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MARROW AND KIDNEY FAT AS CONDITION INDICES IN GRAY WOLVES

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Among ungulates, marrow fat is the last body fat reservoir to be mobilized as an individual becomes increasingly undernourished (Ransom 1965, Neiland 1970, Franzmann and Arneson 1976, Brooks et al. 1977). Ransom (1965) found that kidney fat level as determined by Riney (1955) was a suitable indicator of condition only when fat depletion was low to moderate. With greater fat withdrawal, marrow fat percentage was a more reliable indicator of total fat depletion. We sought to determine if fat mobilization trends in wolves (*Canis lupus*) were similar to ungulates and if body fat indices in wolves can be interpreted similarly.

METHODS

Marrow and kidney fat levels were determined for 42 wolves >6 months old. Ontario Ministry of Natural Resources personnel solicited carcasses of wolves that were either shot or trapped in northern Ontario between January and April 1989–1991 and kept the carcasses frozen during storage. The femur, tibia, humerus, and radius of each animal were removed from the frozen carcasses and were frozen intact in plastic bags to minimize dehydration prior to analysis (Kie 1978, Peterson et al. 1982, Davis et al. 1987). Only unbroken and uncracked bones were used in the study. Peterson et al. (1982) found that partial thawing in undamaged bones resulted in little or no dehydration and had no significant effect on marrow integrity. A 25- to 35-g marrow sample was collected from the central portion of each bone. Fat content was determined using a reagent dry-weight assay method described by Verme and Holland (1973). This technique uses a 2:1 mixture of chloroform and 95% methanol to extract and dehydrate fat.

A kidney fat index (KFI) was generated for each animal using a method described by Bear (1971):

$$\mathrm{KFI} = \left(\frac{\text{mass of kidney + perirenal fat}}{\text{mass of kidney}}\right) \times 100.$$

Other visceral (peritoneal cavity) and subcutaneous fat deposits were used to determine fat mobilization patterns. Observation of the carcasses showed that, in general, 1 of the last areas of subcutaneous fat to be depleted was in the mid-dorsal thoracic region. The thickest fat layer in this area was measured (mm). All visceral fat was collected and weighed (g).

Depletion patterns of various fat deposits were compared using linear regression, with appropriate transformations applied to achieve linearity. The order of fat depletion was determined by examining whether or not Y-intercept values for regression equations were >0 (Draper and Smith 1966:21). Pairwise comparisons of marrow fat levels in different leg bones were made using the Student's *t*-test (Sokal and Rohlf 1969:143–150).

RESULTS

Marrow fat remained >70% until KFI levels dropped below 20 (Fig. 1), after which marrow fat was rapidly depleted. Marrow fat content for most individuals was either >65% fat (83% of total sample) or <30% fat (Fig. 1).

Comparisons between bones of individual wolves (Table 1) indicated that proximal leg bones tended to have lower marrow fat levels than distal bones. Within proximal and distal bones, anterior leg bones became depleted before posterior leg bones. Indications of marrow fat depletion were first observed in the humerus, followed closely by the femur. Proximal-distal differences became more pronounced when marrow fat was being actively mobilized (<70% fat).

Subcutaneous, visceral, and kidney fat reservoirs all were depleted simultaneously (Figs. 2, 3), but in a definite order consistent with the ungulate pattern as reviewed by Mech and Delguidice (1985). Subcutaneous fat was de-

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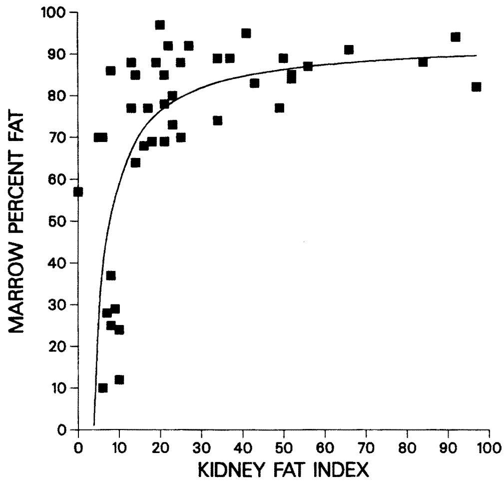

Fig. 1. Relationship between wolf kidney fat index and bone marrow fat (%), northern Ontario, 1989–1991. Regression line is $Y = 95 - 363X^{-1}$ ($R^2 = 0.439$, $P = 0.0001$), omitting 1 wolf with a kidney fat index of 0.

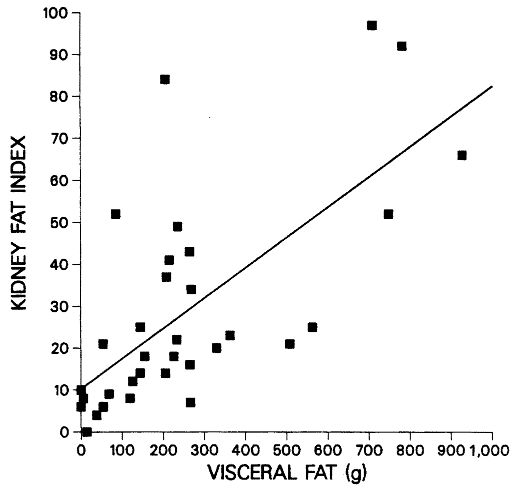

Fig. 2. Relationship between wolf visceral fat and kidney fat index, northern Ontario, 1989–1991. Linear regression line is $Y = 10.2 + 0.07X$ ($R^2 = 0.449$, $P = 0.0001$).

pleted before visceral fat ($P = 0.017$), and visceral fat was depleted before kidney fat ($P = 0.046$), based on Y-intercept values of regression equations.

DISCUSSION

Kidney and marrow fat were useful as indicators of wolf condition. As in ungulates (Ransom 1965, Bear 1971), significant mobilization of marrow fat followed depletion of all other fat stores. Although kidney fat was metabolized at the same time as other fat in the peritoneal cavity, it was the last to be totally exhausted, and also was the easiest interior fat deposit to measure. Marrow fat provides energy for body maintenance only for a few days (Mech and Delguidice 1985). Presumably, animals with marrow fat <30% remain alive primarily through active catabolism of muscle protein.

Differences in marrow fat content between proximal-distal and between anterior and posterior leg bones were in general agreement with data on ungulates (Cheatum 1949, Brooks et al. 1977, Peterson et al. 1982, Davis et al. 1987).

Lochmiller et al. (1985) found that a combination of KFI and femur marrow fat con-

Table 1. Difference in bone marrow fat (%) between paired leg bones from individual wolves, northern Ontario, 1989–1991.

Bone pairs	All samples (n = 42)			Bones <70% fat[a] (n = 12)		
	$\bar{x}$	SE	P	$\bar{x}$	SE	P
Femur > humerus	3.3	1.0	0.003	4.4	2.4	0.091
Tibia > radius	1.4	1.6	0.390	3.3	6.2	0.600
Tibia > femur	7.2	1.3	0.0001	12.9	3.1	0.0016
Radius > humerus	8.8	2.1	0.0002	17.9	3.1	0.0001

[a] Bone pairs including at least 1 bone with <70% fat.

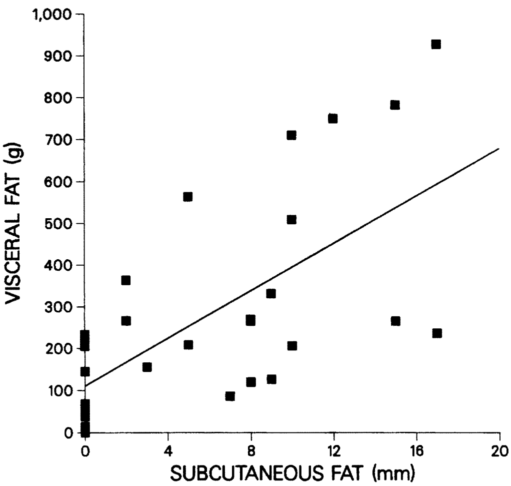

Fig. 3. Relationship between wolf subcutaneous fat and visceral fat, northern Ontario, 1989–1991. Linear regression line is $Y = 110 + 28.4X$ ($R^2 = 0.432$, $P = 0.0001$).

centrations could be used to evaluate condition in collared peccaries (*Tayassu tajacu*). We found that fat mobilization patterns were nearly identical for wolves. Thus, kidney and marrow fat indices can be used to evaluate condition of species other than ungulates.

Mech and Delguidice (1985) indicated that bone marrow only provides a 1-way test of condition; marrow fat loss indicates nutritional distress, but high marrow fat does not necessarily imply good condition. Our results indicate that marrow fat levels <70% reflect active mobilization of this fat deposit. The relationship between marrow fat reserves and survivability has not been established for wolves, ungulates, or any other mammal.

SUMMARY

Marrow fat percentage and KFI, previously developed as condition indices for ungulates, were evaluated for wolves. Marrow fat content was determined for 4 major leg bones, and fat levels of subcutaneous and interior (visceral) fat reserves were measured. Proximal leg bones exhibited marrow fat depletion before distal bones. Secondarily, anterior leg bones were depleted before posterior bones. In wolves, as in ungulates, marrow fat was mobilized only after exhaustion of all other fat reserves. Although kidney fat was mobilized simultaneously with other visceral and subcutaneous fats we measured, it was the last to be exhausted prior to marrow fat. When interpreted correctly, kidney and marrow fat indices developed for ungulates can be employed to evaluate condition of wolves and probably other mammals.

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