AN EVALUATION OF MANDIBULAR MARROW FAT AS AN INDICATOR OF CONDITION IN MOOSE

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ABSTRACT: The availability of mandibles from hunter killed moose and the growing awareness of the importance of fall condition led to the investigation of mandibular marrow fat as an indicator of fall condition in moose. There was a strong correlation between mandibular marrow fat and femur marrow fat. Mandibular marrow fat reflected the expected lower condition of post-rut adult males. The marrow fat from mandibles was lower in fall shot yearlings and male calves following a severe winter and short growing season. Male calves and male yearlings had shorter diastemas following a severe winter and shorter growing season. It was concluded that the marrow fat from mandibles is a valid fat measurement for determining fall condition.

Bone marrow fat has been used as an indicator of condition in cervids and the bone of choice has been the femur (Cheatum 1949, Riney 1955). The lower mandible or jaw bone is also a bone that has a central cavity used for the storage of fat (Baker & Leuth 1966). In this study relationships between femur fat and mandibular marrow fat were determined for moose, and the relationship between the severity of the previous winter and mandibular fat content was explored.

There has been growing attention focused on the importance of fat reserves for winter survival of cervids (Gasaway and Coady 1974, Stewart et al. 1976). Mautz (1978) refers to northern living cervids as semi-

hibernators. Alaskan moose (*Alces alces*) lost 30% of their body weight from early winter to late spring (Franzmann et al. 1978). It is estimated that 75% to 80% of such a weight loss may be from fat stores (Gasaway and Coady 1974), wherein each gram of fat contributes 9.3 kilocalories.

Reproduction in female cervids is influenced by fall or pre-ovulation condition, as shown for white-tailed deer (*Odocoileus virginianus*) (Verme 1969), mule deer (*O. hemonius*) (Julander et al. 1961), caribou (*Rangifer tarandus*) (Dauphine 1976), and moose (Blood 1973). The rut is costly for bulls in terms of weight loss. Franzmann et al. (1978) reports a loss of over 10% for Alaskan moose during the rut, whereas McMillan et al. (1980) show 15-20% during the rut of white-tailed deer.

STUDY AREA:

Mandibles and femurs were collected from Wildlife Management Unit 21 that lies adjacent to the north shore of Lake Superior (Fig. 1). This unit is 28,000 km^2 in size and is entirely within the boreal forest region (Rowe 1972). Approximately 15% of this unit has been logged since the early 1940's. Observed winter moose densities are 0.2 moose per km^2 and the unit is considered understocked in relation to available winter browse.

MATERIALS:

A sample of 28 paired femurs and mandibles were collected from 1977 through 1979, mainly from road killed moose. These samples were collected during all seasons of the year, and represent all age and sex cohorts.

The collection of moose mandibles from hunters began with the opening of moose season on October 11 and ended with the close of the season on December 15 for both study years of 1977 and 1979. In 1977, 93% of the mandibles came from the first 31 days of the season, and in 1979, 95%

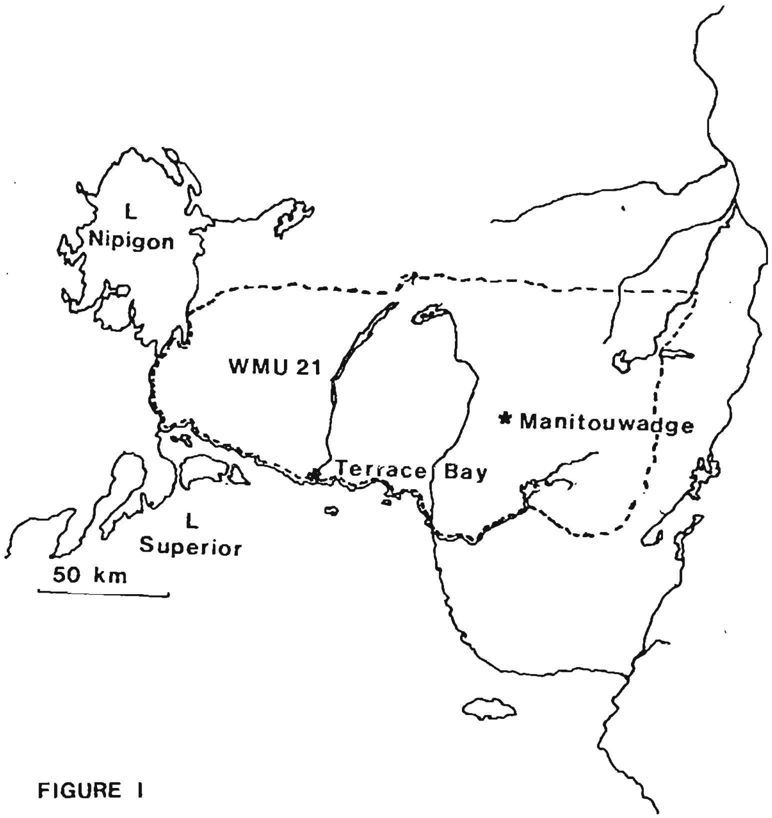

FIGURE I

came from the first 31 days of the season. Fat determinations were made on 108 mandibles in 1977 and 130 mandibles in 1979, collected from hunters in the Terrace Bay and Manitouwadge areas of Unit 21 (Fig. 1). Fat determinations were not made on mandibles collected from hunters in 1978.

METHODS:

The percent bone marrow fat in mandibles and femurs was determined by removing the mid-portion of marrow, weighing it immediately and then oven-drying it at 55°C to 65°C until no further moisture remained. This point was detected by repeated weighing until no further weight loss occurred. Drying time took from three to six days. Percent fat was calculated as dry weight divided by fresh weight times 100. The small amount of residue that Neiland (1970) reported by this method was ignored as being of little consequence in this study. Franzmann (1976) also ignored the residue in his study of femur fat levels in moose.

Mandibles were collected from hunters and were frozen until processing. Mandibles that had undergone excessive drying when collected were not used for fat analysis. Excessive drying was noted by the appearance of the flesh adhering to the mandibles and by a change in marrow colour from the expected pink or red colour to a light brown. Mandibles that were discarded for fat determinations were not discarded for length measurements.

The diastema of intact moose mandibles was measured to the nearest millimeter from the posterior side of the canine tooth at the point where it erupts through the gum back to the anterior side of the second pre-molar where it erupts through the gum.

Moose were segregated as to calves, yearlings and $\geq 2\frac{1}{2}$ years, aged by the wear-class method (Passmore et al. 1955). Adult moose ($\geq 2\frac{1}{2}$) were also aged by the cementum annuli method (Pimlott and Sergeant 1959).

Spring leaf flush was calculated by the use of the degree day concept of Moss (1959) and recently used by Stewart et al. (1976). Weather office data from Thunder Bay was used to calculate on what date 41.67 degree days of heat over 12.2°C was reached. The end of the growing period was estimated by observed leaf fall. Winter severity was calculated from snow depth at Terrace Bay and Manitouwadge by adding the end of month snow depths in the manner of Stewart et al. (1976). Statistical procedures as contained in Snedecor and Cochran (1967) were used.

RESULTS:

The percent fat in the mandible was significantly correlated with femur fat content in males ($r = 0.87$) and females ($r = 0.81$). The intercept and slope of the lines did not differ significantly so the sexes were combined for further analysis. The relationship between the femur and mandible fat content is best expressed as a third degree polynominal, $Y = 32.13 + 4.4\,X - 0.8X^2 + 0.0005X^3$ (Fig. 2), where Y = mandible fat content and X = femur fat.

Mandibular fat content differed significantly between sexes for the yearling age class in 1979 and for all moose $\geq$ 2½ years old (Table 1). In all cases, males were significantly lower than females.

The effects of a preceeding moderate and severe winter and growing season differences on mandibular fat content were tested. The winter of 1978-79 was relatively severe with a late calculated leaf flush (Table 2). All age and sex classes had lower mandibular fat levels in 1979 with significantly lower results occurring in male calves and in yearlings (Table 3). Diastema lengths were shorter in 1979 in calves and yearlings but only significantly shorter in male calves and male yearlings (Table 4).

DISCUSSION:

No differences were observed between the sexes for the mandibular to femur fat relationship. This allowed combining the values and arriving at a single equation that best describes this relationship. The fat content of both depots is nearly equal at 50%. Above 50% the fat content of the femur is greater than that of the mandible. Below 50% the fat

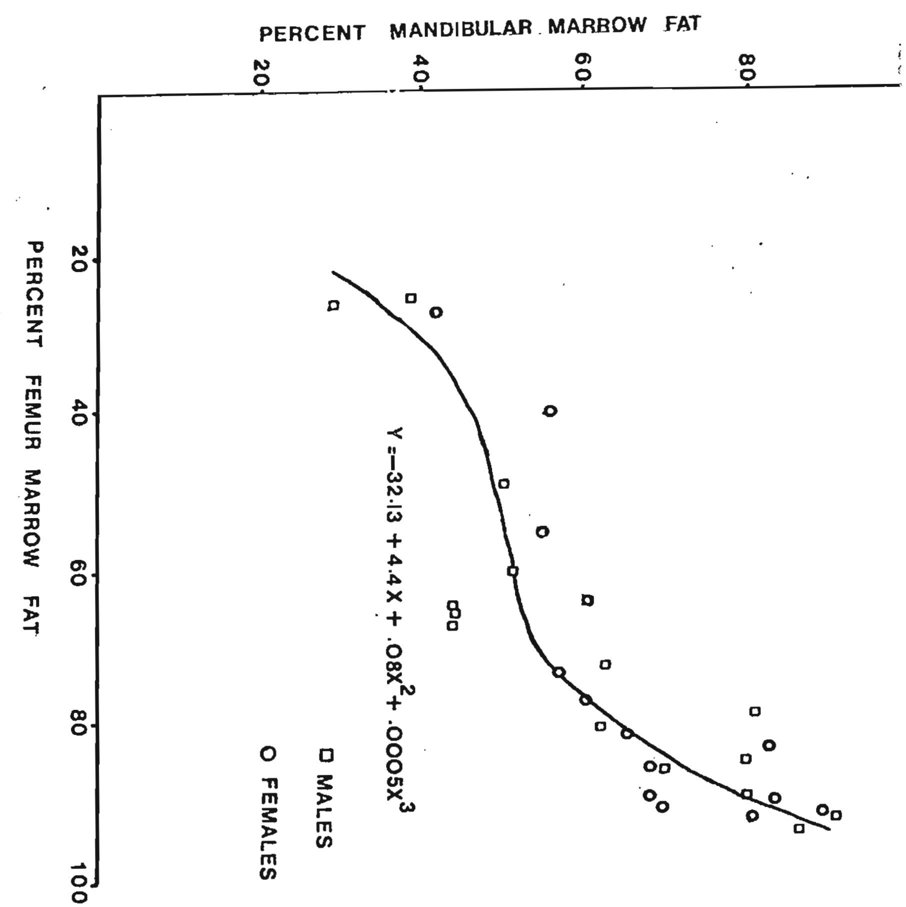

Figure 2. Relation of mandibular fat to femur fat.

Table 1. Fat levels in moose mandibles by sex, age, and year of collection.

Age	Year	Percent Fat	
		Males	Females
½	1977	66.5±3.4(10)	63.5±8.7(12)
	1979	57.9±4.1(5)	59.7±8.2(15)
1½	1977	69.5±8.9(15)	71.4±3.3(9)
	1979	57.7±5.9(25)[a]	64.4±7.0(22)[a]
≥2½	1977	57.7±12.5(28)[a]	71.8±15.6(31)[a]
	1979	52.1±10.8(30)[a]	67.8±10.1(35)[a]

Differences in rows bearing same alpha superscript differ significantly at $P<0.001$.

content is less in the femur than in the mandible (Fig.2). A similar relationship between these two fat depots in female white-tailed deer is described by Purol et al. (1977). Ransom (1965) described the differential utilization of kidney and femur fat depots in white-tailed deer.

In assessing the physiological condition of the animal from marrow fat, the investigator must know the relationships between the fat depots, and the relationship between the depot and animal condition. For moose, the depletion of mandibular fat appears to be at a slower rate than femur fat below the 50% level. Thus, the femur is a more sensitive indicator than the mandible at these lower levels.

Bulls were in poorer physical condition than cows, as indicated by the mandibular fat content. This would be expected, as the samples were collected immediately following the rut, a period when bulls lose weight and body condition. These losses were further accentuated by a severe winter and shortened growing season. Assuming this reflects overall reduced fat stores, it would be expected that fall condition would strongly influence the condition of animals emerging from winter.

The effects of a severe winter, combined with a short growing season are further evidenced by the lowered mandibular fat and reduced diastema lengths of calves and yearlings (Table 3 and 4). This reduction in fat deposition and in growth is similar to that found in long bones of moose calves as reported by Peterson (1974).

Additional work is required to verify the relationships suggested in this paper. Specifically, the relationship between total fat reserves and mandibular fat should be established, as should the relationship of previous weather history to fat deposits, utilization and diastema growth.

Table 2. Winter Severity and growing season comparisons for study area.

	Year	
	1977	1979
Winter severity index	2,413	3,467
Calculated leaf flush	7 May 1977	28 May 1979
Growing season length	153	129

Table 3. Fall fat levels in moose mandibles following a moderate and severe winter.

Age	Sex	Winter Severity	
		Moderate (1977)	Severe (1979)
½	Male	66.5±3.4(10)[a]	57.9±4.1(5)[a]
	Female	63.5±8.7(12)	59.7±8.2(15)
1½	Male	69.5±8.9(15)[b]	57.7±5.9(25)[b]
	Female	71.4±3.3(9)[b]	64.4±7.0(22)[b]
≥ 2½	Male	57.7±12.5(28)	52.1±10.8(30)
	Female	71.8±15.6(31)	67.8±10.1(35)

[a] Row means differ significantly at $P < 0.01$.

[b] Row means differ significantly at $P < 0.001$.

It would also be useful to determine overwinter condition given the fall fat content of an indicator sample and various levels of winter severity.

CONCLUSIONS:

1. A correlation exists between mandibular marrow fat and femur marrow fat in moose. Mandibular fat may be more labile of the two.
2. Mandibular marrow fat was lower for post-rut adult males as was expected from other studies of fat indices.
3. A severe winter coupled with a short growing season in 1979 resulted in lower mandibular fat levels in male and female yearlings and male calves. In conjunction with this, less growth occurred in male yearlings and male calves in 1979 as indicated by shorter diastema lengths.

RECOMMENDATIONS:

Moose mandibles are routinely collected from hunters in well established programs for the purpose of determining the age structures of the harvested population. Mandibles are also routinely collected by wildlife workers from carcasses of road killed, predator killed, and disease killed moose. The marrow fat of these readily available mandibles reflects the physiologic adjustment of the animal with its environment and its use as an indicator of condition is encouraged.

ACKNOWLEDGEMENTS:

I want to thank Gary Johnston and Peter MacLean for their help in measuring moose mandibles and for extracting the marrow fat. Pat Karns offered many suggestions to improve earlier drafts of the manuscript and his help was much appreciated. The advice of Geoff Black and Lynn Ryder on the analysis of the data was appreciated. Raj Sandhu, at the MNR Regional office in Thunder Bay, aged adult moose by the cementum annuli method.

Table 4. Diastema length (mm) in fall shot moose in relation to severity of the previous winter.

Age	Sex	Moderate (1977)	Severe (1979)	Level of Significance
½	Male	122 ± 2.6(6)	113 ± 7.6(4)	.02
	Female	120 ± 9.9(9)	117 ± 6.8(16)	NS
1½	Male	155 ± 14.0(11)	145 ± 6.3(24)	.006
	Female	156 ± 13.6(6)	148 ± 7.5(24)	NS
$\geq$2½	Male	176 ± 10.8(31)	176 ± 11.7(31)	NS
	Female	175 ± 8.0(30)	171 ± 9.1(38)	NS

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