

## RELATIONSHIPS BETWEEN BLOOD-SERUM VARIABLES AND DEPTH OF RUMP FAT IN ALASKAN MOOSE

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**ABSTRACT:** We studied the relationship between maximum depth of rump fat determined from ultrasound measurements and 22 blood values for Alaskan moose (*Alces alces gigas*) by sampling 38 pregnant, adult females. Moose were immobilized, and blood was drawn simultaneously with the determination of depth of rump fat during 1-4 March 1996. Multiple-regression models were used to detect relationships between blood-serum variables and depth of fat. Four of 22 blood-serum variables were removed to control for multicollinearity. Remaining variables were regressed against induction time ( $\bar{X}=6.1$  min,  $SD=4.4$  min). Glucose, sodium, and blood urea nitrogen were correlated with induction time ( $R_a^2=0.27$ ,  $P=0.010$ ) and likely represented a response to handling; these blood values also were removed from the final regression model. Mallow's  $C_p$  statistic indicated the most appropriate regression model included only 2 variables. Creatinine ( $\bar{X}=2.08$  mg/dl,  $SD=0.26$  mg/dl) and aspartate aminotransferase (AST) ( $\bar{X}=79.10$  U/l,  $SD=13.61$  U/l) met all necessary assumptions and explained a portion of the variability observed in fat depth ( $\bar{X}=1.5$  cm,  $SD=1.0$  cm). Thus, our final model was: maximum depth of rump fat =  $0.28 + 1.68(\text{creatinine}) - 0.03(\text{AST})$ . This model was significant ( $P=0.0002$ ) and accounted for 33.7% ( $R_a^2$ ) of variability observed in fat depth. Partial regression coefficients for creatinine and AST were 0.222 ( $P=0.0025$ ) and 0.150 ( $P=0.006$ ), respectively, and indicated that creatinine was slightly more influential than AST in the model. These blood variables may provide insights into the predicted condition of moose and the response of moose to environmental conditions. A model using blood variables thought to be indicators of physical condition (protein, phosphorus, and calcium) did not explain significant variation in maximum depth of rump fat.

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Body-fat reserves often are used to index the relative condition of individual animals (Kirkpatrick 1980); this technique has been used widely in assessing body condition in northern cervids (Schwartz *et al.* 1988b, Allaye-Chan and White 1991, Stephenson 1995, Gerhart *et al.* 1996). Body-fat reserves can be logistically difficult to obtain in many situations, and until recently, could not be sampled easily in the field. Blood variables also are potentially

useful measures in evaluating the physical condition of ruminants (LeResche *et al.* 1974, Franzmann *et al.* 1987, Wolkers *et al.* 1994), are easier to obtain than measurements of body fat, and do not require destruction of the study animal. Moreover, condition of cervids often has been implicated as a controlling factor in reproductive success (McCullough 1979, Clutton-Brock *et al.* 1982, Schwartz and Hundertmark 1993, Cameron and Ver Hoef 1994), and

hence influences productivity of populations. We compared blood-serum variables with rump-fat measurements to test for a relationship between these two indices; this is the first study to use this approach on moose. In addition this method allows the application of the animal-indicator concept (Franzmann and Schwartz 1988) to populations from which only blood samples are available. We hypothesized that protein, phosphorous, and calcium would be the best predictors of condition based on previous research on Alaskan moose (*Alces alces gigas*) (Franzmann and LeResche 1978, Franzmann *et al.* 1987). We also tested for a relationship between these variables using a broader suite of serum components.

#### STUDY AREA

We captured moose in interior Alaska (64° 39.17' N, 148° 07.05' W) between the Tanana River and the Alaska Range, about 25 km south of Fairbanks, Alaska, USA. This area comprises a large portion of the Tanana Flats described previously by Gasaway *et al.* (1983). The region is underlain by permafrost and typified by poorly drained lowlands consisting of numerous shallow ponds, bogs, and creeks. Fires have created a mosaic of early successional and mature black spruce (*Picea mariana*) forests (Gasaway *et al.* 1983). Elevation within this region varies from 130 to 300 m (Boertje *et al.* 1996).

The climate of the study area is typical of interior Alaska and is characterized by cold winters, low-level temperature inversions, and relatively dry, warm summers (Gasaway *et al.* 1983). Temperatures frequently reach 25°C in summer and fall to -40°C in winter. Snow depth is generally <80 cm, and snow pack usually remains dry and loose throughout winter.

Estimated density of moose within the study area was 1.1 moose/km<sup>2</sup> (R. Boertje,

AK Dept. of Fish and Game, *pers. comm.*). This density was high compared with other areas of interior Alaska, where populations are held at low levels by predation (Gasaway *et al.* 1992, Van Ballenberghe and Ballard 1994). The moose population in the Tanana Flats is increasing (R. Boertje, AK Dept. of Fish and Game, *pers. comm.*).

#### METHODS

We captured 38 pregnant, female moose between 1-4 March 1996. This narrow window for sampling moose was selected to help minimize seasonal variation in both fat and blood values, and because this period (about 2.5 months preparturition) is one in which rapid fetal growth occurs (Schwartz and Hundertmark 1993). Moose typically give birth in late May in interior Alaska (Bowyer *et al.* 1998). Moose initially were located with fixed-wing aircraft. We then darted moose from a helicopter with 3-cc projectile syringes filled with a mixture of carfentanil (4.5 mg) and xylazine (150 mg) and propelled by a CAP-CHUR extra long-range rifle. Following darting of the moose, the helicopter left the area until the drug took effect. During this time (approximately 5 min), the fixed-wing aircraft maintained visual contact with the moose to record induction time (the time between darting and the immobilization of the moose) and notify the helicopter and crew when processing of the moose could begin.

We initiated handling of moose by drawing 50 cc of blood from the jugular vein using an 18 gauge (38 mm) needle. After blood was drawn, we determined maximum depth of rump fat and pregnancy via the ultrasound method (Stephenson *et al.* 1993, Stephenson 1995) using an Aloka model 210 portable ultrasound device (Corometrics Medical Systems, Inc., Wallingford, CT). A lower canine tooth was extracted for determination of age from cementum annuli (Matson's Lab, Milltown, MT). Moose

were fitted with 1,130 g transmitters from Advanced Telemetry Systems (Isanti, MN). At the completion of handling, immobilization was reversed with an intra-muscular injection of 450 mg naltrexone (100 mg naltrexone/1 mg carfentanil). No capture-related mortalities occurred during this project. Serum was removed from whole blood by centrifugation and stored at  $-50^{\circ}\text{C}$  until processing. Serum was analyzed for 22 blood variables at Fairbanks Memorial Hospital in Fairbanks, Alaska, USA. This research was approved by the Institutional Animal Care and Use Committee at the University of Alaska Fairbanks.

Correlation matrices were used to inspect blood-serum variables, and those exhibiting multicollinearity (i.e., an absolute value  $r \geq 0.70$ ) were removed from analyses. Variables correlated with drug-induction time also were removed from the list of potential variables to control for capture-related effects on blood chemistry. Multiple-regression models ( $\alpha = 0.15$  to enter and stay) were used to identify the remaining blood-serum variables related to variation in rump-fat reserves (Neter *et al.* 1990). We examined residuals to assure our model met assumptions of regression analysis, and performed additional tests to verify the model was apt (Bowyer *et al.* 1988). Mallows'  $C_p$  statistic and the adjusted multiple coefficient of determination ( $R^2_a$ ) were used to determine the most appropriate regression model (Neter *et al.* 1990). Partial regression coefficients, which measure the contribution of each independent variable when all others have been included in the model, also were provided.

## RESULTS

Mean maximum depth of rump fat was 1.5 cm and this measurement was highly variable among individuals (Table 1). The mean age of 38 female moose from which data on blood sera and rump fat were gath-

ered was 6.9 years (SD = 3.2 years). Of the original 22 blood variables, 4 were removed to control for multicollinearity (blood urea nitrogen:creatinine, albumin-globulin, ALT, and protein). Additionally, glucose, sodium, and blood urea nitrogen all were significantly correlated with induction time ( $R^2_a = 0.27$ ,  $P = 0.01$ ), and were removed from the final model regressors. Of the remaining variables, creatinine and AST were the only ones to enter the model. The final model was: depth of rump fat =  $0.28 + 1.68$  (creatinine) -  $0.03$  (AST). Partial regression coefficients for creatinine and AST were 0.222 ( $P = 0.0025$ ) and 0.150 ( $P = 0.006$ ), respectively; the overall  $R^2_a$  was 0.34 ( $P = 0.0002$ ).

Contrary to our initial hypothesis and previous research conducted on moose in Alaska, phosphorous and calcium did not enter our model. Protein was not a possible model parameter because it was removed to control for multicollinearity.

## DISCUSSION

Body condition is a major factor controlling productivity of moose (Schwartz *et al.* 1988a, 1988b; Schwartz and Hundertmark 1993; Heard *et al.* 1997) and other cervids (McCullough 1979, Clutton-Brock *et al.* 1982, Cameron and Ver Hoef 1994). Indeed, Heard *et al.* (1997) reported a positive relationship between fertility of female moose and fat reserves of hunter-harvested animals.

Previous researchers have attempted to measure productivity by comparing biological data among years or areas, and using winter severity or population status as a surrogate for body condition. For example, Gasaway *et al.* (1992) reported differences in rates of twinning and pregnancy between moose populations existing at different points relative to carrying capacity. Likewise, Ballard *et al.* (1996) determined that several blood variables (packed cell volume,

Table 1. Summary statistics for variables used to examine the relationship between rump fat and blood serum components from 38 pregnant, adult moose, from the Tanana flats, Alaska, USA, March 1996.

| Variable                                 | $\bar{X}$ | SD     | CV(%) | Range    |
|--|-----------|--------|-------|----------|
| Maximum Depth of Rump Fat (cm)           | 1.54      | 1.01   | 65.6  | 0-3.8    |
| Sodium (meq/l)                           | 134.53    | 4.78   | 3.6   | 123-147  |
| Potassium (meq/l)                        | 8.29      | 1.4    | 16.9  | 5.7-10.9 |
| Chlorine (meq/l)                         | 95.42     | 3.91   | 4.1   | 87-103   |
| Glucose (mg/dl)                          | 97.87     | 19.53  | 20.0  | 64-153   |
| Blood Urea Nitrogen (mg/dl)              | 3.38      | 1.15   | 34.0  | 2-5      |
| Creatinine (mg/dl)                       | 2.08      | 0.26   | 12.5  | 1.4-2.6  |
| Blood Urea Nitrogen : Creatinine (ratio) | 1.55      | 0.40   | 25.8  | 0.8-3.3  |
| Calcium (mg/dl)                          | 11.07     | 1.09   | 9.9   | 8.2-13.4 |
| Phosphorus (mg/dl)                       | 4.77      | 1.13   | 23.7  | 2.5-8.5  |
| Cholesterol (mg/dl)                      | 72.27     | 11.39  | 15.8  | 54-117   |
| Total Bilirubin (mg/dl)                  | 0.29      | 0.07   | 24.1  | 0.2-0.6  |
| Protein (gm/dl)                          | 6.87      | 0.47   | 6.8   | 5.4-7.6  |
| Albumin (gm/dl)                          | 3.78      | 0.36   | 9.5   | 2.8-4.5  |
| Globulin (gm/dl)                         | 3.09      | 0.24   | 7.8   | 2.5-3.8  |
| Albumin : Globulin (ratio)               | 1.23      | 0.13   | 10.6  | 0.9-1.5  |
| Aspartate Aminotransferase (U/l)         | 79.11     | 13.61  | 17.2  | 52-107   |
| Alanine Aminotransferase (U/l)           | 71.55     | 17.62  | 24.6  | 43-124   |
| Total Lactate Dehydrogenase (U/l)        | 626.29    | 118.92 | 19.0  | 343-907  |
| Creatine Kinase (U/l)                    | 50.82     | 28.87  | 56.8  | 20-122   |
| Glutaryl Transferase (U/l)               | 21.18     | 4.30   | 19.7  | 16-39    |
| Alkaline Phosphate (U/l)                 | 43.87     | 19.07  | 43.5  | 25-135   |

percent hemoglobin, calcium, phosphorus, beta globulin, albumin, total protein, and glucose) measured in moose varied following severe winters compared with mild ones. Franzmann *et al.* (1987) documented differences in 5 blood variables (packed cell volume, hemoglobin, total serum protein, phosphorus, and calcium) between moose populations existing on differing nutritional planes. We made direct measures of body condition simultaneously with blood sampling for a particular individual; thus, we

eliminated the necessity of making assumptions about effects of population size or winter conditions on the fat reserves of moose.

Others have reported on blood values of moose (Houston 1969, Franzmann and LeResche 1978, Franzmann and Schwartz 1983, Ballard *et al.* 1996), but direct comparisons with our data should be made cautiously because of potential variability from differences in sex, age, reproductive status, season, and the handling of individuals. Our

purpose was to test hypotheses regarding relationships between rump fat and blood chemistry. In our regression model, creatinine was positively correlated with fat reserves, whereas AST was inversely related to condition. The positive relationship between creatinine and fat depth may be explained by the muscle mass of an individual; most variation in creatinine levels between individuals is because of differences in muscle mass (Taylor 1989). Indeed, Stephenson (1995) reported a positive linear relationship between maximum depth of rump fat and body mass of 8 female moose sampled between November and January. Thus, creatinine levels are likely to be elevated in female moose with larger fat reserves, which are indicative of larger overall body size and muscle mass, and probably better physical condition.

Increases in AST often are associated with some type of trauma, or muscle and liver disease (Taylor 1989). The inverse relationship we observed is consistent with the idea that animals in better physical condition are likely to be less susceptible to disease and thus should have decreased levels of AST. Sams *et al.* (1996) concluded physical condition could play a role in reducing infections or disease that might ultimately predispose an individual to increased chance of infection or mortality. We hypothesize the same trend may be present in our data with adult female moose.

Although our model identified two blood values that were significantly correlated with depth of rump fat, caution must be used in interpreting those data. First, blood-serum components likely track immediate changes in physiology, whereas depletion of fat may occur more gradually; thus, a time lag may exist between these two measurements. A second important consideration is the degree of variability in condition as indexed by depth of rump fat. Subcutaneous fat is the first of the body fat reserves to be

depleted by an individual (Harder and Kirkpatrick 1996). Based on the linear relationship between rump fat and total body fat reported by Stephenson (1995), all moose we sampled would have had between 2% and 13% body fat. Because the range of fat reserves we observed was limited, applying our model across all levels of condition may not be appropriate.

Ballard *et al.* (1996) concluded blood variables obtained following severe winter were significantly lower compared with those obtained following mild winters for adult female moose; however, no differences were detectable between mild or moderately severe winters. Likewise, Franzmann *et al.* (1987) emphasized the importance of using blood variables only to identify populations on the extremes of physical condition. These studies suggest that great variability in animal condition is necessary prior to significant changes in some blood values. Our model indicates blood values may change gradually with depth of rump fat. More samples over a wider array of physical condition, however, may be necessary for a more complete understanding of how these variables are related in moose.

Our model is not a replacement for measurement of fat reserves. These blood variables, however, may provide insights into the condition of moose and their response to changing environmental conditions. Additionally, blood-serum variables (protein, phosphorus, and calcium) previously thought to be indicators of physical condition (Franzmann and LeResche 1978, Franzmann *et al.* 1987) did not explain significant variation in maximum depth of rump fat for moose on the Tanana Flats, Alaska, USA. Finally, like Messier *et al.* (1987), who conducted similar research on caribou (*Rangifer tarandus*), we conclude that we have not identified a set of blood parameters that adequately predict condition of moose as indexed by their rump fat.

Nonetheless, there is a significant relationship between rump fat and blood values that warrants further research.

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