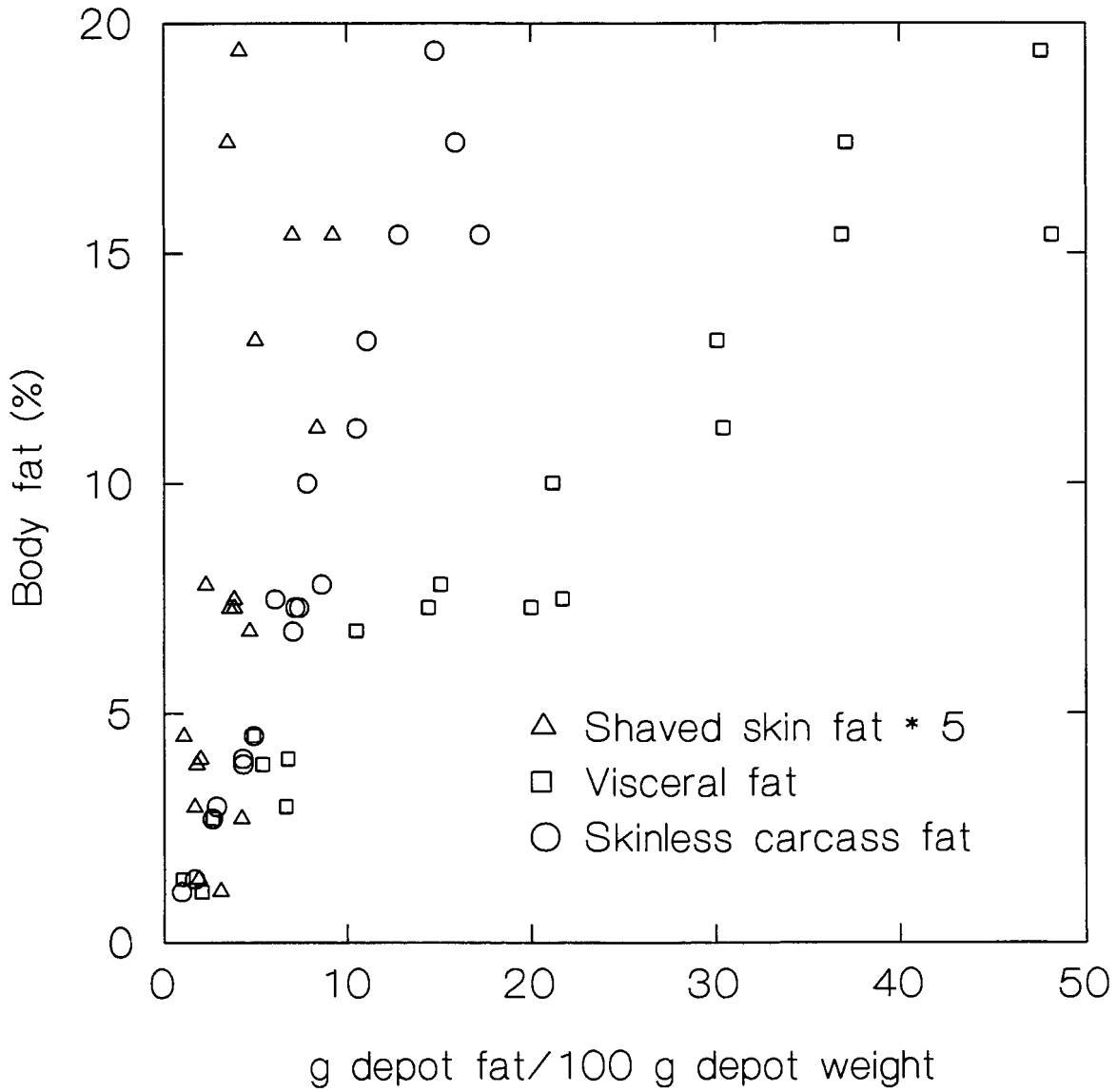

Fig.1. The relationship between percent body fat and percent fat in the shaved skin, skinless carcass and viscera components.

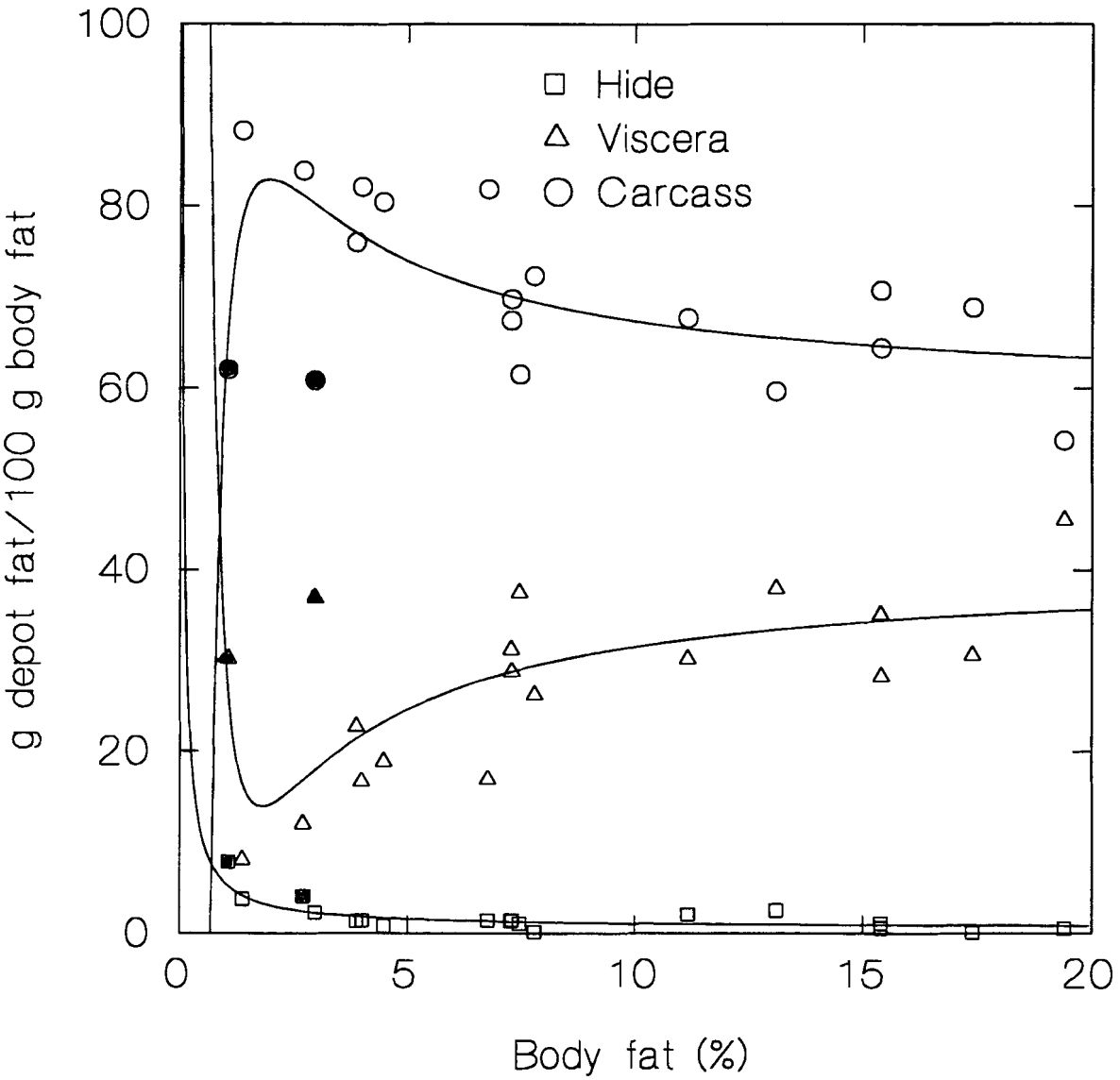

Fig. 2. The relationship between percent body fat and the percentage of body fat comprised by the fat in hide, carcass, and viscera depots (expressed as g depot fat/100 g body fat). Two animals are responsible for the near vertical shape of the models near body fat = 0. These animals may be outliers and are identified by shaded symbols.

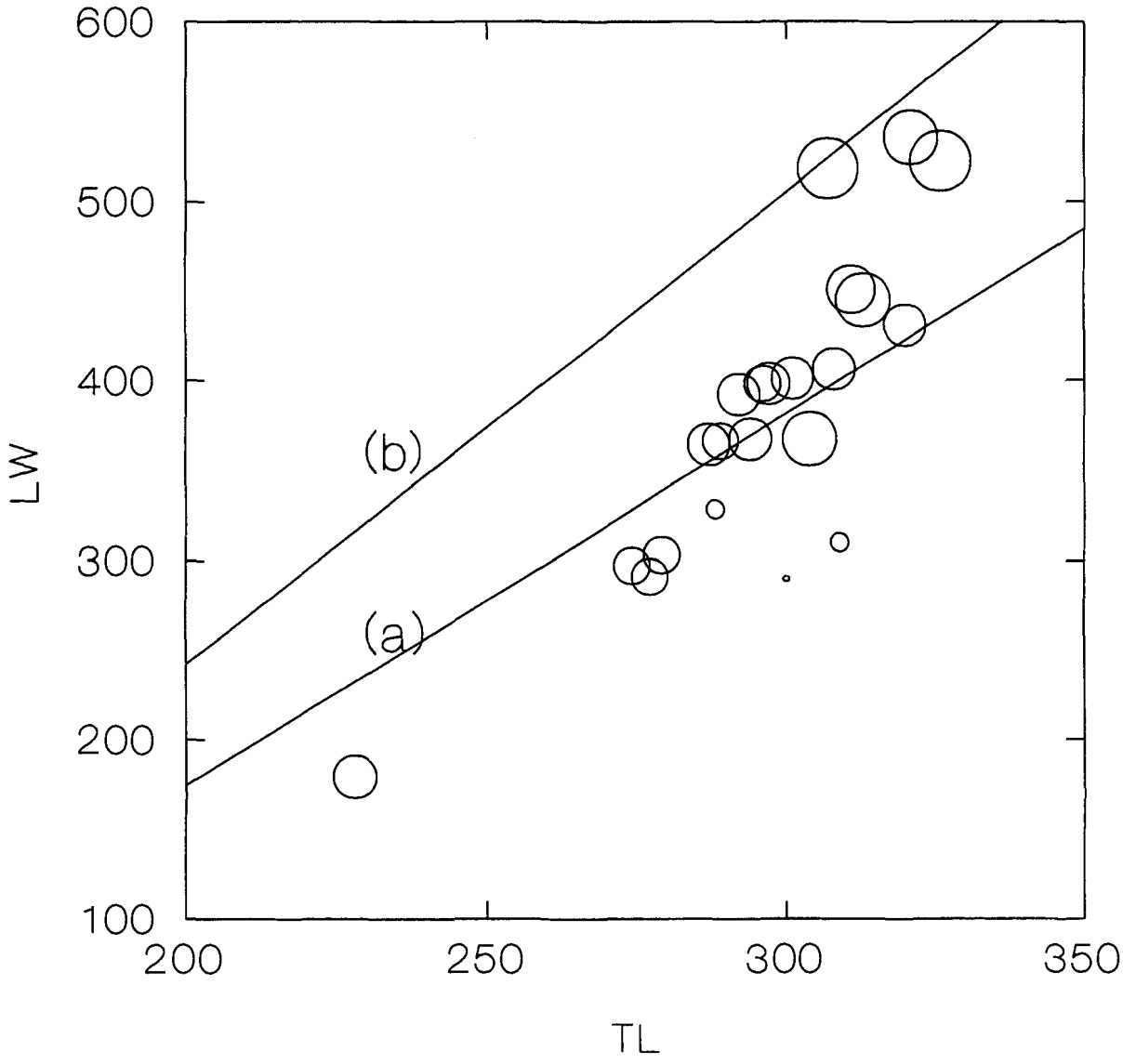

Fig.3. The relationship between LW and TL. Lines were calculated from predictive equations from (a) Franzmann et al. (1978) and (b) Haigh et al. (1984). Relative size of data points indicate CC, with the largest circles representing CC = 10 (best) and the smallest circle representing CC = 1 (worst).

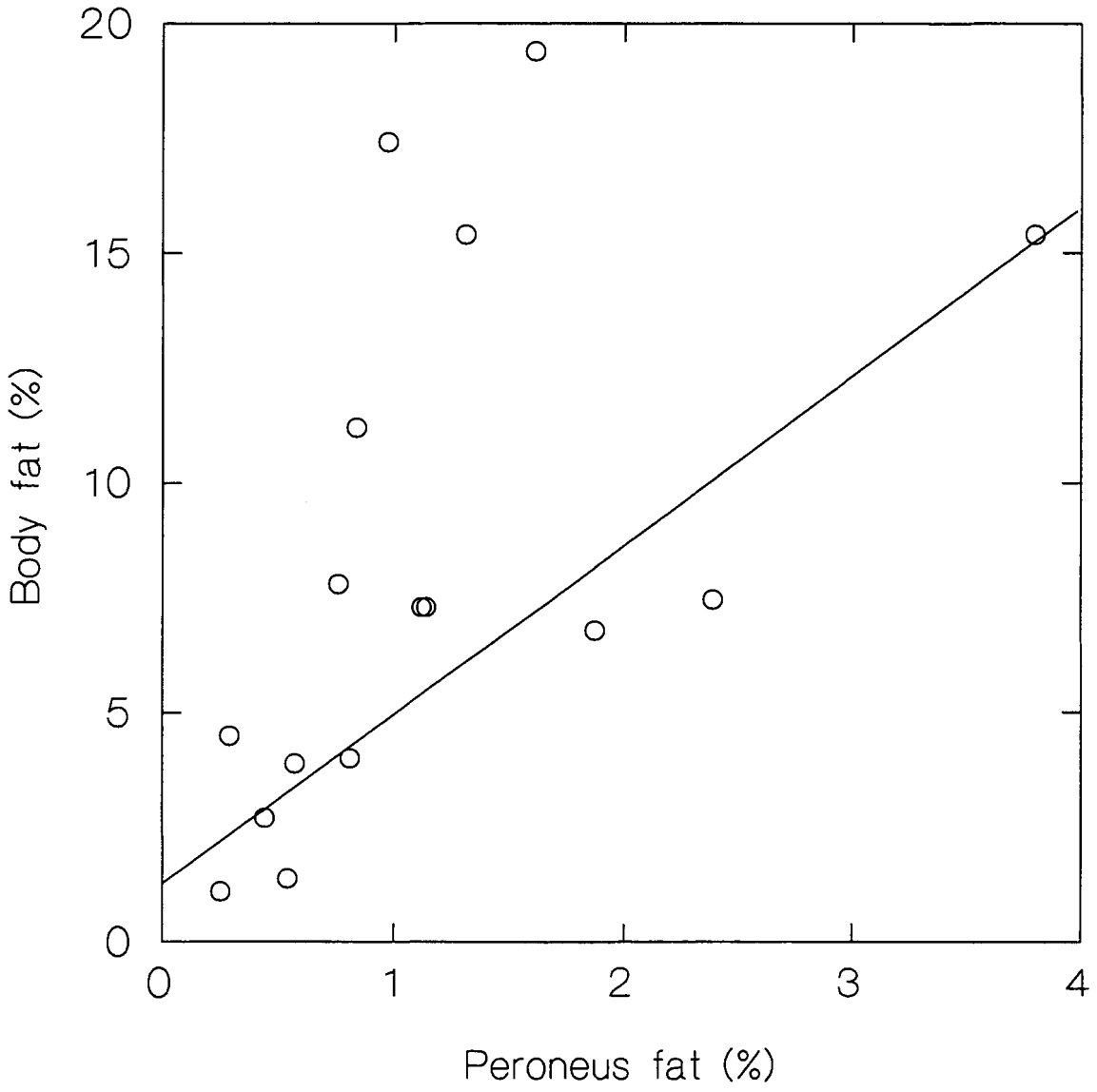

Fig. 4. The relationship between peroneus fat and body fat. The line was calculated from the relationship between these 2 parameters in caribou (Huot and Goodreault 1985).

Table 1. Mean values of R and Xc and associated estimates of variation for 15 moose used in the body composition study, Moose Research Center.

		R			Xc		
Animal	N	Mean	SE	CV	Mean	SE	CV
Angel	5	235.6	3.5	3.3	14.0	0.0	0.0
Brooks	3	302.0	1.2	0.7	21.0	0.0	0.0
Oly	5	581.6	8.2	3.2	42.0	2.8	14.7
Luke	3	363.0	0.6	0.3	30.7	0.3	0.3
Hydro	3	365.3	6.1	2.9	29.3	0.3	2.0
Sol	4	317.0	1.1	0.7	30.0	0.7	4.7
Stripes	3	411.7	2.3	1.0	30.0	0.6	3.3
Kobuk	3	365.3	7.1	3.3	34.3	0.3	1.7
Deneki	4	373.8	3.5	1.9	34.0	1.1	6.4
Zumu	3	446.7	2.0	0.8	39.3	0.7	2.9
Vicki	3	653.0	10.1	2.6	39.7	0.7	2.9
Sinuk	4	536.8	9.0	3.4	36.5	0.6	3.5
Betsy	3	709.7	11.3	2.8	41.3	1.2	5.0
Kelley	3	473.7	13.6	5.0	31.0	1.2	6.5
Terra[1]	3	478.3	10.4	3.8	35.3	1.2	5.9
Terra[2]	3	449.0	2.5	1.0	31.0	0.6	3.2

[1] Measured on a wet substrate
[2] Measured on a dry substrate

Table 2. Live weight (LW), ingesta-free body weight (IFBW), and body composition estimates determined by proximate analysis for animals used in this study.

			Weight (kg)				%			
Animal	LW	IFBW	Water	Fat	Protein	Ash	Water	Fat	Protein	Ash
Angel	290	296	219.3	7.7	55.2	13.7	75.6	2.7	19.0	4.7
Brooks	535	539	324.1	91.9	97.0	25.8	60.6	17.2	18.1	4.8
Hydro	364	347	236.4	25.8	67.4	17.6	65.5	7.2	18.7	4.9
Kobuk	344	337	245.3	12.6	61.9	17.4	70.1	3.6	17.7	5.0
Luke	415	417	261.5	45.1	85.4	24.6	63.0	10.9	20.6	5.9
Oly	340	351	265.8	3.5	61.6	17.4	70.1	1.0	18.4	6.0
Sol	392	387	266.6	26.1	74.8	19.9	67.5	6.6	18.9	5.0
Stripes	309	295	210.6	12.1	57.1	15.3	69.0	4.0	18.7	5.0
Butch	350	296	218.1	4.0	59.3	15.0	74.8	1.4	20.3	5.2
Bill	397	374	257.6	14.6	83.9	18.4	68.4	3.9	22.3	4.9
Rex	238	217	150.5	16.4	83.9	18.4	68.4	3.9	22.3	4.9
Yogi	263	212	140.8	14.5	43.9	12.8	65.8	6.8	20.5	6.0
Deneki	385	351	206.0	54.2	69.8	21.3	58.6	15.4	19.9	6.1
Zumu	445	401	247.8	52.2	81.7	18.9	62.0	13.1	20.4	4.7
Vicki	360	310	172.2	27.4	56.7	19.4	62.5	10.0	20.6	7.0
Terra	510	462	259.6	89.5	93.4	19.4	56.2	19.4	20.2	4.2
Sinuk	525	448	260.5	78.8	87.8	20.8	57.5	17.4	19.4	4.6

Table 2. Continued.

Betsy	310	293	193.9	22.8	62.5	13.3	66.4	7.8	11.8	4.6
Kelley	180	148	108.6	3.7	32.1	3.4	78.1	2.7	23.1	2.5

Table 3. Regression equations, coefficients of determination (R^2), standard errors of the estimate (SEE), and error degrees of freedom (DF) for prediction of moose live weight (LW) from total length (TL), heart girth (HG), and condition class (CC), Moose Research Center, N = 23.

Regression equation	R_a^2	SEE	DF
LW = 3.41(TL)-632	0.68[a]	47.7	21
= 2.50(TL)+1.25(HG)-602	0.68[a]	46.6	17[b]
= 2.90(TL)+17.9(CC)-598	0.88[a]	29.6	20
= 3.40(TL)-161.3(1/CC)-595	0.80[a]	37.5	20
= 3.45(TL)-125.3(1/CC^2)-634	0.76[a]	40.9	20
= 2.57(TL)+0.43(HG)+16.2(CC)-575	0.87[a]	30.1	16[b]
= 2.51(TL)+1.26(HG)-152.0(1/CC)-573	0.82[a]	35.1	16[b]
= 2.45(TL)+1.44(HG)-124.2(1/CC^2)-611	0.79	37.9	16[b]

[a] $P<0.01$
[b] Heart girth measurements were not available for 4 animals.

Table 4. Estimates of ingesta-free body composition components using TL, LW, PCV and BIA parameters ($I,TL^2/I$, S, C), fit by stepwise regression, and associated regression parameters.

Regression equation	Error df	R_a^2	SEE	P[a]
All animals, all parameters:				
body water (kg) = 58.2 + 0.4(LW)	13	0.85	16.1	<0.001
body water (%) = 81.1 - 0.06(LW) + 1909(C)	12	0.82	2.5	<0.001
body fat (kg) = -60.9 + 0.25(LW)	13	0.76	13.5	<0.001
body fat (%) = -9.8 + 0.05(LW)	13	0.69	3.3	<0.001
All animals, LW removed as a predictor:				
body water (kg) = -104+1.5(TL)-0.2(I)-1563(S)	11	0.81	18.4	<0.001
body water (%) = 125-0.2(TL)-0.3(PCV)+123(S)	9	0.76	3.0	<0.001
body fat (kg) = -190 + 0.6(TL) + 1.7(PCV)	10	0.46	19.3	<0.018
body fat (%) = -40 + 0.1(TL) + 0.4(PCV)	10	0.48	4.1	<0.015

[a] Significance level of *F* statistic from regression ANOVA.

EVALUATION AND TESTING OF TECHNIQUES FOR MOOSE MANAGEMENT (STUDY 1.45)

Charles C. Schwartz

RESEARCH PROGRESS REPORT

State: Alaska

Cooperators: Kenai National Wildlife Refuge, Soldotna, Alaska; Dr. Steve Monfort, National Zoological Park, Smithsonian Institution, Front Royal, Virginia

Project No.: W-24-2 Project Title: Wildlife Research and Management

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

Period Covered: 1 July 1993-30 June 1994

SUMMARY

For a second year, adult cow moose (*Alces alces*) presumed to be pregnant (n = 7) were maintained on restricted (approximately 75% ad libitum) rations from December through April to determine the effect of nutritional restriction on gestation length. Although this degree of restriction was below maintenance requirements for energy in captive moose, six of seven cows gained weight over the duration of the study. The single cow that lost weight aborted during the trial and was removed from the analysis. The remaining six cows exhibited a mean (SD) gestation of 232 (1.3) days, which was not different from the expected length of 231 days. Feces were collected from captive moose to continue our studies of monitoring estrus and pregnancy. Analysis of these data was completed and a manuscript prepared and submitted for publication. Data collected on compensatory growth were analyzed and presented at the North American Moose Conference.

Key Words: *Alces alces*, feces, formulated ration, gestation, moose, reproduction, urine, body mass.

CONTENTS

BACKGROUND

The Moose Research Center (MRC), with known numbers of confined animals and facilities to handle them, provides unique conditions for developing and testing techniques applicable to moose management. This study has been continuously active since 1969 when the MRC became functional. Four Federal Aid final reports covering the period from 1968 through 30 June 1991 have been published (Franzmann et al. 1974, Franzmann and Schwartz 1982, Franzmann et al. 1987, Schwartz et al. 1993), in addition to more than 35 journal publications (see Schwartz et al. 1993).

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

Studies of reproduction in captive moose would benefit from a technique that would reliably assess onset of estrus and pregnancy. Monfort et al. (1993) evaluated the effectiveness of

using urine and feces to assess pregnancy and estrus in moose and found they were promising indicators but that further work needed to be done with feces before this medium could be used reliably. During this reporting period we completed a study to evaluate feces as an indicator of estrus and pregnancy.

This report contains information collected from 1 July 1993 through 30 June 1994. Active jobs include: reproduction studies (Job 5), and miscellaneous techniques (Job 7).

OBJECTIVES

- To test and evaluate techniques that are potentially useful for management of moose. (study objective)
- To investigate the basic parameters of moose reproduction. (Job 5).
- To test miscellaneous techniques. (Job 7).

METHODS

Job 5. Reproduction Studies

Effect of food restriction on estrus length: Seven pregnant females with known breeding dates were placed on restricted amounts of a formulated ration (Schwartz et al. 1985) beginning on 16 January and continuing through 30 April. Amount of food offered (g/kg $BW^{0.75}$) daily during the months January through April was between 45 and 40g, respectively, based upon weekly weights. Any uneaten food (orts) was weighed and subsampled for dry-matter determination. We determined intake by subtracting dry weight of orts from dry weight of feed offered. On 1 May all animals were offered approximately 40% more feed and this amount was increased until animals were eating ad libitum amounts by 8 May. We weighed animals weekly from 16 January through 6 May to monitor condition. We recorded dates of parturition for all cows and compared these dates to normal gestation lengths (Schwartz and Hundertmark 1993).

Use of feces to detect estrus and pregnancy: Three yearling females were held in a pen with a bull that was vasectomized by procedures described by Franzmann and Schwartz (1987). We observed the cows daily and noted date of estrus based upon observed mounting by the bull. We collected fecal samples from these females daily from 1 October through 21 December 1992 for use in estrus detection. We selected this period because it encompassed the first

three estruses of cows at the MRC (Schwartz and Hundertmark 1993). The samples were stored frozen until they were shipped to S. Monfort for analysis.

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

Job 7. Miscellaneous Projects

Compensatory growth in moose calves: From 1987-91, we conducted studies of first and second estrous breeding. Prior to the rut in 1986, 2 adult bull moose were vasectomized on 5 and 11 September following the procedures outlined by Franzmann and Schwartz (1987). To determine the day of breeding, we observed captive moose daily during daylight hours beginning in early September and continuing until all cows were bred. Estrus was defined as time during which a female would stand for mounting. Estrus was confirmed by observing mounting by a bull, or indirectly by physical appearances of the female's rump hairs, which were ruffled, parted, bent, and generally showed signs of mounting. Rump hair of a non-estrous female was orderly. On many mornings there was a layer of frost on the rump hairs of nonestrous females. Frost was absent on females mounted during the night. Some cows were maintained with an intact bull from prerut until they were bred. A second group of cows was maintained with a vasectomized bull from prerut until 2 weeks after first observed estrus. These cows then were bred by the intact bull during their second estrus, and length of the estrous cycle determined. Cows were alternated between treatments over 4 years. Two yearling females were also accidentally bred by a bull during their third estrus, and these data are included for comparison. We lost some individuals and added others, but over the 4 years we used 10 different females.

We calculated length of gestation for all females observed breeding. During the calving season (late May-early Jun), each female was observed daily for signs of birth. Cows frequently paced enclosure fences within 24 hours of parturition. We observed birth in many cases, and when we did not, we estimated it to within 6 hours. Day length during the calving season was 18-19 hours. Gestation was calculated as the time from conception (day of breeding) to parturition.

We determined the mass of moose on a walk-on cattle scale accurate to the nearest kg (Schwartz et al. 1987). Mass of neonates was determined <24 hours after birth using a spring scale that was accurate to 0.5 kg. We weighed the calves in the autumn just prior to rut and throughout winter prior to their release back into the large pens during spring and summer. We also weighed these individuals opportunistically throughout the remainder of the study. Some of the calves were used in other studies, hence not all individuals were monitored as yearlings and adults. We aggregated monthly measurements (n = 1-6) of mass for each individual. Weight gain was calculated as the body mass minus birth mass. Daily weight gain was calculated as weight gain divided by the age of the animal in days.

RESULTS AND DISCUSSION

Job 5. Reproduction Studies

Effect of food restriction on estrus length: Of the seven cows in this study, none gained weight except during their third trimester of pregnancy (Fig. 1), indicating severe nutritional restrictions. Apparently, the feed restriction placed upon these cows was adequate to impose undernutrition unlike the feeding trial the previous year.

The single cow that did not gain weight went off feed in late January and lost body condition during the later phases of the study. Six of the seven cows gave birth after a mean (SD) gestation of 232 (1.3) days, which was similar to the mean of 231 (5.4) days reported by Schwartz and Hundertmark (1993) for moose on a high plane of nutrition. The seventh cow aborted two partially developed fetuses on day 213 of gestation. The fetuses, a male and a female, weighed 6.8 kg each.

Four of the 6 cows giving birth after a normal gestation period lost one of their calves shortly after parturition (Table 1). In addition, one cow that did not loose her calves at birth lost both to black bear predation less than a month later. This is the first black bear predation recorded at the MRC since 2 separate instances in 1989. It is interesting that both of these predations were calves of cows that were either old (age 11) or stressed the previous winter. Of 14 calves conceived to the 7 cows in this trial, 64% (9) died before 1 month of age.

Data from this study along with last year's information will be analyzed and put into manuscript form for presentation at the 31st North American Moose Conference and Workshop.

Use of feces for estrus and pregnancy detection: These data were analyzed and a manuscript submitted for publication (Appendix A.)

Job 7. Miscellaneous Projects

Compensatory growth in moose calves: This project was completed and a paper was presented at the 30th North American Moose Conference and Workshop (Appendix B).

RECOMMENDATIONS

We plan to continue to evaluate new drugs and related products as they become available. We will continue to investigate various components of moose reproduction. This year we will evaluate the influence of the bull moose on estrous timing in cows.

LITERATURE CITED

Franzmann, A. W., and C. C. Schwartz. 1982. Evaluating and testing techniques for moose management. Alaska Dep. Fish and Game Fed, Aid in Wildl. Rest. Final Rep.

_____, and _____. 1987. Anesthesia of moose for vasectomy using carfentanil/xylazine and reversal with naloxone/yohimbine. *Alces* 23:221-226.

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

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

Monfort, S. L., C. C. Schwartz, and S. K. Wasser. 1993. Monitoring reproduction in captive moose using urinary and fecal steroid metabolites. *J. Wildl. Manage.* 57:400-407.

Schwartz, C. C., and K. J. Hundertmark. 1993. Reproductive characteristics of Alaskan moose. *J. Wildl. Manage.* 57:454-468.

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

___, ___, and ___. 1987. Seasonal weight dynamics of moose. Swedish Wildl. Res. Suppl. 1:301-310

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

_____, K. J. Hundertmark, C. C. Shuey, and D. C. Johnson. 1993. Evaluation and testing of techniques for moose management. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Juneau.

Thelen, T. H. 1991. Effects of harvest on antlers of simulated populations of elk. *J. Wildl. Manage.* 55:243-249.

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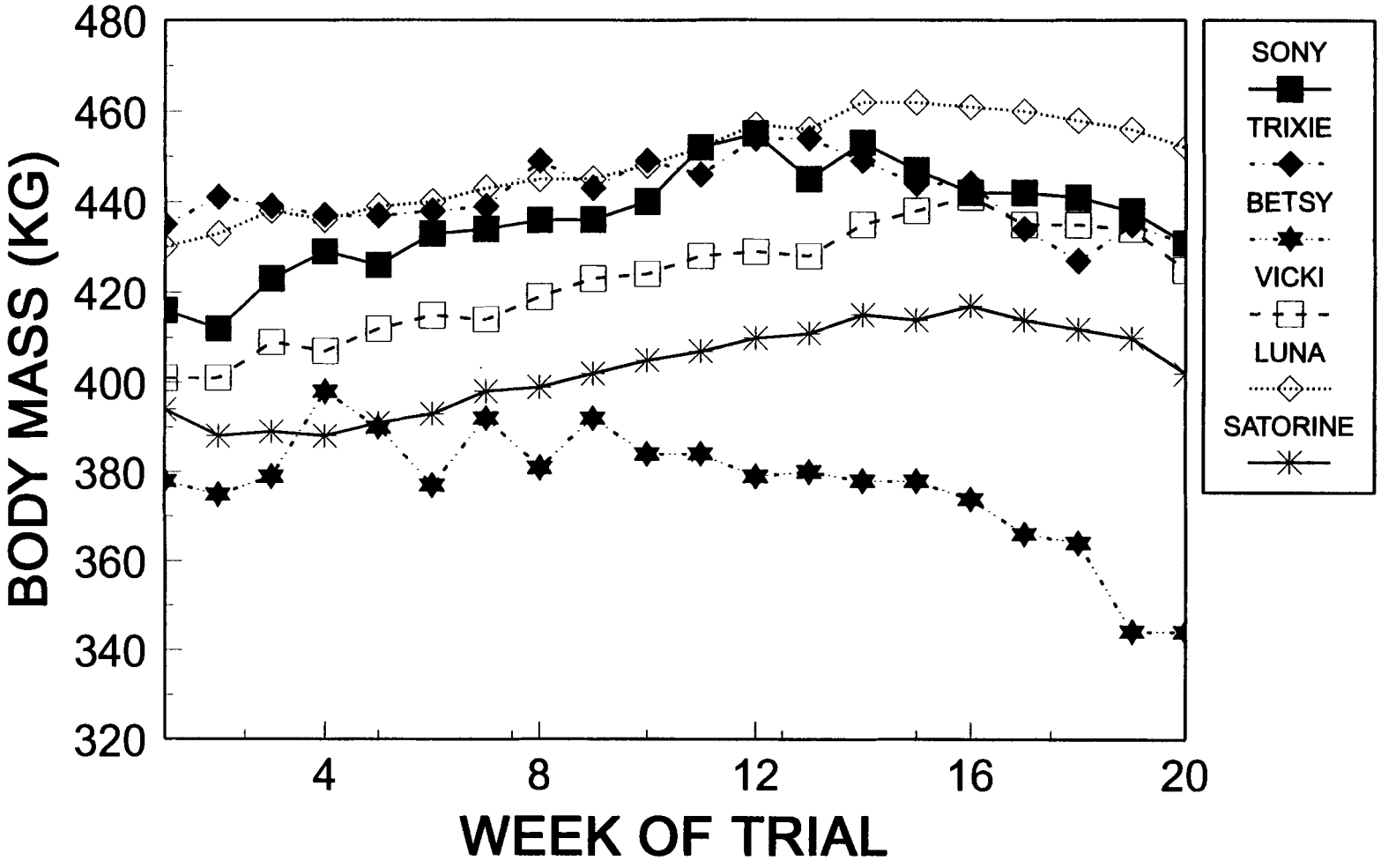

Fig. 1. Body mass of six cows maintained on restricted intake during gestation.

Table 1. Cow, breeding and parturition dates, sex, mass, and fate of their calves.

Cow	Estrus Date	Parturition Date	Calf Sex	mass (kg)	Fate
Deskha	Oct 6	May 7	M	6.8	Aborted
			F	6.8	Aborted
Satorene	Sep 29	May 18	F	7.3	Died 19 May
			F	15.9	Alive
Luna	Oct 3	May 21	M	13.1	Bear predation
			M	12.7	Bear predation
Allye	Oct 1	May 21	M	10.9	Alive
			M	10.9	Born dead
Liz[1]	Oct 3	May 23	M	12.3	Died 26 May
			M	13.6	Born dead
Lara	Oct 5	May 26	F	13.2	Alive
			F	5.4	Born dead
			M	14.1	Alive
Sony	Oct 8	May 30	F	17.8	Alive

[1]This cow died on 3 June from complications during pregnancy.

APPENDIX A.

GROWTH OF MOOSE CALVES CONCEIVED DURING THE FIRST VERSUS SECOND ESTRUS

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Abstract: It has been hypothesized that a low bull:cow ratio can result in delayed or late breeding in some female moose (*Alces alces*). A consequence of late breeding is late born calves. It has also been speculated that late born calves may grow faster and attain a size similar to early born calves. We tested this accellerated growth hypothesis by breeding cow moose during their first and second estrus, and tracking the growth rates of their calves. We conducted the experiment over a 4 year period using 10 mature cow moose that produced 33 calves in 22 litters. Birth mass of calves conceived during the first and second estrus was not different ($P = 0.613$) but single calves weighted more ($P = 0.006$) than twins regardless of date conceived. Body mass of calves born to first estrus bred cows was significantly ($P < 0.0001$) greater by weaning in September and thoughout the winter than calves conceived the second estrus. Daily weight gain was not different ($P = 0.395$) between the two groups. These data substantiate our hypothesis that 2nd-estrus calves do not exhibit accellerated growth prior to entering their 1st winter. We were unable to detect a significant different ($P = 0.079$) in body mass among yearlings conceived in the first and second estrus, but suspect our small sample size precluded a definitive test. There was a significant ($P < 0.05$) positive relationship between April body mass of short yearlings and their autumn body mass in September. The slope of the line (0.98) suggested a lack of compensatory growth. Likewise a non-significant ($P > 0.05$) relationship between April body mass of short yearlings and their weight gain to autumn confirmed a lack of compensatory growth. We concluded that second estrous calves enter winter at a lower body weight and are more susceptible to winter mortality, especially in deep snow years. Yearling moose do not possess the mechinisms of compensatory growth and remain smaller. Management implications are discussed.

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APPENDIX B.

FECAL PROGESTAGEN CONCENTRATION AS AN INDICATOR OF THE ESTROUS CYCLE AND PREGNANCY IN MOOSE

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Abstract: We established a noninvasive technique for monitoring the estrous cycle and pregnancy in the moose (*Alces alces*). Fecal samples were collected daily from nonpregnant yearlings ($n = 3$) for the duration of 3-4 estrous cycles, and weekly throughout gestation from 3 pregnant cows. Samples were analyzed by radioimmunoassay (RIA) to quantify the concentration of progestagen metabolites in feces. Peak luteal phase concentrations of progestagens were 45.3 $\pm$ 9.1 (S.D.) mg/g compared to 4.9 $\pm$ 1.2 mg/g during the follicular phase. Observed ($n = 7$) and suspected ($n = 2$) matings all occurred within $\pm$ 2 days of the nadir in progestagens excretion. Fecal progestagens were elevated above peak luteal phase concentrations by the 8th week of gestation, permitting accurate pregnancy detection by this time. Relative concentrations of fecal progestagens during the follicular phase, luteal phase, and pregnancy were 1:10:35, respectively. These results suggest that fecal progestagen monitoring is a useful noninvasive technique for tracking ovarian activity and pregnancy in moose.

Key words: *Alces alces*, estrus, gestation, moose, reproduction.

J. Wildl. Manage. 00(0):000-000

EVALUATION AND TESTING OF TECHNIQUES FOR UNGULATE MANAGEMENT (STUDY 1.45)

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

Editor's note: The scope of Study 1.45 was redefined to include ungulate research. This study represents this extension and has the same study number as the previous moose study.

RESEARCH PROGRESS REPORT

State: Alaska

Cooperators: Kenai National Wildlife Refuge, Soldotna, Alaska

Project No: W-24-2 Project Title: Wildlife Research and Management

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

Period Covered: 1 July 1993-31 June 1994

SUMMARY

We continued to collect baseline information on parameters of calving in nutritionally unrestricted caribou (*Rangifer tarandus*) for later comparison with nutritionally stressed animals, and to develop improved facilities and methods for obtaining such information. By only allowing the bulls access to the cows during daylight hours of the rut, we were able to observe four of five breedings. Five calves were born and processed (weighed, measured, sexed, and ear tagged) without loss. Using a digital electronic scale, we weighed all caribou regularly, with little stress to the caribou. Two caribou died, one due to a parasite infestation (*Besnoitia tarandi*), the other from an accident (broken neck from hitting fence).

Key Words: Body weight, caribou, gestation, nutrition, *Rangifer tarandus*, reproduction.

CONTENTS

BACKGROUND

Recent data from the Southern Alaska Peninsula caribou herd (SAP) indicate a reduced population, small adult body size, low birth weights, late calving dates, and low calf survival. Undernutrition is the suspected agent affecting the population dynamics of that herd (Pitcher 1991). Because effects of nutrition on caribou condition are unclear, we have not yet defined appropriate management strategy for the herd.

Evidence from studies of domestic and wild reindeer in Norway and caribou in Canada indicates body condition affects reproductive performance of females and survival of their calves. Lenvik (1988) found that conception date in reindeer was related to weight (and possibly energy reserves) of females during the breeding season. Pregnancy rate was closely associated with fat reserves and body weights of Peary caribou in Arctic Canada (Thomas 1982). Calves of undernourished female reindeer had reduced birth weights and reduced survival (Espmark 1980, Skogland 1984).

Several studies found that undernutrition of females during gestation and possibly before breeding resulted in late calving (Espmark 1980, Reimers et al. 1983, Skogland 1984). Late calving reduces the summer growth season during the first year (Klein et al. 1987) and likely reduces survival of calves into the following winter (Haukioja and Salovaara 1978).

OBJECTIVE

For caribou there are strong indications that nutrition, growth, condition, productivity, and survival are linked; however, our knowledge of these relationships is incomplete and

additional information is needed to guide management. The objective of this study is to determine the effects of nutrition on breeding chronology, calving chronology, birth size, and neonatal survival.

METHODS

Field Procedures

Eight adult (>1 year) caribou (6 female, 2 male) were captured in September, 1990 from the Nelchina Basin caribou herd in Alaska with the use of a helicopter mounted net gun. They were drugged (Xylazine HCL) and transported in a sling to a staging area, where they underwent bioelectrical impedence analysis, were inoculated (Ivermectin),treated with a dual-penicillin type anti-biotic, weighed, measured, ear tagged, crated, and loaded on a truck for transport to the MRC. They were maintained in a 10 x 20 meter divided holding pen for several months, and soon adapted to a 1:1 ratio of pelleted reindeer ration and pelleted moose ration, supplemented with alfalfa hay. They were then permanently moved to a 4-ha enclosure and provided ad libitum feed and water.

On the morning of 7 November 1990, one of the males (Red) was found in shock outside of the holding pen and died soon after. A necropsy showed damage to the back of the neck and bruising on the back and rump. The holding pen gate had been lifted off its hinges by a rutting bull moose in an adjacent pen. It is presumed Red was attacked by a moose or, more likely, panicked and ran into a nearby gate. On 24 July 1991 the remaining male was drugged to remove an infectious growth in the velvet near an antler base. He died sometime in the next two weeks, presumably due to complications arising from the infection or the drugging. A young male caribou in the Tustemena transplant herd was darted from a helicopter on 29 August 1991 and brought to the MRC in a sling. It arrived dead. A second male (Lowland) in the Kenai Lowland herd was subsequently captured and transported successfully on the same day. It became very lame in the left rear leg, but eventually recovered fully. On 25 Sept. 1991, another male from the Tustemena herd was captured and brought to the MRC. It arrived in good condition, but renarcotized and died during the night due to aspiration of rumen contents. The last wild caribou was added to our group on 2 Oct. 1991, a male (Killey) from the Tustemena herd. He was in good condition and did all of the observed breeding that fall. He was found dead on 13 March 1992. The necropsy showed a blockage in the abomasum consisting of alfalfa stems. Alfalfa was immediately eliminated from their diet.

Although at least one breeding incident occurred among the caribou in 1990 after their capture, there were no births the following spring. The difficulties obtaining a breeding bull for the 1991 rut have been discussed above. Lowland was quite lame and in poor condition at the time, probably incapable of breeding. Killey arrived on 2 Oct. 1991 and immediately took charge of the captive herd. Both bulls were estimated to be yearlings. With six adult females, we observed two definite breedings and another was inferred from behavior. All six cows calved successfully the following spring (1992). One of the "unobserved" cows (BY) gave birth on 15 June 92, likely the result of a second estrus breeding due to the absense of a sound

breeding bull prior to 2 Oct. 1991. As soon after birth as possible, the calves were weighed using a spring scale (Salter No.235, London, England), ear tagged, sexed, and measured for total length, jaw length, metatarsus length (hind foot length less hoof length), and hind foot length (heel to tip of hoof). One of the calves was abandoned after we processed it and died that night (possibly by a coyote). We subsequently delayed processing calves for 12-24 hours after birth, wore plastic gloves to handle them, and used a clean plastic weighing sling. No abandonment has occurred since these methods were instituted. The mother (RW) of the abandoned calf died on 28 May 1992 due to a weighing injury. Two more calves died in June 1992 of unknown causes (not predation), and another disappeared in July 1992, after being separated from its mother while she was weighed. Although Killey died during the winter, Lowland was fully recovered for the 1992 rut. Only one breeding was observed among the 5 remaining adult cows. All 5 successfully calved in May 1993 (3 males, 2 females) with one of the males dying of unknown cause (not predation) on 11 June 1993.

This study requires periodic weighing of study animals, particularly of the adult females and calves, throughout the year. We initially attempted to bait them onto our enclosed platform scale, but this was very time-consuming and successful only with calmer individuals. We forced panicky caribou onto the scale. Although weights were obtained for all individuals, weighings proved extremely stressful, with numerous minor injuries and one death. We modified equipment and allowed time for caribou to calm and adapt to the procedure, but the results were not significantly better. In the interest of the welfare of the caribou, we suspended regular weighings until receiving more suitable equipment.

Analytical Procedures

During the 1993 breeding season, two adult (>1 year) male, six adult female and four calf caribou were confined in a 4-ha enclosure and fed a 1:1 ratio of pelleted reindeer ration and pelleted moose ration ad libitum. We changed our protocol for breeding observations, confining the breeding bull separately from the 5 breeding-aged cows for most of each day, allowing them to mingle a few hours each morning and evening when an observer was available to continuously watch them.

A 12-volt electronic digital readout open platform scale (Tru-Test Limited Model 700, Auckland, New Zealand) was installed in September, and we attempted to weigh all caribou at least once per month thereafter. They were deprived of feed for a day, then provided feed in a location that necessitated standing individually on the scale platform.

Newborn calves were weighed using a spring scale (Salter No.235, London, England), ear tagged, sexed, and measured for total length, jaw length, hind foot length 1 (metatarsus), and hind foot length 2 (heel to toe). We processed calves within 12 to 24 hours after birth.

RESULTS AND DISCUSSION

Breedings were observed for 4 of 5 sexually active cows. A yearling female (Shebou) was not sexually active. All 5 breeding cows successfully calved in May (4 males, 1 female), with all 5 calves in good condition. The first 2 calves were born during a 48 hour period when no one was in attendance. Their birth dates were estimated based on activity of the calves and condition of their umbilici. Mean gestation length was 224.3 (range 217-231) days for the 4 animals with known breeding dates (Table 1).

Weights were obtained regularly and without stress, using the digital electronic scale. October through May the bred females gained 8% to 15% to a precalving peak, adult males remained stable, and calves gained approximately 9% (Table 2).

When a female yearling (Shebou) died on 5 December, it was necropsied and histopathology samples were sent to a lab (Terry Spraker, Wildlife Pathology International, Ft. Collins, CO) for analysis. Results indicated an overwhelming infection with *Besnoitia tarandi*, for which caribou are an intermediate host and carnivores the primary host.

A male calf (Tangerine, born 1993) broke its neck and died on 29 March when it was trapped in a small pen and struck the fence. A visual barrier has been added to critical areas of the fence and gates to reduce the possibility of such incidents in the future.

LITERATURE CITED

Espmark, Y. 1980. Effects of maternal pre-partus undernutrition on early mother-calf relationships in reindeer. Pages 485-496 *in* Proc. 2nd Int. Reindeer and Caribou Symp., Trondheim, Norway.

Haukioja, E., and R. Salovaara. 1978. Summer weight of reindeer (*Rangifer tarandus*) calves and its importance for their future survival. Rep. Kevo Subarctic Res. Sta. 14:1-4.

Klein, D. R., M. Meldgaard, and S. G. Fancy. 1987. Factors determining leg length in *Rangifer tarandus*. J. Mamm. 68:642-655.

Lenvik, D. 1988. Selection strategy in domestic reindeer. 6. Oestrus peak and oestrus synchronization in domestic reindeer in Trondelag County, Norway. *Norsk landbruksforskning* 2:163-174.

Pitcher, K. W. 1991. Nutritional status of the Southern Alaska Peninsula, Nelchina and other Southcentral Alaska caribou herds. Fed. Aid Wildl. Res. Prog. Rept., Juneau, AK.

Reimers, E., D. R. Klein, and R. Sorumgaard. 1983. Calving time, growth rate, and body size of Norwegian reindeer on different ranges. *Arctic and Alpine Research* 15:107-118.

Skogland, T. 1984. The effects of food and maternal conditions on fetal growth and size in wild reindeer. *Rangifer* 4:39-46.

Thomas, D. C. 1982. The relationship between fertility and fat reserves in Peary caribou. *Can. J. Zool.* 60:597-602.

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Table 1. Descriptive data for captive caribou held at the Moose Research Center.

Animal	Sex	Date		Gestation length (days)	Birth weight (kg)	Total length (mm)	Mandible length (mm)	Metatarsus length[1] (mm)	HF2[2] (mm)	Source	Dam	Sire	Current status
		Conception	Birth										
Yellow	M		1989[3]		-	-	-	-	-	NELCHINA, 1990	WILD	WILD	DIED AUG 91
Red	M		1989[3]		-	-	-	-	-	NELCHINA, 1990	WILD	WILD	DIED NOV 90
Orange	F		1989[3]		-	-	-	-	-	NELCHINA, 1990	WILD	WILD	ALIVE
BR	F		1985-86[3]		-	-	-	-	-	NELCHINA, 1990	WILD	WILD	ALIVE
Blue	F		1985-86[3]		-	-	-	-	-	NELCHINA, 1990	WILD	WILD	ALIVE
BY	F		PRE-1985[3]		-	-	-	-	-	NELCHINA, 1990	WILD	WILD	ALIVE
RW	F		PRE-1989[3]		-	-	-	-	-	NELCHINA, 1990	WILD	WILD	DIED MAY 92
White	F		1986[3]		-	-	-	-	-	NELCHINA, 1990	WILD	WILD	ALIVE
Unnamed	M		1990[3]		-	-	-	-	-	TUSTEMENA, 1991	WILD	WILD	DIED AUG 91
Lowland	M		1990[3]		-	-	-	-	-	LOWLAND, 1991	WILD	WILD	ALIVE
Unnamed	M				-	-	-	-	-	TUSTEMENA, 1991	WILD	WILD	DIED SEP 91
Killey	M		1990[3]		-	-	-	-	-	KILLEY RIVER, 1991	WILD	WILD	DIED MAR 92
BB92	F	14 OCT 91	23 MAY 92	222	7.3	79.0	-	26.0	34.0	MRC	BLUE	KILLEY	DISAPPEARED JUL 92
Shebou	F	13 OCT 91[3]	24 MAY 92	224[3]	-	-	-	-	-	MRC	WHITE	KILLEY	DIED DEC 93
0092	M		25 MAY 92		-	-	-	-	-	MRC	ORANGE	KILLEY	DIED JUN 92
RW92			26 MAY 92		-	-	-	-	-	MRC	R.W.	KILLEY	DIED MAY 92
BR92		13 OCT 91	MAY 92		-	-	-	-	-	MRC	B.R.	KILLEY	DIED JUN 92
Hebou	M		15 JUN 92		10.0	92.0	-	28.0	36.5	MRC	B.Y.	KILLEY	ALIVE
Snow	F		16 MAY 93		7.7	92.0	13.5	28.0	35.5	MRC	WHITE	LOWLAND	ALIVE
Tangerine	M		17 MAY 93		7.7	85.0	14.5	27.0	34.0	MRC	ORANGE	LOWLAND	DIED APRIL 94
Buck	M	6 OCT 92	18 MAY 93	224	8.6	91.5	14.5	28.0	36.5	MRC	BLUE	LOWLAND	ALIVE
BY93	M		24 MAY 93		10.0	92.0	15.0	27.5	34.5	MRC	B.Y.	LOWLAND	DIED JUN 93
Violet	F		25 MAY 93		7.3	84.5	13.5	26.5	34.0	MRC	B.R.	LOWLAND	ALIVE
0094	F	7 OCT 93	12 MAY 94[3]	217[3]	7.3	81.5	13.5	27.5	33.0	MRC	ORANGE	LOWLAND	ALIVE
WW94	M		12 MAY 94[3]		9.5	89.0	17.5	28.5	37.0	MRC	WHITE	LOWLAND	ALIVE
BB94	M	6 OCT 93	18 MAY 94	224	10.0	92.5	14.5	30.0	37.5	MRC	BLUE	LOWLAND	ALIVE
BR94	M	6 OCT 93	25 MAY 94	231	9.5	94.0	14.5	29.5	37.5	MRC	B.R.	LOWLAND	ALIVE
BY94	M	13 OCT 93	26 MAY 94	225	10.0	94.0	14.0	29.0	37.0	MRC	B.Y.	LOWLAND	ALIVE

[1] Length of the hind foot minus the hoof
[2] Length of hind foot to tip of hoof
[3] Estimated

Table 2. Weights (kg) recorded for captive caribou at the Moose Research Center.

Date	BR	Blue	BY	White	RW	Orange	Lowland	Killey	Hebou	Shebou	Violet	Snow	Buck	Tangerine
Mar 92	-	-	-	-	-	-	-	117	-	-	-	-	-	-
Apr 92	122	122	117	126	115	102	101	-	-	-	-	-	-	-
May 92	-	-	-	-	101	-	-	-	-	-	-	-	-	-
Jun 92	-	-	110	-	-	-	-	-	-	-	-	-	-	-
Jul 92	107	105	-	114	-	97	115	-	-	-	-	-	-	-
Apr 93	117	126	120	127	-	111	126	-	78	60	-	-	-	-
Sep 93	-	-	-	-	-	-	-	-	131	87	64	64	78	73
Oct 93	120	128	113	117	-	106	165	-	-	85	66	71	85	-
Nov 93	124	130	113	120	-	-	165	-	128	83	67	73	85	79
Dec 93	124	133	115	124	-	113	168	-	128	-	69	73	89	84
Jan 94	123	132	117	127	-	113	168	-	126	-	69	76	90	85
Mar 94	124	134	120	130	-	113	164	-	129	-	70	78	91	87
Apr 94	124	136	122	134	-	117	163	-	128	-	69	76	91	-
May 94	130	139	130	135	[1] -	122	165	-	127	-	72	78	92	-
May 94	-	-	-	111	[2] -	-	-	-	-	-	-	-	-	-
Jun 94	104	119	112	117	-	102	176	-	-	-	-	82	-	-

[1] Prior to parturition
[2] After parturition

INFLUENCE OF SELECTIVE HARVEST SYSTEMS ON POPULATION GENETICS OF ALASKAN MOOSE (STUDY 1.48)

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Charles C. Schwartz
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RESEARCH PROGRESS REPORT

State: Alaska

Cooperators: Kenai National Wildlife Refuge, Soldotna, Alaska; Boone and Crockett Club; Dr. Michael H. Smith, Savannah River Ecology Lab, University of Georgia, Aiken, SC; Doug Larson, Charlie Land, Matt Robus, Roy Nowlin, Ted Spraker, Herman Griese, Bob Tobey, Tim Osborne, Robin Eagan, Alaska Department of Fish and Game

Grant No.: W-24-2 Project Title: Wildlife Research and Management

Study. No.: 1.48 Job Title: Influence of selective harvest systems on population genetics of Alaskan moose

Period Covered: 1 July 1993-30 June 1994

SUMMARY

Tissue samples and antler measurements were collected from hunter-killed moose from 8 populations across Alaska, and tissue samples were collected from female moose from a separate research project in an additional population. Analysis of these samples, for both mitochondrial DNA (mtDNA) and electrophoresis of allozymes, will commence in 1994. Five moose calves (2 male, 3 female) were captured in the Three Day Slough area of the Koyokuk River, north of Galena, and were transported to the Moose Research Center (MRC) where they were hand-reared. These calves, along with a female calf born at the MRC, will be used in a captive breeding program to assess heritability of antler traits and to determine if traits such as palmated brows are genetically based. This breeding program will commence in 1994, when these animals will enter their first season of sexual maturity. Herd composition of populations subject to selective harvest will be analyzed in subsequent years when enough data become available to assess temporal changes. Populations sampled in 1993-94 will be sampled again in 1994-95 to increase sample size, and 2 new populations (Colville River and Sheenjak River) will be sampled.

Key Words: *Alces alces*, antlers, genetics, genetic diversity, moose, selective harvest system.

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BACKGROUND

In 1987, the Alaska Board of Game approved a selective harvest system (SHS) for bull moose (*Alces alces*) on the Kenai Peninsula. This system limited bull harvest to those with either a spike or forked antler, or animals with at least a 50-inch (127 cm) antler spread or at least 3 brow tines on one antler. One of the many reasons cited for instituting this system was that focusing harvest on spike/fork yearlings eliminates "inferior" bulls from the gene pool. This statement derives from the assumptions antler characteristics are inherited, age-specific variation in antler size is related to genetics, and antler characteristics are indicative of overall individual fitness.

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

As public demand for consumptive and nonconsumptive use of moose increases, it is contingent upon the state to manage populations more intensively, which in turn requires a more complete knowledge of population processes. In attempting to understand temporal and spatial differences in the attributes of moose at the population (e.g., natality, mortality) and

individual animal (e.g., antler size, body condition) levels, biologists focus primarily on nutrition, predation, and harvest rates. The possibility that genetic factors are responsible for many intra- and interpopulation differences in these parameters is distinct; however, there is little information concerning population genetics of moose. In order to manage moose populations more effectively, we must understand the degree genetics contribute to antler development and the extent antler development reflects fitness. Additionally, we must describe the potential effects antler-based management strategies may have on genetics.

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

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

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

Although genetic diversity is thought to be maintained in natural populations by means of stabilizing selection (Pemberton et al. 1991), populations subject to hunting can exhibit unexpected trends in genetic composition due to different mortality rates. Improperly designed hunting seasons can cause dramatic changes in the genetics of populations without

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

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

Recently, genetic analyses have identified relationships between alleles and selective pressures. Pemberton et al. (1988, 1991) detected a relationship between gene frequencies at a particular locus and juvenile survival and adult fecundity in red deer. Hartl et al. (1991) demonstrated that selective harvesting of spike-antlered red deer caused a decline in frequency over time of a specific allele. This latter study is supported by Templeton et al. (1983), who demonstrated the number of antler points in white-tailed deer likely is controlled by a single gene. In a subsequent study, Hartl et al. (in press) concluded that red deer homozygous for a particular allele at the Idh-2 locus developed significantly more antler points than did individuals with alternative genotypes. Animals homozygous for a particular allele at the Acp-2 locus exhibited larger antlers overall compared with animals with other genotypes.

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

OBJECTIVES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

   H_{60}: The percentage of spike-fork yearlings in populations subject to SHS will not decrease over time.

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

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

H_{70}: Populations characterized by historically low bull:cow ratios and/or low population densities will exhibit no differences in genetic diversity compared with populations close to management objectives.

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

METHODS

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

A sample of skeletal muscle, as well as kidney, liver, and heart tissue if possible, will be collected from as many animals as possible, using harvested animals as well as road-kills. The desired sample size will be a minimum of 20 individuals per population per year. If animals in populations of interest are sceduled to be collared for other projects, we will collect whole blood and ear tissue samples from those animals.

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

Antler characteristics will be measured at hunter check stations in certain moose populations across the state. The populations of interest are Kenai Peninsula (GMU 15A and 15B-East), Copper River Delta (GMU 6D), Three Day Slough (GMU 21D), and Stikine River/Thomas Bay (GMU 1B), although animals from other populations will be measured opportunistically. Antler measurements will include greatest spread, number of points on the main palms, number of points on the brow palms, and beam circumference. Hind foot length will be measured when possible to serve as an index of body size. A data collection form was prepared for use by check station personnel but can be completed by the hunter if necessary (Fig. 1). A tooth will be extracted for age determination (Sergeant and Pimlott, 1959).

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

This job will be conducted at the MRC using moose (from different parts of the state) with different antler forms. In May 1993, 5 newborn calves (2 male, 3 female) were captured in the Three Day Slough area of the Koyukuk River, an area known for producing moose with large brow formations. These animals, along with a female calf born at the MRC, were hand-reared at the MRC to allow them to become accustomed to human presence and handling. The calves were allowed to forage on natural

vegetation during the summer and were provided a formulated ration (Schwartz et al. 1985) ad libitum during the winter to maximize nutritional effects on antler and body growth.

Selective breeding will follow the methodology of Harmel (1983). The 4 cows will be divided randomly into 2 groups and a bull will be placed with each group based upon random selection and allowed to breed. All offspring will be ear-tagged and weighed at birth. Male offspring will be placed in a large pen and fed a formulated ration ad libitum. Females will be retained to be bred to their fathers as yearlings and 2-year-olds. Male offspring will be weighed weekly in September, and their antlers will be removed, weighed and measured. Weights and antler measurements will be analyzed by partitioning the variance among sires and sibs (Wright 1969). Pedigrees of all MRC moose will be constructed to determine if these data can be used in this analysis.

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

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

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

Job 5. Laboratory analysis of tissue samples.

Electrophoretic analysis of tissue samples will be conducted at the Savannah River Ecology Lab under the supervision of M. H. Smith. Number of loci examined will be determined by the types of tissue samples, but at a minimum the 20 loci examined by Hundertmark et al. (1992) will be scored. Additionally, the Idh and Acp loci will be scored (Hartl et al. in press). Genetic variability will be expressed as heterozygosity (H), alleles per locus (A), and percent polymorphic loci (P). Genetic differentiation among populations will be determined by use of F statistics (Wright 1965) and Nei's genetic distance (Nei 1978).

Mitochondrial DNA (mtDNA) will be analyzed at the Institute of Arctic Biology, University of Alaska-Fairbanks under the supervision of G. F. Shields. Nucleic acid sequences will be determined directly for the control region of the mtDNA molecule.

RESULTS AND DISCUSSION

Job 1. Collect tissue samples from moose populations across the state. Tissue samples were collected from 9 moose populations across the state (Fig. 2). Populations sampled were: Unuk River (n=1), Thomas Bay (n=25), Chilkat Valley (n=23), Copper River Delta (n=ca. 100), Kenai Peninsula (n=30), Matanuska-Susitna Valleys (n=29), Three Day Slough (n=45), Tanana Flats (n=5), and the Nelchina Basin (n=41). These samples represent hunter-killed animals (with the exception of the Nelchina Basin moose) collared for another project and from which we collected blood and a sample of ear tissue.

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

These data have not yet been analyzed.

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

The animals selected for this Job did not reach sexual maturity during this reporting period.

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

Herd composition surveys for the study areas have not yet been analyzed because at the most only 1 survey has been conducted in each area since implementation of the selective harvest system.

Job 5. Laboratory analysis of tissue samples.

Analysis of mtDNA can only be conducted when Hundertmark travels to Fairbanks because this analysis is part of the Ph.D. program in which he is enrolled. He plans on spending 3.5 months in Fairbanks during the next reporting period, at which time he will begin this analysis. Electrophoretic analysis is conducted once yearly at Savannah River Ecology Lab. Samples collected thus far will be shipped there during the next reporting period for analysis during their 1994-1995 lab schedule.

RECOMMENDATIONS

Electrophoretic and mtDNA analyses begin during the next reporting period, as will analyses for Jobs 2 and 4. Tissue samples from moose in the populations sampled in 1993 will be solicited from successful hunters in 1994 to increase sample sizes. We will collect tissue samples from moose taken by hunters in the Colville River drainage on the North Slope. Also, we will collect blood and ear tissue from no more than 60 moose to be collared in the Sheenjak River area in the Arctic National Wildlife Refuge, and no more than 40 moose to be

collared in the upper Susitna River drainage. The captive moose will be allowed to breed during 1994.

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LITERATURE CITED

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

Chesser, R. K., and M. H. Smith. 1987. Relationship of genetic variation to growth and reproduction in white-tailed deer. Pages 168-177 *in* C. M. Wemmer, ed. Biology and management of the Cervidae. Smithsonian Inst. Press, Washington, DC.

Cothran, E. G., R. K. Chesser, M. H. Smith, and P. E. Johns. 1983. Influences of genetic variability and maternal factors on fetal growth in white-tailed deer. *Evolution* 37:282-291.

Dratch, P. A., and U. Gyllensten. 1985. Genetic differentiation of red deer and North American elk (wapiti). Pages 37-40 *in* P. F. Fennesey and K. R. Drew, eds. The biology of deer production. Royal Soc. New Zealand, Wellington, Bull. 20.

Dratch, P. A., and J. M. Pemberton. 1992. Application of biochemical genetics to deer management: what the gels tell. Pages 367-383 *in* R. D. Brown, ed. The biology of deer. Springer-Verlag, New York, NY.

Goss, R. J. 1983. Deer antlers: regeneration, function, and evolution. Academic Press, New York, NY.

Harmel, D. 1983. Effects of genetics on antler quality and body size in white-tailed deer. Pages 339-348 *in* R. D. Brown, ed. Antler development in the Cervidae. Caesar Kleberg Wildl. Res. Inst., Kingsville, TX.

Hartl, G. B., G. Lang, F. Klein, and R. Willing. 1991. Relationships between allozymes, heterozygosity and morphological characters in red deer (*Cervus elaphus*), and the influence of selective hunting on allele frequency distributions. Heredity 66:343-350.

_____, F. Klein, R. Willing, M. Appolonio, and G. Lang. In press. Allozymes and genetics of antler development in red deer (*Cervus elaphus*). *J. Zool.* (Lond.).

Hedrick, P. W., and P. S. Miller. 1992. Conservation genetics: techniques and fundamentals. *Ecol. Appl.* 2:30-46.

Hundertmark, K. J., P. E. Johns, and M. H. Smith. 1992. Genetic diversity of moose from the Kenai Peninsula, Alaska. *Alces* 28:1-6.

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

Manlove, M. N., M. H. Smith, H. O. Hillestad, S. E. Fuller, P. E. Johns, and D. O. Straney. 1976. Genetic subdivision in a herd of white-tailed deer as demonstrated by spatial shifts in gene frequencies. *Proc. Annual Conf. S. E. Assoc. Fish Wildl. Agencies* 30:487-492.

Mitton, J. B., and M. C. Grant. 1984. Associations among protein heterozygosity, growth rate, and developmental homeostasis. *Ann. Rev. Ecol. Syst.* 15:479-499.

Nei, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. *Genetics* 89:583-590.

Pemberton, J. M., S. D. Albon, F. E. Guinness, and T. H. Clutton-Brock. 1991. Countervailing selection in different fitness components in female red deer. *Evolution* 45:93-103.

Pemberton, J. M., S. D. Albon, F. E. Guinness, T. H. Clutton-Brock, and R. J. Berry. 1988. Genetic variation and juvenile survival in red deer. *Evolution* 42:921-934.

Røed, K. H., and K. R. Whitten. 1986. Transferrin variation and evolution of Alaskan reindeer and caribou, *Rangifer tarandus* L. *Rangifer* (Special Issue 1):247-251.

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

Ryman, N., 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.

Schwartz, C. C., W. L. Regelin, and A. W. Franzmann. 1987. Suitability of a formulated ration for moose. *J. Wildl. Manage.* 49:137-141.

Schwartz, C. C., K. J. Hundertmark, and T. H. Spraker. 1992. An evaluation of selective bull moose harvest on the Kenai Peninsula, Alaska. *Alces* 28:(in press).

Scribner, K. T., and M. H. Smith. 1991. Genetic variability and antler development. Pages 460-473 *in* G. A. Bubenik and A. B. Bubenik, eds. Horns, pronghorns and antlers: evolution, morphology and social significance of cranial appendages in ruminants. Springer-Verlag, New York, NY.

Scribner, K. T., M. H. Smith, R. A. Garrott, and L. H. Carpenter. 1991. Temporal, spatial, and age-specific changes in genotypic composition of mule deer. *J. Mamm.* 72:126-137.

Scribner, K. T., M. C. Wooten, M. H. Smith, and P. E. Johns. 1985. Demographic and genetic characteristics of white-tailed deer populations subjected to still or dog

hunting. Pages 197-212 *in* S. L. Beasom and S. F. Roberson, eds. Game harvest management. Caesar Kleberg Wildl. Res. Inst., Kingsville, TX.

Seargent, D. E., and D. H. Pimlott. 1959. Age determination in moose from sectioned incisor teeth. *J. Wildl. Manage.* 23:315-321.

Smith, M. H., R. Baccus, H. O. Hillestad, and M. N. Manlove. 1984. Population genetics. Pages 119-128 *in* L. K. Hall, ed. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, PA.

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. Am. Wildl. Nat. Res. Conf.* 41:119-123.

Templeton, J. W., R. M. Sharp, J. Williams, D. Davis, D. Harmel, B. Armstrong, and S. Wardroup. 1983. Single dominant major gene effect on the expression of antler point number in the white-tailed deer [abstract]. Page 469 *in* R. D. Brown, ed. Antler development in the Cervidae. Caesar Kleberg Wildl. Res. Inst., Kingsville, TX.

Thelen, T. H. 1991. Effects of harvest on antlers of simulated populations of elk. *J. Wildl. Manage.* 55:243-249.

Wright, S. 1965. The interpretation of population structure by use of F-statistics with special regard to systems of mating. *Evolution* 19:395-420.

Wright, S. 1969. Evolution and the genetics of populations. Vol. 2. The theory of gene frequencies. Univ. of Chicago Press, Chicago, 511 pp.

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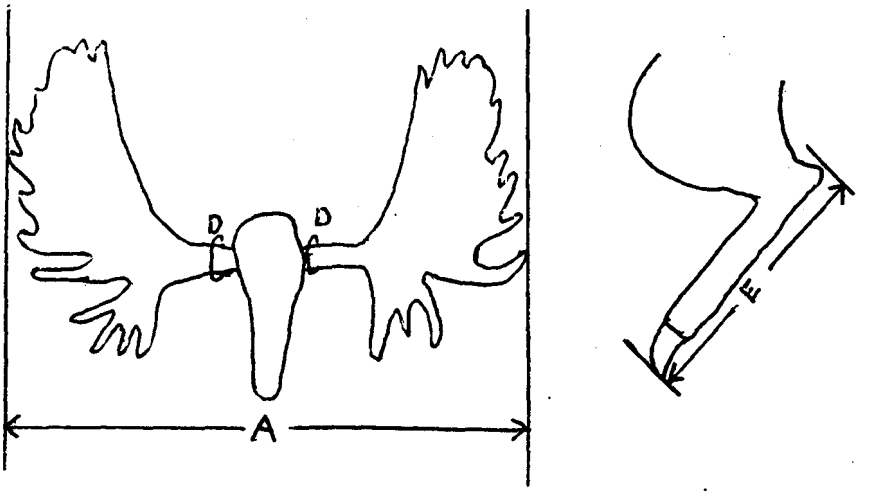
ALASKA DEPARTMENT OF FISH AND GAME
MOOSE ANTLER GENETICS STUDY



	RIGHT	LEFT
A. GREATEST SPREAD		
B. NUMBER OF ANTLER POINTS (EXCLUDING BROW POINTS)		
C. NUMBER OF BROW POINTS		
D. CIRCUMFERENCE OF BEAM AT SMALLEST PLACE		
E. HIND FOOT LENGTH (EITHER FOOT)		

NOTE: THE DEFINITION OF A POINT IS A PROJECTION THAT IS AT LEAST 1″ LONG AND THAT IS LONGER THAN IT IS WIDE

Hunt Number _____ (if applicable) Permit Number _____ (if applicable)

Game Management Unit/Subunit _____

General location of kill site _____
(name of river, creek, lake, mountain, or highway milepost)

Samples collected: muscle ____ kidney ____ liver ____ heart ____ jaw ____

The following information is optional, periodic updates will be mailed to those participants that complete this section

Name _____

Address _____

City, State, Zip _____

Please return this form alnong with the samples to your local Fish and Game office.

Fig. 1. The data collection form for tissue samples and antler measurements used in this study.

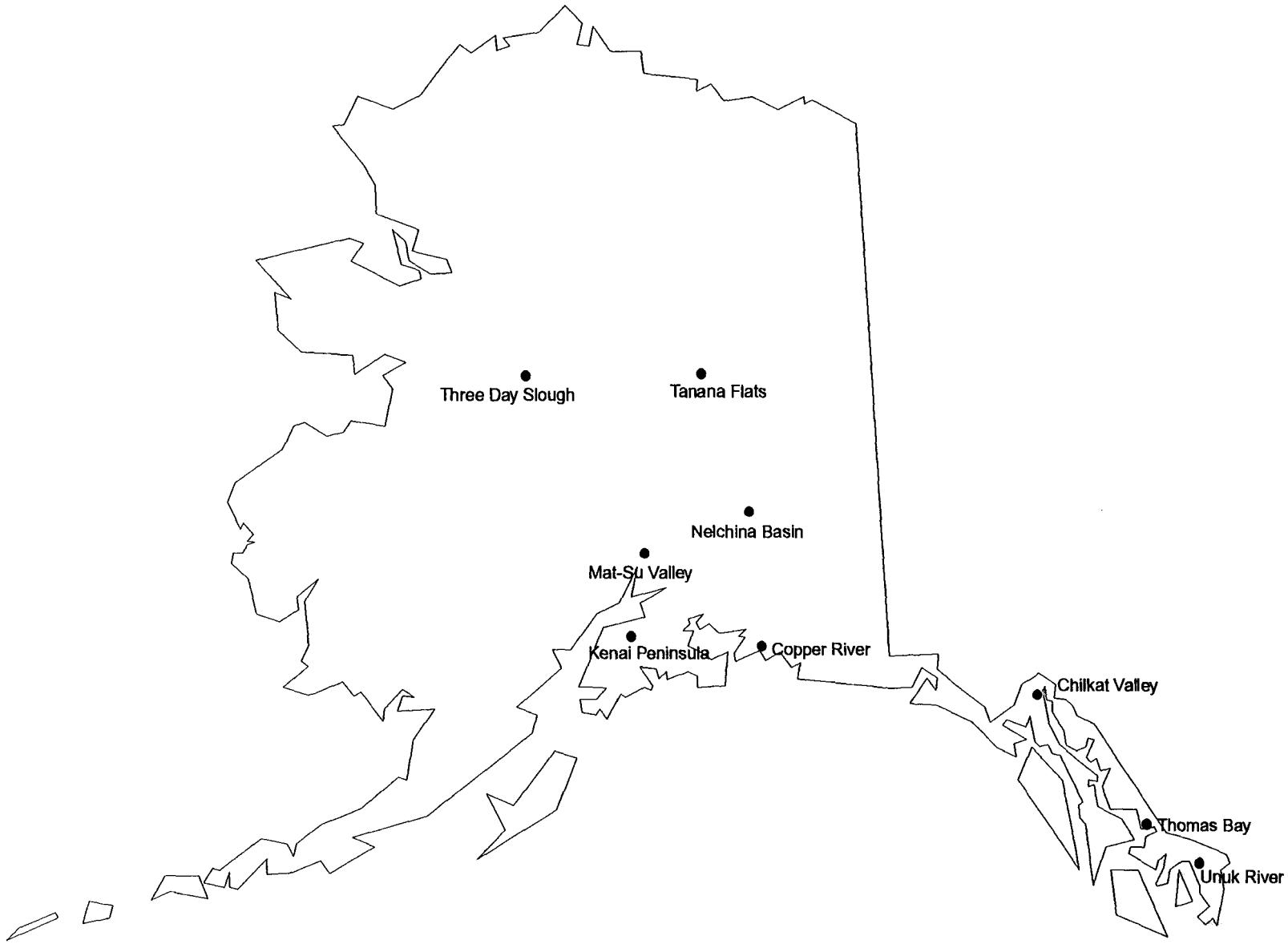
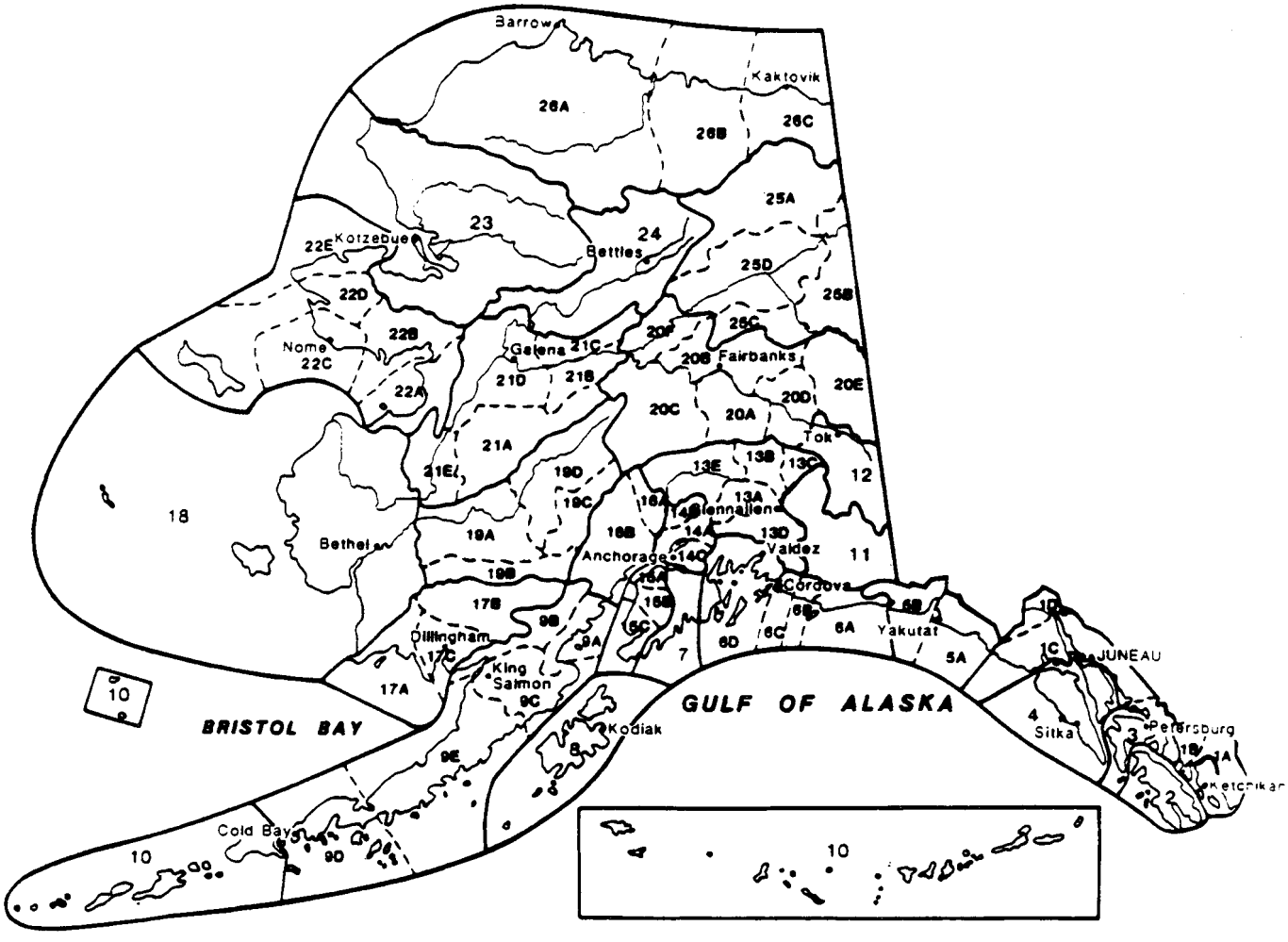


Fig.1. Location of moose populations from which tissue samples were collected in 1993-94 for analysis of genetic composition

Alaska's Game Management Units



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


Pat Costello