USE OF MANDIBLE VERSUS LONGBONE TO EVALUATE PERCENT MARROW FAT IN MOOSE AND CARIBOU

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Abstract: During winters 1977 through 1980 the mandible and a longbone were collected from moose (*Alces alces*) and caribou (*Rangifer tarandus*) kills found while conducting a wolf (*Canis lupus*)-moose relationships study in southcentral Alaska. Percent marrow fat for the paired samples was significantly correlated, suggesting that mandibles could be used in lieu of longbones for marrow fat analyses. Results of the study were compared with those obtained for Ontario moose and were combined for analysis. Percent fat for the paired bones was significantly correlated for both calf and adult moose; however, the slopes and intercepts for the two age classes were different, suggesting differences in fat mobilization by age class.

Marrow fat of longbones has been widely used as an index of physical condition of ungulates in North America. Prior to 1970 procedures for determining marrow fat content consisted of either crude visual estimates based upon marrow color and consistency, or extraction procedures which were relatively expensive and time consuming. Development of Neiland's (1970) dry weight method for determining percent

marrow fat in caribou allowed marrow fat content to be quantified with relative ease and at a relatively low cost per sample.

Since 1970, Neiland's (1970) method of determining marrow fat content has been widely used on a number of ungulate species for assessing physical status. This type of information is of particular interest to students of predator-prey relationships because it allows inferences to be drawn about the physical condition of prey selected by predators. For comparison, samples from nonpredator killed ungulates are needed to determine condition of predator kills relative to the condition of other members of the population.

The most widely used bone for determining percent marrow fat of ungulates has been the femur (Cheatum 1949), although other longbones have been widely used also (Peterson 1977). Percent fat in the mandibular cavity has also received some attention as an indicator of physical condition (Baker and Lueth 1966, Purol et al. 1977 and Snider 1980).

While conducting a wolf-moose relationships study in Game Management Unit 13 of southcentral Alaska, we attempted to collect longbones from moose and caribou dead from all sources of mortality. Although we strove for collection of femurs, we often had to settle for metatarsals or metacarpals, and in many other cases no bone was collected at all. Reasons for this varied depending upon both the cause of mortality and the time available for specimen collection. On both predator- and winter-killed ungulates, which were only partially consumed, the flesh was frozen and extraction of the femur was often time consuming and expensive, particularly when kills were visited via helicopter. On heavily consumed predator kills, often the ends of longbones had been chewed and the marrow either eaten or exposed to the air rendering the sample useless. In these latter cases no specimens were collected. On several predator kills the only remaining intact bones suitable for marrow analysis were the mandibles. Similar types of problems occurred with collection of samples from road kills. Because of these problems and the presence of mandibles at many heavily consumed predator kills, it appeared desirable to determine if a relationship existed between percent marrow fat estimated from longbones compared to that estimated from mandibles. Since mandibles are relatively easy to extract and are often collected routinely for aging purposes, establishment of a fat relationship between the two bones would result in a considerably larger sample size of condition data. The purpose of this paper is to compare the percent marrow fat of mandibles to that of longbones for moose and caribou killed primarily by predators.

STUDY AREA

The study was conducted in Game Management Unit 13 of southcentral Alaska. Detailed descriptions of vegetation, totography, weather patterns, etc. have been provided by Skoog (1968), Rausch (1969), Bishop and Rausch (1974) and Ballard (1981).

METHODS

During winters 1977 through 1980, 58 paired mandible and longbone samples were obtained from moose and caribou kills. Moose samples were comprised of 21 calves and 24 adults of both sexes, while the 13 caribou samples were adults of both sex. Ages of moose were determined by

incisor eruption and cementum annuli counts according to methods described by Sergeant and Pimlott (1959). Caribou were aged on the basis of tooth wear described by Skoog (1968).

Samples were collected on an opportunistic basis but most kills were detected while making flights to monitor radio-collared wolf packs. Causes of death for the paired samples were as follows: for calf moose--8 wolf kills, 7 winter kills and 6 road or accidental kills; for adult moose--15 wolf kills, 8 road or accidental kills, and 1 from unknown causes; and for adult caribou--12 wolf kills and 1 from unknown causes.

Procedures for determining percent fat of longbones were identical to those of Neiland (1970). Mandible marrow was extracted by cutting a 10 cm longitudinal section of bone from the labial side of the mandible beginning at the 2nd or 3rd premolar. The section was cut with a bone saw and the resulting bone dust was scraped from the marrow with a spatula. Later we simplified this process by ventrally splitting the left or right ramus with a chisel and then extracting the entire section of marrow with a spatula. This modified procedure also eliminated the need for scraping off bone dust fragments. The remainder of the procedure was identical to that for the longbone, described by Neiland (1970).

RESULTS AND DISCUSSION

Paired samples for both calf and adult moose were compared with standard least squares regression techniques (Snedecor and Cochran 1973). The best fit was by linear regression (Fig. 1, $r=.92$, $P<0.05$); however, the data appeared clumped according to age class (calf versus

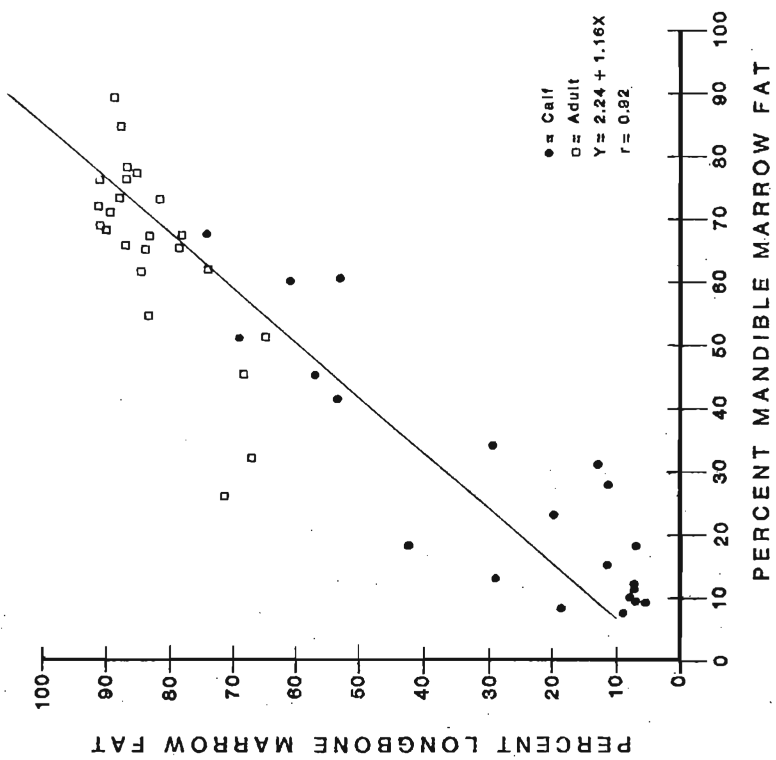

Figure 1. Relationship between percent marrow fat for mandibles and longbones from calf and adult moose in the Nelchina Basin, Alaska.

adult). Analysis of covariance for calf and adult moose indicated that the variances were significantly different (F=4.11, P<0.001) and, thus, comparison of slope and intercept between the two age classes was not possible. We subjected each age class to polynomial regression techniques and determined that the percent marrow fat relationship for adult moose could be expressed as a 3rd order polynomial. The relationship was also significantly related linearly and thus we chose it for adults because it allowed additional statistical tests to be performed.

Figures 2 and 3 depict the relationship between percent fat for longbones and mandibles for calf and adult moose separately. Percent marrow fat in the two bones was signficantly correlated for both age classes (calves r=.88, P<0.05; adults r=.78, P<0.05) suggesting that longbone fat could be estimated from mandible fat for each age class. However, there was considerably more variation in the relationship for calves (mean square [ms]=127.8) than for adults (ms=26.7). This may have been the result of sample size since all of the adult moose were above 65 percent fat which would have placed them in a relatively high condition class based upon criteria established by Greer (1968) and Franzmann and Arneson (1976).

Snider (1980) compared percent marrow fat for femurs and mandibles for 29 moose from Ontario. He, like us, concluded that the two variables were significantly correlated. He combined calf moose (n=6) with adults (n=22) and determined that the percent fat relationship between the two bones was best expressed as a third degree orthogonal polynomial (Fig. 4) where Y= mandible fat and X= femur fat. His data were subject to an orthogonal regression. For comparison we subjected Snider's data to the same analyses performed on Nelchina Basin moose and determined that

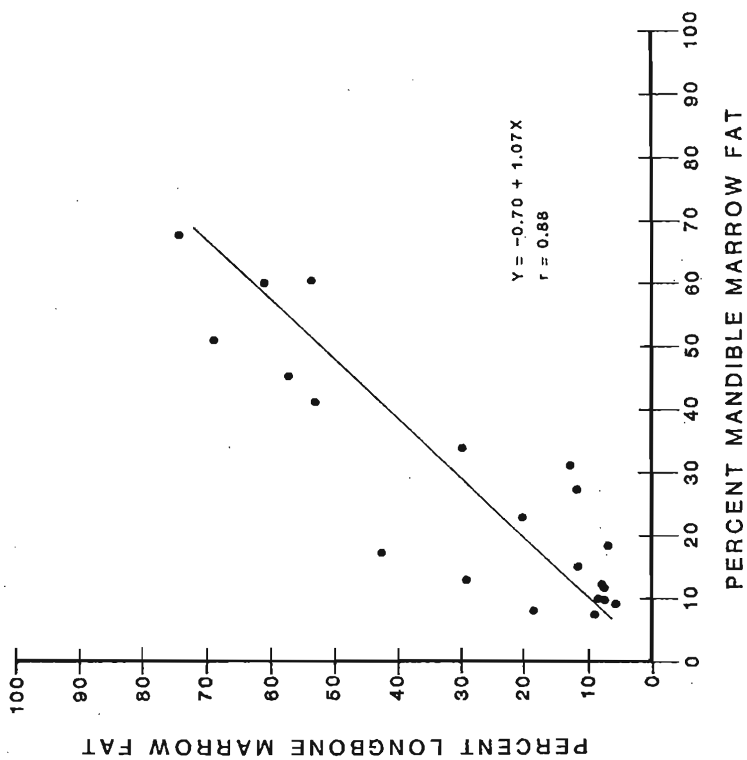

Figure 2. Relationship between percent marrow fat of mandibles and longbones for calf moose in the Nelchina Basin, Alaska.

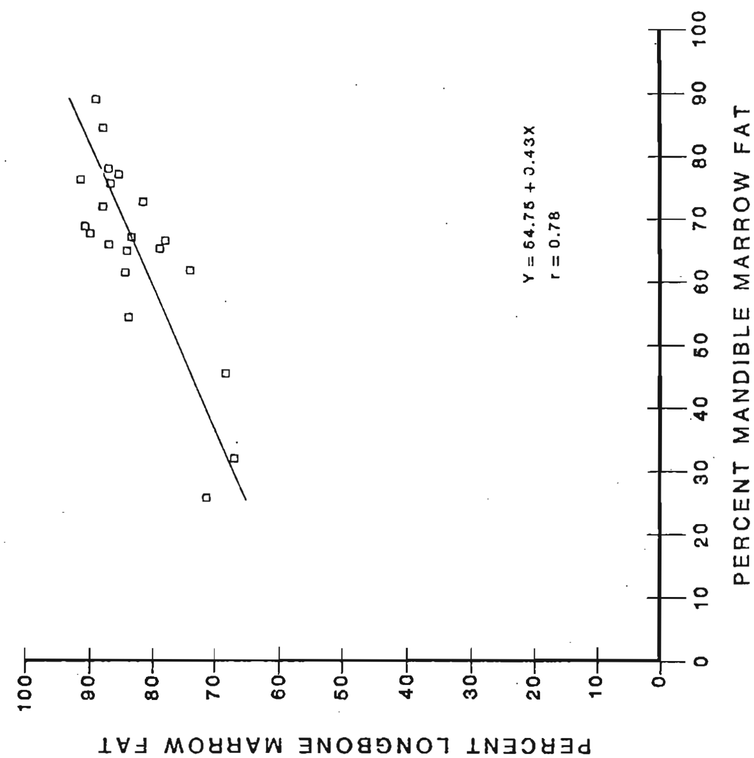

Figure 3. Relationship between percent marrow fat of mandibles and longbones for adult moose in the Nelchina Basin, Alaska.

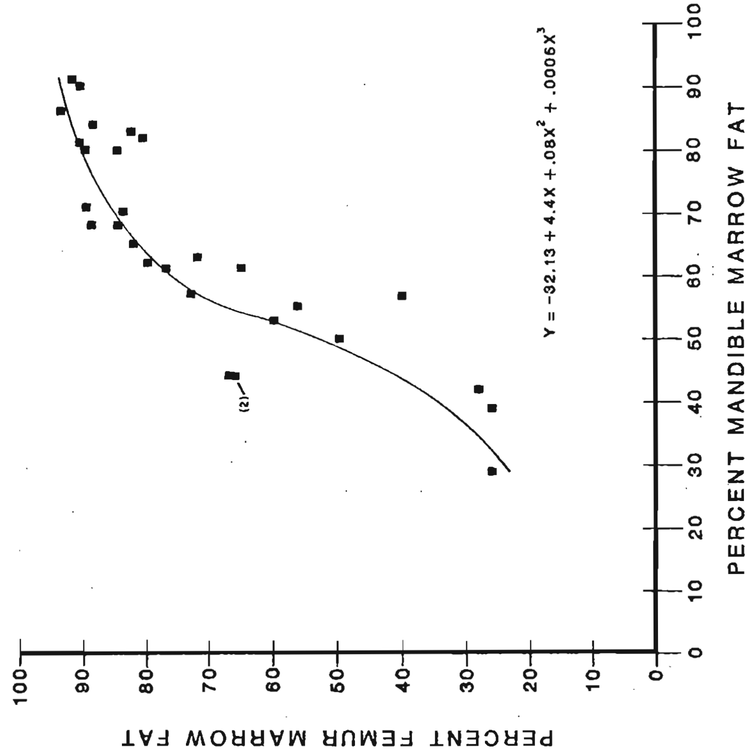

Figure 4. Relationship between percent marrow fat of mandibles and femurs for calf and adult moose in Ontario (from Snider 1980).

his data also exhibited a significant linear relationship (r=.87, P<0.05) [Fig. 5]. In contrast to Nelchina data, however, the variances between age classes were equal (F=.85, P>0.05) and there were no significant differences between slopes (F=.87, P>0.05) or intercepts (F=.32, P>0.05). Reasons for the differences in homogeneity of variances between the two studies are unknown but could have been related to a combination of use of different longbones in the Nelchina study, small sample size in both studies, or differences in fat deposition and mobilization between the study moose populations.

Because of small sample sizes in each of the studies and because samples in the Nelchina study were collected primarily during winter from predator kills while those in Ontario were collected primarily in October or June mainly from road-killed moose, we combined samples in an effort to better describe the relationship between longbone and mandible fat (Table 1). The analysis assumed that there were no differences in fat mobilization between the two populations. Variances between calf and adult moose in these clumped data were not significantly different (F=1.12, P>0.05) which allowed additional comparisons to be made. Both the slope and intercept for calf and adult moose were significantly different (P<0.05) suggesting that fat mobilization in the two bones was different for the two age classes. The relationship between longbone and mandible marrow fat for each age class was best described by linear regression (Fig. 6 and 7). However, because only three adult moose had longbone fat values of less than 60 percent, the relationship between the two bones at lower fat levels warrants further investigation.

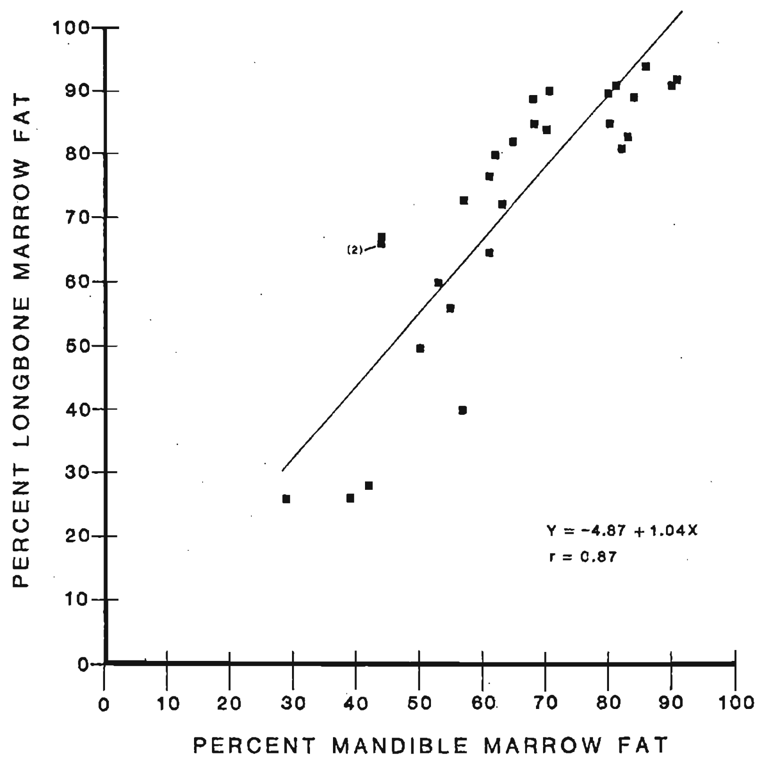

Figure 5. Relationship between percent marrow fat of mandibles and longbones for calf and adult moose in Ontario (from Snider 1980).

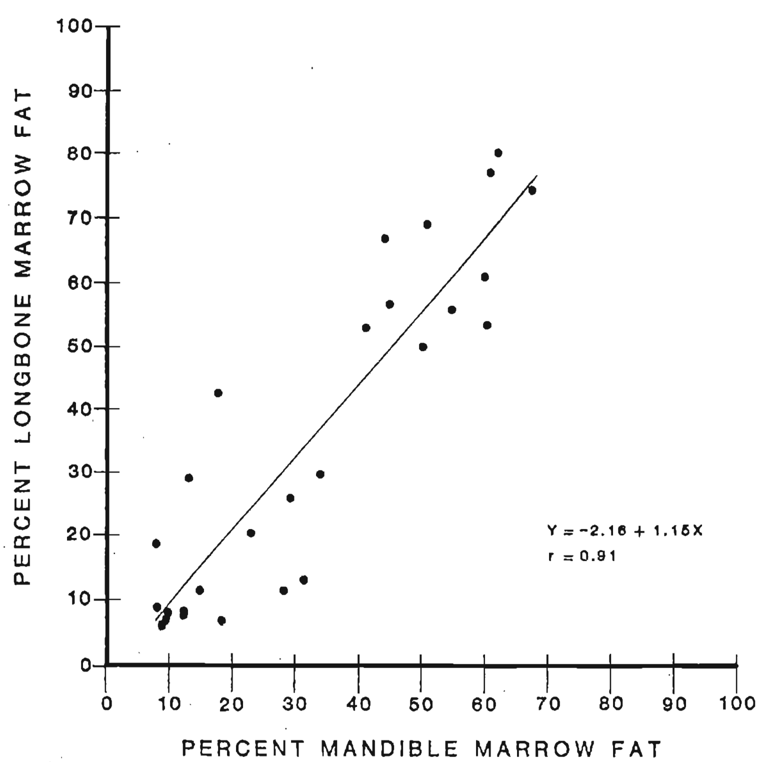

Figure 6. Relationship between percent marrow fat of mandibles and longbones for calf moose in Ontario (from Snider 1980) and the Nelchina Basin, Alaska.

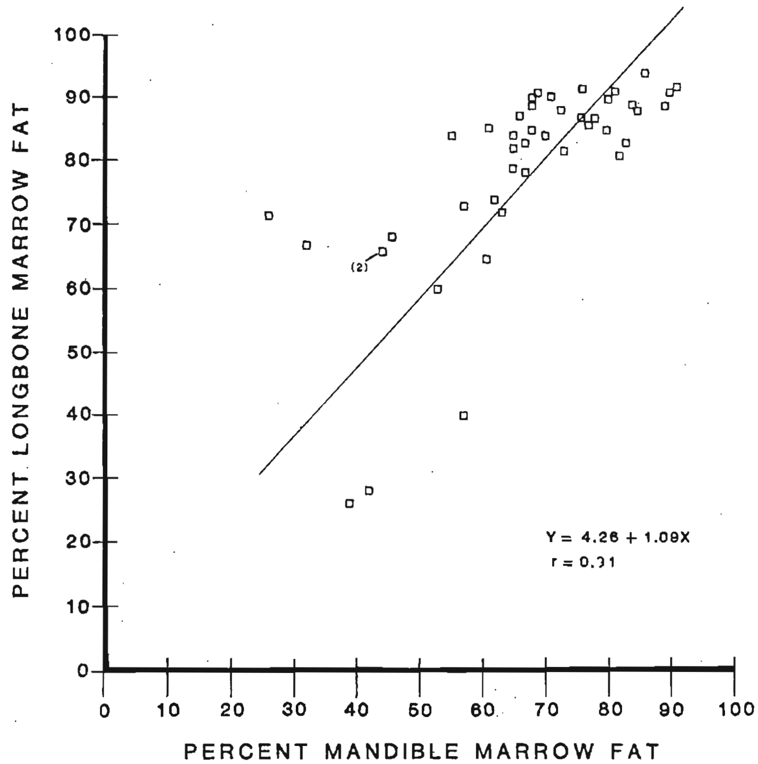

Figure 7. Relationship between percent marrow fat of mandibles and longbones for adult moose in Ontario (from Snider 1980) and the Nelchina Basin, Alaska.

Table 1. Analysis of covariance of percent marrow fat estimated from mandibles and longbones of calf and adult moose from southcentral Alaska and Ontario. 1/

Source	d.f.	S.S.	M.S.
Within			
Calves	25	3084.36	123.37
Adults	58	6094.55	105.08
	83	9178.91	110.59
Pooled Within	84	10221.90	121.69
Differences Between Slopes	1	1042.99	1042.99
Within and Between	85	30743.21	361.68
Between Adjusted Means	1	20521.31	20521.31

Significance Tests

(1) Heterscedasticity

$F = 123.37/105.08 = 1.17$ $F_{(25,58)}$ $.25 = 1.23$

$1.17 < 1.23$ accept Ho: $_c$ 2 = $_a$

(2) Difference in Slopes

$F = 1042.99/110.59 = 9.43$ $F_{(1,83)}$ $.005 = 8.30$

$9.43 > 8.30$ reject Ho: $B_C = B_a$

(3) Difference Between Intercepts

$F = 20521.31/121.69 = 168.6$ $F_{(1,84)}$ $.001 - 11.8$

$168.6 > 11.8$ reject Ho: $_c = _A$

1/ Ontario data from Snider (1980).

Similar to samples from Nelchina adult moose, bone marrow fat from mandibles and longbones of adult caribou were also significantly correlated (Fig. 8, r=.90, P<0.05) suggesting that mandibles might be useful for estimating longbone fat in caribou. However, because sample sizes were extremely small and no samples of caribou in poor condition were collected, this relationship should be viewed with caution. Also, since no calf caribou were examined it is unknown whether a correlation exists in this age class as well.

Peterson (In Press) recently compared marrow fat levels between several longbones of individual moose and determined that fat mobilization appeared to have proceeded more quickly in proximal than in distal longbones. If correct, this may partially explain some of the variability between longbones (femurs, metatarsals, and metacarpals) and mandibles found in this study. Even with this variation, however mandibles appear useful for determining the percent marrow fat in longbones and consequently appear useful as an indicator of condition. Although results of this study suggest a positive relationship exists between marrow fat mobilization in mandibles and longbones, we suggest that biologists collect paired samples from ungulate kills in other populations to determine if relationships are similar. If this relationship is confirmed, then biologists should consider using the mandible in lieu of longbones for marrow fat analyses. Use of mandibles will allow biologists to greatly increase sample sizes for marrow fat analysis with minimal effort at relatively small additional costs.

ACKNOWLEDGEMENTS

Appreciation is expressed to Charles Lucier and Enid Goodwin, both

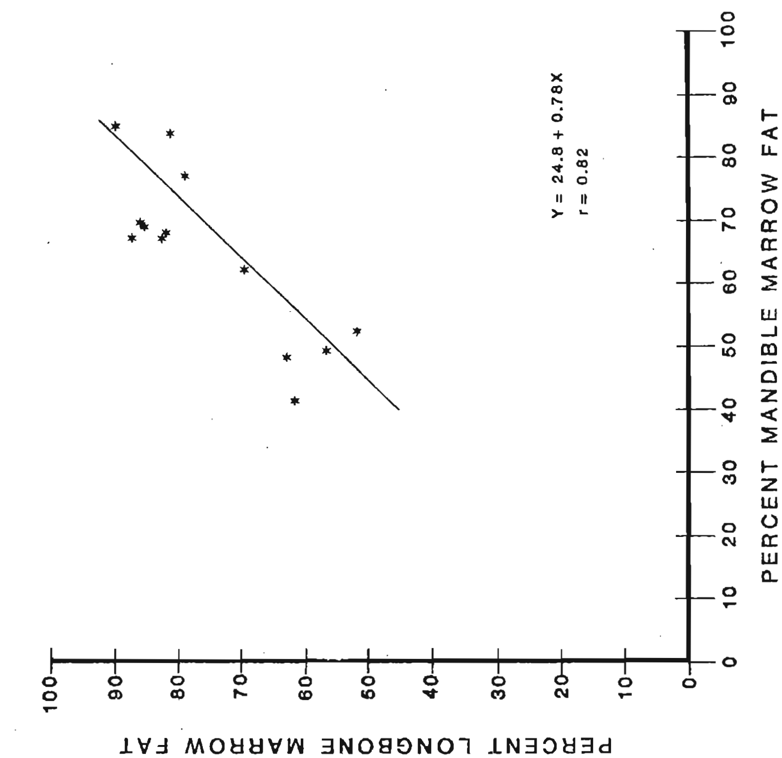

Figure 8. Relationship between percent marrow fat of mandibles and longbones for adult caribou in the Nelchina Basin, Alaska.

Alaska Department of Fish and Game (ADF&G) employees, for processing marrow samples. Donald McKnight, Karl Schneider, and Karen Wiley (all ADF&G) reviewed the manuscript and made many helpful suggestions. We also thank Lita Lewis for typing the manuscript on her personal time. The study was funded in part by Federal Aid in Wildlife Restoration Project W-17-R with additional support provided from the Alaska Power Authority.

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