PREDICTING BODY MASS OF ALASKAN MOOSE (*ALCES ALCES GIGAS*) USING BODY MEASUREMENTS AND CONDITION ASSESSMENT

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ABSTRACT: The ability to predict body mass (BM) of moose in the field using simple morphometric indices would be useful in assessing numerous aspects of moose biology and management. Previous studies have used length and girth measurements but generally have ignored estimates of condition as potential predictors. We evaluated the efficacy of adding a subjective condition class (CC) index to mass-length regressions to improve estimates of body mass; we also evaluated the repeatability of standard morphometric measures. Total length (TL) was a significant but poor predictor of BM and exhibited non-constant variance of residuals. Chest girth (CG) was a better predictor of BM, but the best single predictor was $TL*CG^2$. The addition of CC to the regression improved the fit and reduced the standard error of the estimate. Total length and CG of 5 moose measured repeatedly over a 3-week period varied considerably, with coefficients of variation ranging from 1.9-5.5%. This variation is attributed to the difficulties associated with positioning moose for precise measurement in the field. Morphometric models assessed in this study are useful for predicting BM of moose generally but are not precise enough to predict seasonal changes in mass of mature moose.

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Body mass (BM) is an important variable in examining physiological processes and in determining nutritional condition in cervids. Measuring BM directly in large free-ranging animals, such as moose (*Alces alces*), is difficult. Tripods large enough to suspend moose from a scale are difficult to transport and use in remote field operations. Moreover, some helicopters involved in capture operations are incapable of lifting moose safely.

Estimating BM of large-bodied ungulates via morphological measurements has proven successful (Hall-Martin 1977, Kelsall *et al.* 1978, Bunnell 1980). Commonly used predictors include total length (TL) and chest girth (CG). Karns (1976) demonstrated a linear relationship between CG and eviscerated mass in moose. Franzmann *et al.* (1978) and Haigh *et al.* (1980) reported high correlations between TL, CG and BM of moose. Both of the latter studies, however, developed predictive equations across a wide range of body sizes (age classes) ensuring a reasonable fit. Estimates of seasonal changes in BM of individuals within a single sex-age class (e.g. adult females), however, are not precise. This is because body measurements are relatively insensitive to changes in the annual mass cycle of cervids, which is caused primarily by changes in the amount of body fat. Models accounting for annual variation in fat mass are untested.

Condition class indices are useful for estimating nutritional status of live animals (Franzmann 1977, Gerhart *et al.* 1991). Franzmann (1977) developed a subjective

11-point scale for assessing condition class of moose based on physical appearance and palpable subcutaneous fat (Table 1). We tested the hypothesis that inclusion of condition class in a predictive equation for BM that included other morphological measurements would improve the accuracy of such an equation. We also evaluated the repeatability of TL and CG measurements. Finally, we compared the results of our research with 2 published reports of mass-measurement relationships in moose.

METHODS

During chemical immobilizations of moose at the Kenai Moose Research Center (MRC), TL and CG are measured routinely with the animal in sternal recumbency. Total length is measured along the head and spine from the dorsal (posterior) margin of the planum nasale to the tip of the tail, following the contour of the body. Chest girth was measured from the center of the sternum to the highest point along the "hump" of the spine between the scapulae, with the tape passing immediately posterior to the foreleg. This measurement was then doubled to obtain circumference. Condition class (Table 1) was assigned according to the criteria developed by Franzmann (1977).

Records of animal immobilizations at the Moose Research Center were reviewed to collect instances where BM, TL, CG, and CC were measured. Only animals with TL > 250 cm were included to limit the analysis to mature animals. Seventy-seven instances

Table 1. Scores and descriptions of condition classes for evaluating nutritional status of moose (from Franzmann 1977).

Class	Description
10	A prime, fat animal with thick, firm rump fat by sight; well fleshed over back and loin; shoulders round and full.
9	A choice, fat moose with evidence of rump fat by feel; fleshed over back and loin; shoulders round and full.
8	A good, fat moose with slight evidence of rump fat by feel; bony structures of back and loin not prominent; shoulders well fleshed.
7	An average moose with no evidence of rump fat, but well fleshed; bony structures of back and loin evident by feel; shoulders with some angularity.
6	A moderately fleshed moose beginning to demonstrate one of the following conditions: (A) definition of neck from shoulders; (B) upper foreleg (humerus and musculature) distinct from chest; or (C) rib cage prominent.
5	A condition in which two of the characteristics listed in Class 6 are evident.
4	A condition in which all three of the characteristics listed in Class 6 are evident.
3	A condition in which the hide fits loosely about neck and shoulders; head is carried at a lower profile; walking and running posture appears normal.
2	Signs of malnutrition are obvious; the outline of the scapula is evident; head and neck are low and extended; the moose walks normally but trots and paces with difficulty, and cannot canter.
1	A point of no return; a generalized appearance of weakness; the moose walks with difficulty and can no longer trot, pace or canter.
0	Dead.

of coincident measurements of mass, TL, and CG were found. Of these, 59 contained an estimate of CC. These data were subjected to forward stepwise regression for the general model BM = CONSTANT + TL + CG + TL*CG^2 + CC + SEX. The parameter TL*CG^2 was included because Haigh *et al.* (1980) reported that this derived variable was the best predictor of BM. Sex was coded as a dummy variable (male = 0, female = 1) and was included in the model to determine if sex-related differences existed. Simple linear models using TL, CG, and $TLCG^2$ were analyzed by using the entire data set and by constraining the analysis to those observations containing an estimate of CC. Additionally, we tested for differences between the sexes in the relationship between TL and CG using the multi-reponse permutation procedure (Biondini *et al.* 1988, Slauson *et al.* 1991).

Five yearling male moose were held in captivity at the MRC and were fed a formulated ration (Schwartz *et al.* 1985). As part of a separate study, each animal was immobilized 8 times within a 3-week interval, with 2-5 days separating consecutive immobilizations. Total length and CG were measured to the nearest cm for each animal during each immobilization. Investigators were not told that the measurements would be analyzed for repeatability. Prior to immobilization, each animal was weighed on a livestock scale and the mass was recorded to the nearest kg. Coefficients of variation (CV) were calculated for TL, BM, and CG for each animal.

Relationships between BM, TL, and CG observed in this study were compared with those reported for Alaskan moose (*A. a. gigas*, Franzmann *et al.* 1978) and moose measured in Alberta and Saskatchewan (*A. a. andersoni*, Haigh *et al.* 1980). We assessed the consistency of the relationships between the 2 Alaska studies and whether the relationships were similar between subspecies. Raw data were not available from the published reports, so our analysis was limited to visual inspection of the relationships. Statistical differences were considered significant at a level of $\alpha = 0.05$.

RESULTS

Total length, CG and CC were significant predictors of BM in mature moose

Table 2. Regression coefficients of models for predicting body mass (kg) of moose using body measurements (cm). The simple linear models are reported twice, once using all animals and once using animals for which CC was recorded. The latter models then are comparable to models that included CC as a predictor. The derived variable TL*CG^2 was computed with TL and CG expressed in meters to eliminate scaling problems.

Equation	R^2	$S_{Y \cdot X}$	Error df
-364.8+2.65(TL)	0.29	61.9	75
-314.0+2.45(TL)	0.24	56.9	57
-314.1+3.80(CG)	0.62	45.3	75
-243.9+3.4(CG)	0.50	46.2	57
87.8+30.0(TL)$(CG)^2$	0.68	41.2	75
105.2+28.1(TL)$(CG)^2$	0.57	42.9	57
-525.9+1.17(TL)+2.60(CG)+13.60(CC)	0.66	38.9	55
48.4+24.7(TL)$(CG)^2$+13.7(CC)	0.67	38.2	56

(Table 2) although TL was a poor single predictor. The variable TL*CG^2 was the first to be entered into the stepwise regression model, and along with CC comprised the best predictive model. Sex was not included in any model. When TL alone was used as a predictor, analysis of residuals indicated increasing variance with increasing TL. Residuals of other regressions were homoscadestic. Condition class estimates were more highly correlated with residuals of the BM-TL regression (r = 0.42) than they were with residuals of the BM-CG equation (r = 0.32).

Sex-related differences were apparent in the relationship between TL and CG (Fig. 1A). For mature animals, CG of females did not vary significantly with changes in TL (test for non-significant slope, $t = 1.32$, $P = 0.198$). Conversely, CG of males increased linearly with TL (CG = 204.0 + 0.433*TL, $t = 4.54$, $P < 0.001$; $R^2 = 0.345$, $P < 0.001$). The bivariate distributions of these data differed between the sexes ($\delta = -2.24$, $P = 0.039$).

Comparison of published regression lines

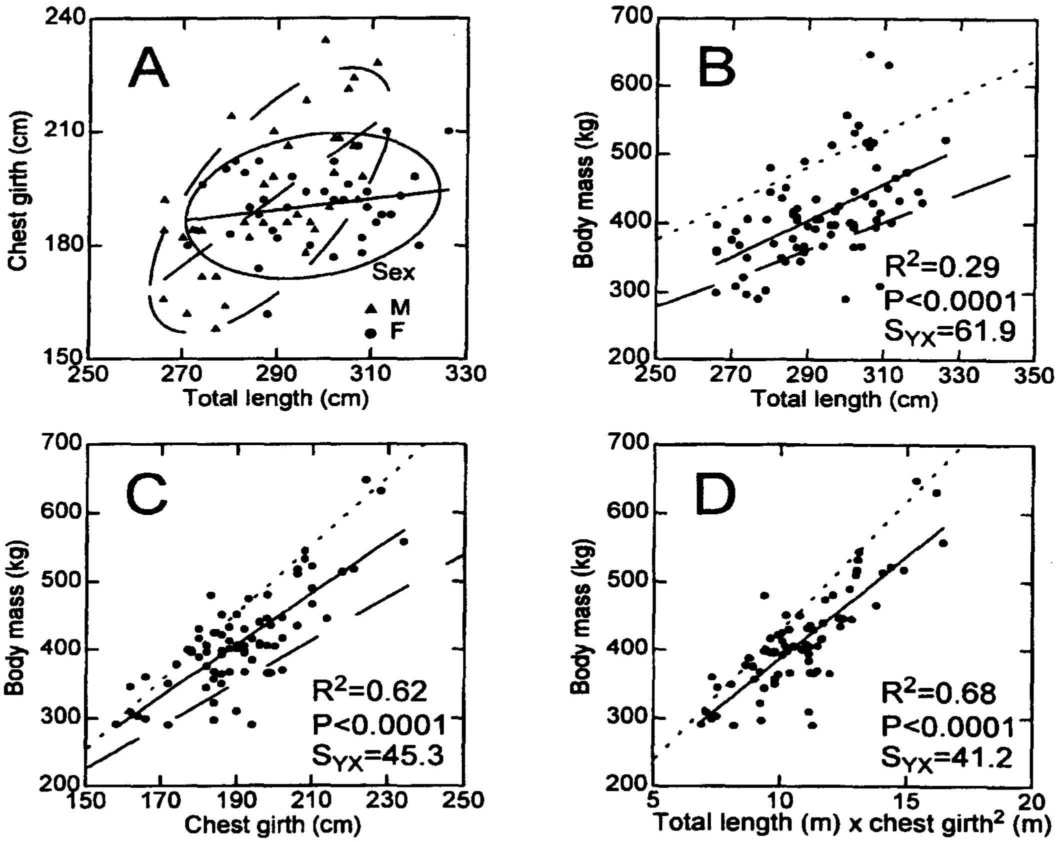

Fig. 1. (A) The relationship between CG and TL, indicating that males continue to increase in CG after they reach maximum TL whereas in females, maximum CG is attained before maximum TL. Least squares regression lines and 80% ellipses are represented for males (broken lines) and females (solid lines). Only mature moose (TL > 250 cm) are included. (B-D) The relationships between (B) BM and TL, (C) BM and CG, and (D) BM and TL*CG^2 for mature moose in this study (open circles and solid line), a previous study of *A. a. gigas* (Franzmann *et al.* 1978, broken line) and a previous study of *A. a. andersoni* (Haigh *et al.* 1980, dotted line). Estimates of CG*TL^2 were not available from Franzmann *et al.* (1978).

indicate a similar relationship between the data collected by Franzmann *et al.* (1978) and those of this study. A difference in slope in the BM-TL plot (Fig. 1B) and a slight difference in elevation in the BM-CG plot (Fig. 1C) suggest that for a given TL, the moose measured in this study were heavier than those observed by Franzmann *et al.* (1978), even though the latter animals also were measured at the MRC. Using $TL*CG^2$ to predict BM (Fig. 1D) yields similar models for this study and the data of Haigh *et al.* (1980); data for Franzmann *et al.* (1978) were not available. Again, the elevation of the Canadian model is slightly higher than that for this study.

Measurements of BM, TL, and CG for the 5 yearling males varied over the trial (Table 3). Coefficients of variation of CG were greater than those of TL for 4 of 5 animals. Variation in TL and CG generally were greater than that of BM, despite the trend of BM to vary over short periods in animals due to changes in intake and gut fill associated with confinement and chemical immobilization.

DISCUSSION

Estimation of BM in the field can be an important process in studying the biology of moose populations. Body size and fatness of cervids on northern ranges are indicators of habitat and weather conditions (Hobbs 1989) and are easier to estimate and interpret than environmental variables. Within a sex-age class, BM is an indicator of condition. Knowledge of condition of populations is essential to understanding demographic processes and prescribing management actions.

Our data indicate that a combination of TL, CG, and CC are better predictors of BM of mature moose than any of these variables alone. Similar to the results of Haigh *et al.* (1980), we found that the derived variable $TL*CG^2$ was the best predictor of BM. Although $TL*CG^2$ was the first variable entered in the stepwise regression model, most of the variation in this predictor is due to variation in CG, which also had the highest CV in our repeatability trial. This is cause for concern for field biologists. The measurement of CG on a sternally-recumbent moose is difficult because the center of the breast must be located by feel and the position of the foreleg can influence the path of the tape between the center of the breast and the top of the hump. For a precise estimate of this parameter, moose should be placed on their side with the foreleg placed in a standing position. We do not recommend this procedure, however, because placing an immobilized moose on its side can cause aspiration

Table 3. Measures of dispersion for mass, total length, and chest girth for 5 yearling male moose. Individual animals were measured 8 times over a 3-week period in September and October, with no less than 2 days separating each measurement of a given animal.

	Mass (kg)				Total length (cm)				Chest girth (cm)			
Animal	Min	Max	Mean	CV	Min	Max	Mean	CV	Min	Max	Mean	CV
1[a]	341	349	344	1.0	272	296	281	2.8	188	200	193	2.4
2[a]	323	328	326	0.7	263	281	273	2.0	180	196	188	2.8
3	364	372	367	0.9	271	294	283	2.9	180	204	193	4.1
4	294	316	307	3.3	265	288	272	2.8	167	198	185	5.5
5	318	338	325	2.6	261	274	267	1.9	182	199	193	3.0

[a] For mass measurements, *n* = 7.

of rumen contents, particularly if the animal is lying on its left side. Alternatively, measuring the complete circumference of the animal, albeit difficult, would be advisable.

The measurement of TL also should be standardized as much as possible to achieve precision. A sternally-recumbent moose often will assume a position with the neck bent to one side. We believe that the animal should be measured with the spine as straight as possible. Also, care must be taken to press the tape into the hair to ensure that the body contour is followed.

The increasing variance associated with increasing TL in the mass-length regression indicates this predictor's inability to account for variation in fat and muscle mass associated with seasonal mass dynamics in large moose. Despite poorer precision, CG was a more accurate predictor of BM than was TL. As moose improve body condition (increase body fat and protein stores) CG is more likely to reflect this change than is TL.

Estimation of CC is subjective and can vary among investigators. We have found that our own estimates of CC for a given moose can vary, although rarely by more than one class. The use of Franzmann's scale by investigators not trained at the MRC likely would introduce more bias. This indicates that biologists intending to use CC as an indicator of condition or as a predictor of BM should gain as much hands-on experience as possible before applying this technique in the field. Also, we recommend that, where possible, the same individual rate CC for all moose to eliminate between-observer bias.

Any real differences in regression lines generated by the two studies of MRC moose likely can be attributed to the better diet provided to moose at the MRC now compared with the natural browse diet available to moose measured by Franzmann *et al.* (1978) and illustrates the utility of CC estimates in differentiating masses of fat and lean animals of similar size. The elevations of the lines for Alberta and Saskatchewan moose seem greater than those for either study of MRC moose and seemingly indicate that, for any given TL or CG measurement, *A. a. andersoni* are heavier than *A. a. gigas*. We do not believe that this is generally true, but rather is an artifact of these data. Moose measured by Haigh *et al.* (1980) may have been in better condition than those measured by us or by Franzmann *et al.* (1978).

Haigh *et al.* (1980) could not determine if differences existed in BM-measurement relationships between the sexes because their sample size was too small. Franzmann *et al.* (1978) noted a small but significant difference between the sexes but claimed that it was not biologically significant. Karns (1976) noted sex-related differences in CG-eviscerated mass relationships in two different areas of Minnesota. Our data indicate that males continue to increase in CG until, and possibly after, increases in TL cease whereas females achieve maximum CG prior to the time when TL ceases to increase. Sex was not included as a significant predictor in stepwise regressions because the slopes of the relationships differ between males and females. These differences could be important in predicting BM of mature animals, in which case sex-specific equations may be in order. Unfortunately, our sample size precluded us from deriving reliable equations for very large moose.

Our data indicate that morphometric models are useful for estimating mass of moose in a general sense but are neither accurate nor precise enough to assess seasonal variation in mass of specific sex-age groups. Therefore, they are not applicable to investigations of relationships between animal condition and environmental variation.

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