

Using ultrasound measurements of rump fat to assess nutritional condition of woodland caribou in northern British Columbia, Canada

David D. Gustine¹, Katherine L. Parker² & Douglas C. Heard³

¹ Institute of Arctic Biology, Department of Biology and Wildlife, University of Alaska Fairbanks, Fairbanks, AK, 99775-7000, U.S.A (corresponding author: ftddg@uaf.edu).

² Natural Resources and Environmental Studies, University of Northern British Columbia, Prince George, BC, V2N 4Z9, Canada.

³ British Columbia Ministry of Environment, 4051 18th Avenue, Prince George, BC, V2N 1B3, Canada.

Abstract: Body reserves (fat and protein) of cervids are important to the reproductive success of individuals, and therefore may limit productivity of populations. We used a portable ultrasound machine to measure thickness of rump fat for 39 woodland caribou (*Rangifer tarandus caribou*) captured in the winters (January–February) of 2003 and 2004. We compared thickness of rump fat between pregnant and non-pregnant individuals in the Besa-Prophet drainage of northern British Columbia, Canada. Thirty-eight of the 39 females captured in British Columbia were adults and 34 of the adult caribou were pregnant ($89.5 \pm 5.1\%$, $\bar{x} \pm$ binomial SE). Pregnant individuals had more rump fat (0.60 ± 0.067 cm) than non-pregnant animals (0.20 ± 0.029 cm). Recognizing that deposition and mobilization of fat vary with age and possibly across the winter season, ultrasonography can be used as a non-invasive technique in the field to assist in estimating body fat of caribou.

Key words: body condition, body fat, index, nutrition, pregnancy rate, *Rangifer*, ultrasonography.

Rangifer, Special Issue No. 17: 249-256

Introduction

Assessing the nutritional condition of cervids is an important tool in identifying limitations in the productivity of cervid populations (Anderson *et al.*, 1972; Dauphiné, 1976; Gerhart *et al.*, 1996a; Heard *et al.*, 1997). Nutritional condition is the state of body components for an individual that may influence current and/or future fitness (Harder & Kirkpatrick, 1994). Therefore, it affects the reproductive capacity of a population (Adams & Dale, 1998a,b; Albon *et al.*, 1986; Cameron *et al.*, 1993; Cameron & Ver Hoef, 1994; Heard *et al.*, 1997; Ouellet *et al.*, 1997) and may provide insights into the quality of habitats that animals occupy (Stephenson *et al.*, 2002). Body condition may also affect appetite (Boertje, 1990) which could alter the levels of predation risk within foraging strategies (Stephens & Krebs, 1986).

Quantifying body fat and protein is an important component of defining the nutritional condition of

individuals within populations (Gerhart *et al.*, 1996a), and has typically involved harvesting individuals (e.g., Anderson *et al.*, 1972; Heard *et al.*, 1997; Ouellet *et al.*, 1997; Chan-McLeod *et al.*, 1999). Harvesting animals may be appropriate for highly reproductive and/or large populations of cervids [e.g., barren-ground caribou (*R. t. groenlandicus*)], but is not applicable for cervid populations that occur at low densities, are endangered, and/or have low rates of recruitment [e.g., woodland caribou (*R. t. caribou*)]. 'Destructive' sampling also precludes multi-year assessments of changes in an individual's body condition over time. Stephenson *et al.* (1998, 2002) showed that ultrasonography is a valid technique for estimating the maximum thickness of rump fat, which correlates well with the total body fat (%) in live moose (*Alces alces*) and mule deer (*Odocoileus hemionus*). Cook *et al.* (2002) reported that maximum thickness of rump fat

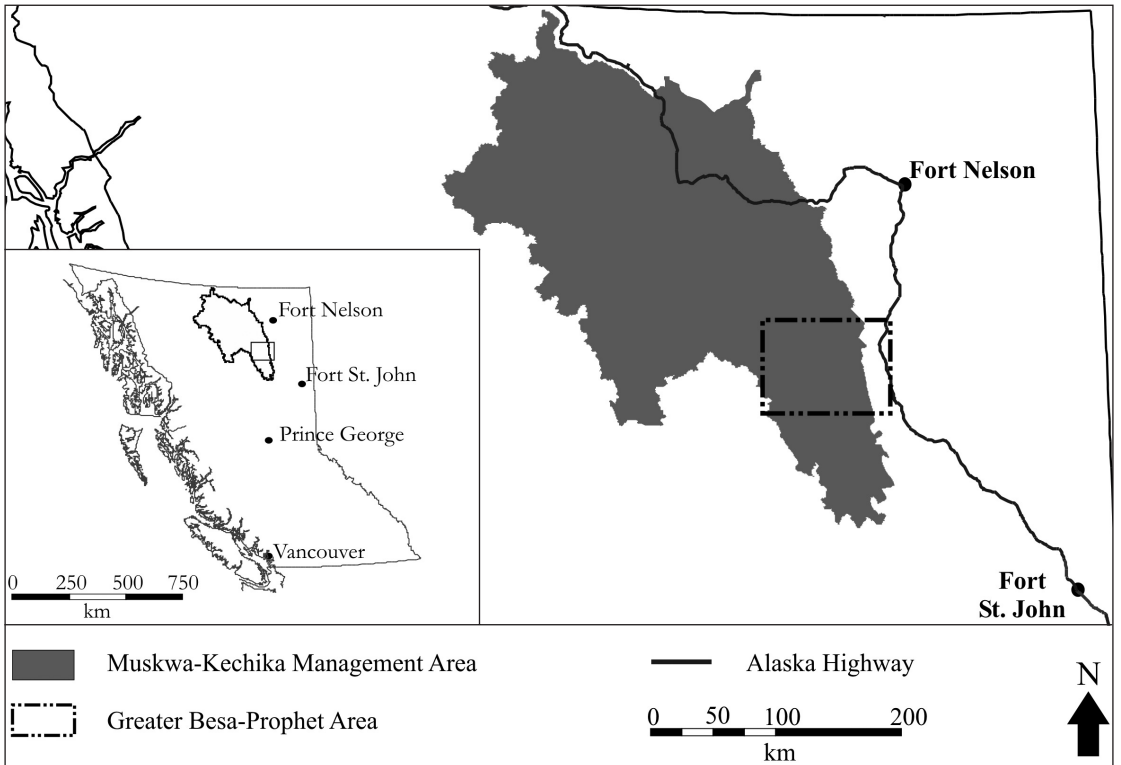


Fig. 1. The Greater Besa-Prophet Area of the Muskwa-Kechika Management Area in northern British Columbia, Canada.

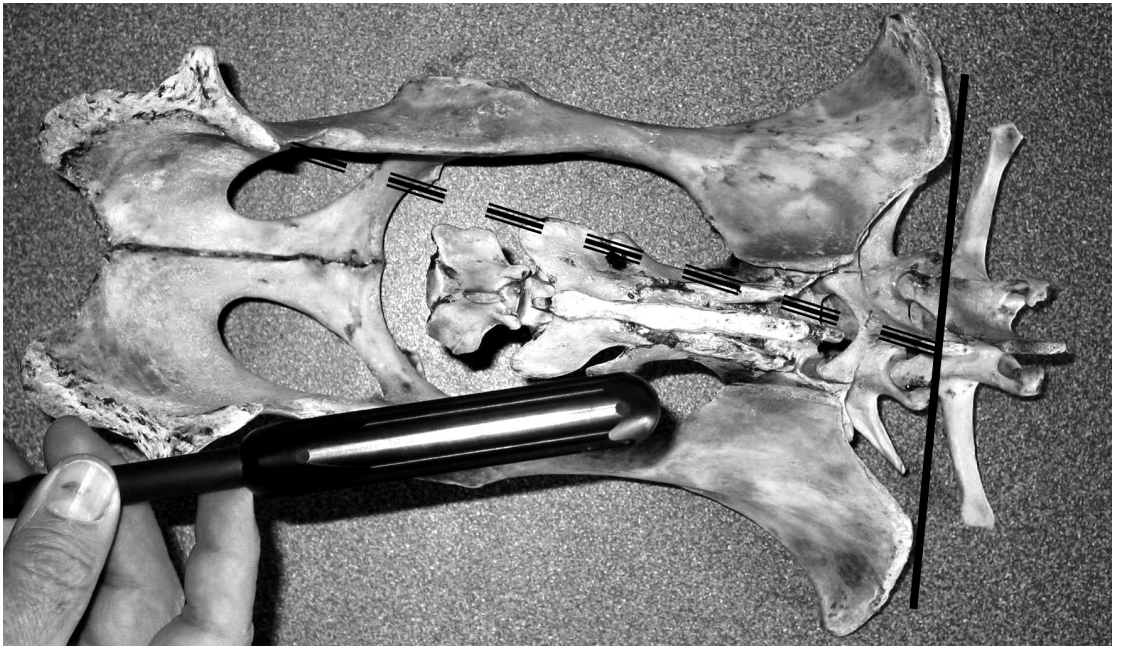


Fig. 2. Ultrasound probe for measuring thickness of rump fat in relation to the caribou pelvic girdle. The dashed line represents the line along which the ultrasound transducer probe should be positioned. The dashed line extends from the pin bone (cranial process of the tuber ischium) to a point along the spine between the hip bones (tuber coxae), as shown by the black line. Rump fat should be recorded at the point of maximum fat depth immediately adjacent to the pin bone.

in combination with a body condition score (Gerhart *et al.*, 1996a) was also the best *in vivo* predictor of percent body fat for elk (*Cervus elaphus*).

Reproductive status during winter may be indicative of body condition in autumn (Cameron *et al.*, 1993). Animals with very low body fat commonly do not come into estrus (Dauphiné, 1976; Thomas & Kiliaan, 1998) or, more rarely, do not carry fetuses to term (Dauphiné, 1976; Russell *et al.*, 1998). Non-pregnant caribou also may have lower body mass than pregnant individuals (Cameron & Ver Hoef, 1994). A valuable index of body condition for caribou in winter should, therefore, be non-destructive, distinguish between reproductive classes, and provide a repeatable measure of relative condition for an individual over time.

We used ultrasound measurements of the thickness of rump fat to determine relative body condition of pregnant and non-pregnant woodland caribou (northern ecotype; Heard & Vagt, 1998) in north-central British Columbia, Canada. We submit that with some limitations and further research, ultrasonography, as reported for other cervids, is a valuable field technique to measure rump fat and enables biologists to estimate percent body fat and trends in nutritional condition of woodland caribou.

Material and methods

Thirty-nine female woodland caribou were captured in February of 2003 ($n = 20$) and January 2004 ($n = 19$) in the Greater Besa-Prophet Area (57°11' and 57°15'N, and 121°51' and 124°31'W) of the Muskwa-Kechika Management Area in northern British Columbia, Canada (Fig. 1). Descriptions for this study area are available in Gustine *et al.* (2006). Caribou were not immobilized for capture, rather we captured individuals with a net-gun (Rongstad & McCabe, 1984) from a helicopter (Bell Jet Ranger II-206B) and 'hobbled' them with leather restraints. Blood samples (approx 10 ml) were taken to determine reproductive condition of caribou via serum progesterone concentrations (Prairie Diagnostics Services, Saskatoon, SK, Canada; Russell *et al.*, 1998). We estimated thickness (cm) of rump fat using a portable ultrasound machine (Medison Sonovet 600 with variable 4–6 MHz linear probe, Universal Medical Systems Ltd, Bedford Hills, NY, USA) as outlined in Stephenson *et al.* (1998) with the location for measurements provided by T. Stephenson (unpublished data) (Fig. 2). We used an unpublished linear equation to estimate body fat (%) for caribou from the measurements of rump fat: body fat (%) = 5.76 + [2.27*(thickness of rump fat (cm))] (T. Stephenson, unpubl. data). We used analysis of variance to examine the effect of capture date on thickness of rump fat (Zar, 1999). We did not examine

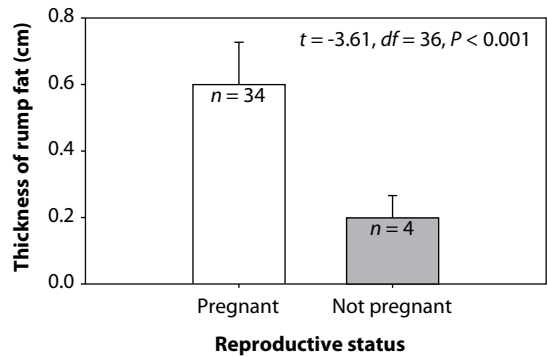


Fig. 3. Ultrasound estimates of thickness of rump fat (cm, $\bar{x} \pm 95\%$ CI) by reproductive status for woodland caribou in the Greater Besa-Prophet Area, northern British Columbia, Canada, 2003–2004.

the effect of year because dates of collection were specific to capture date in each year (i.e., all animals were captured in either February 2003 or January 2004; therefore capture date was synonymous with year). We tested the hypothesis that non-pregnant woodland caribou females would have less rump fat, and therefore lower estimates of body fat, than pregnant females (Dauphiné, 1976; Gerhart *et al.*, 1996a; Heard *et al.*, 1997; Thomas & Kiliaan, 1998). If there was no effect of capture date on thickness of rump fat, we pooled data across years and examined thickness of rump fat for adults (>3 years) by reproductive status using a one-tailed *t*-test (Zar, 1999). Because of violations in the assumption of normality, we log-transformed rump-fat measurements for all tests. We used Stata 9.0 (Stata Corporation, College Station, TX, USA) for analyses and assumed significance for all tests at $\alpha = 0.05$.

Results

Thirty-eight of the 39 woodland caribou females captured were adults (Table 1) and 34 of the adult caribou were pregnant (89.5 ± 5.1%, $\bar{x} \pm$ binomial SE). The individual <1.5 years of age had one of the lowest estimates of body fat and was not pregnant (Table 1), and, subsequently, was not included in comparisons. There was no effect of capture date ($F_{(1,36)} = 1.030$, $P = 0.316$) on estimates of body fat, so we pooled all data to examine differences in thickness of rump fat for pregnant and non-pregnant animals. Pregnant caribou had more rump fat (Fig. 3) and, therefore, higher estimates of percent body fat (7.1 ± 0.15%, $\bar{x} \pm$ SE) than non-pregnant caribou (6.1 ± 0.06%). Estimates of body fat ranged from 6.0–9.6% in pregnant caribou and 6.0–6.2% in non-pregnant animals, but we only had estimates for four non-pregnant adults (Table 1).

Table 1. Reproductive status and ultrasound estimates of rump fat for female woodland caribou in the Greater Besa-Prophet Area in northern British Columbia, 2003–2004. Reproductive status for 38A was confirmed via necropsy and 33A was <1.5 years old.

Animal	Date of capture	Progesterone (ng/ml) ¹	Reproductive status	Thickness of rump fat (cm)	Body fat (%) ²
26A	10-Feb-03	4.7	Pregnant	0.3	6.4
27A	10-Feb-03	4.3	Pregnant	0.1	6.0
21B	11-Feb-03	3.7	Pregnant	0.5	6.9
25B	11-Feb-03	3.9	Pregnant	0.7	7.3
28A	11-Feb-03	7.3	Pregnant	0.4	6.7
29A	11-Feb-03	4.8	Pregnant	0.2	6.2
30A	11-Feb-03	2.7	Pregnant	0.9	7.8
31A	11-Feb-03	3.8	Pregnant	0.5	6.9
32A	12-Feb-03	5.0	Pregnant	1.3	8.7
33A	12-Feb-03	<0.2	Not pregnant	0.1	6.0
34A	12-Feb-03	5.8	Pregnant	0.5	6.9
35A	12-Feb-03	3.1	Pregnant	1.6	9.4
36A	12-Feb-03	<0.2	Not pregnant	0.1	6.0
37A	12-Feb-03	<0.2	Not pregnant	0.1	6.0
38A	13-Feb-03	n/a	Pregnant	0.4	6.7
39A	13-Feb-03	4.7	Pregnant	0.3	6.4
40A	13-Feb-03	10.9	Pregnant	0.7	7.3
41A	14-Feb-03	4.3	Pregnant	0.9	7.8
42A	14-Feb-03	6.2	Pregnant	0.2	6.2
43A	14-Feb-03	4.8	Pregnant	1.7	9.6
44A	20-Jan-04	7.2	Pregnant	0.4	6.7
45A	20-Jan-04	<0.2	Not pregnant	0.2	6.2
46A	20-Jan-04	3.8	Pregnant	0.5	6.9
47A	20-Jan-04	4.4	Pregnant	0.3	6.4
48A	20-Jan-04	7.8	Pregnant	0.9	7.8
49A	20-Jan-04	<0.2	Not pregnant	0.2	6.2
50A	20-Jan-04	5.7	Pregnant	0.4	6.7
51A	20-Jan-04	4.5	Pregnant	0.2	6.2
52A	20-Jan-04	5.6	Pregnant	0.6	7.1
53A	21-Jan-04	5.0	Pregnant	0.3	6.4
54A	21-Jan-04	4.8	Pregnant	0.5	6.9
55A	21-Jan-04	3.9	Pregnant	0.6	7.1
56A	21-Jan-04	5.4	Pregnant	0.2	6.2
57A	21-Jan-04	6.1	Pregnant	0.3	6.4
58A	21-Jan-04	12.4	Pregnant	0.3	6.4
59A	21-Jan-04	3.4	Pregnant	0.4	6.7
60A	21-Jan-04	4.8	Pregnant	0.9	7.8
61A	21-Jan-04	5.3	Pregnant	1.1	8.3
62A	21-Jan-04	5.6	Pregnant	0.4	6.7

¹ Determined from serum progesterone assays (Prairie Diagnostics Services, Saskatoon, SK, Canada; Russell *et al.*, 1998).

² Estimated using the equation $y = 5.76 + 2.27x$, where y = estimate of body fat (%), and x = ultrasound measurement of rump fat (cm); $r^2 = 0.77$ (T. R. Stephenson, unpublished data for caribou).

Discussion

Ultrasonography was effective in differentiating the variation in rump fat between pregnant and non-pregnant female woodland caribou in the Greater Besa-Prophet Area. With sufficient training and access to an ultrasound machine, biologists can incorporate this technique into annual capture and collaring operations (Stephenson *et al.*, 1998). Data on snow conditions during winter, changes in energetic reserves by individuals within and among years, and estimates of calf productivity will become increasingly useful for predicting population trajectories as climatic factors and vegetative parameters become more variable (Lenart *et al.*, 2002; Adams, 2005).

Maternal body mass affects the probability of pregnancy in autumn (Reimers, 1983; Cameron *et al.*, 1993; Cameron & Ver Hoef, 1994) as well as calf survival through summer (Eloranta & Nieminen, 1986; Gustafson *et al.*, 1998). Specific components (i.e., fat and protein) of body mass, however, are better predictors of pregnancy (Gerhart *et al.*, 1996a; Ouellet *et al.*, 1997). The role that fat and/or protein set points, or thresholds, have in determining the probability of pregnancy, viability of the fetus, and/or calf growth and survival in caribou is undetermined. Relative to energetic reserves, Crête *et al.* (1993) suggested that body fat must be 7.8% or approximately 7.0 kg of the ingesta-free body mass in autumn–early winter for pregnancy to occur in caribou. Ouellet *et al.* (1997) recommended that the threshold is probably lower (approx 6.0%). Five of the 10 animals that we measured with $\leq 6.2\%$ body fat were pregnant and of the 4 animals with 6.0% body fat, only one was pregnant (Table 1). Recognizing that loss of fat through winter is expected and that the rates of this loss are largely undetermined, the observed similarities in rump fat for non-pregnant woodland caribou suggest that animals with body-fat levels of 6.0–7.0% in mid-winter may have approached the limit needed for pregnancy in fall. Some of the pregnant woodland caribou in the Greater Besa-Prophet Area may be at or near this limit (Table 1). Neonatal calf weights for woodland caribou in our study area [males, 8.09 ± 0.52 kg, $\bar{x} \pm$ SE, $n = 19$; females, 7.78 ± 0.28 kg, $n = 31$ (Gustine *et al.*, 2006)], however, were similar to the 10-year average of calf weights (males, 8.04 ± 0.07 kg; $n = 244$; females, 7.50 ± 0.07 kg, $n = 267$) from barren-ground caribou in generally excellent condition (Denali herd; Adams, 2005). Low body fat, therefore, may not necessarily result in lower calf weights for those caribou that do reproduce, although it is not currently known if winter body-fat levels of 6–7% are low enough to evoke a 'threshold' effect in fetal development.

A means of monitoring body protein in late winter would be a valuable complement to ultrasonography,

given that fetal tissue is comprised primarily of maternal protein (P. Barboza & K. Parker, unpublished data). Nutritional restrictions in late winter associated with decreased forage availability (e.g., increased snow depth or hardness) may increase both energetic costs (e.g., movement) and catabolism of energetic and protein reserves to maintain body processes (Parker *et al.*, 2005). Fetal development and subsequently, fetal and neonatal viability [e.g., white-tailed deer (*O. virginianus*; Sams *et al.*, 1995)] may be compromised when maternal protein is progressively depleted to meet energetic demands. Pregnant females are likely most sensitive to these types of restrictions during the third trimester when physiological demands of fetal growth are the highest. Monitoring changes in body protein, however, is challenging because of the relatively small changes that occur throughout the year (approx 9.5–11.2% of body mass for breeding female caribou, Chan McLeod *et al.*, 1999). Recent use of nitrogen isotopes in snow urine to assess nitrogen balance in late winter (Parker *et al.*, 2005; Barboza & Parker, 2006) is promising, but this technique requires validation in wild populations of caribou.

Certainly there are limitations to the ultrasound technique as well as challenges in interpreting the observed differences in the thickness of rump fat between reproductive classes of woodland caribou. First, ultrasound estimates of rump fat are not useful for animals with no rump fat (Stephenson *et al.*, 1998; 2000; Cook *et al.*, 2002) because lack of measurable rump fat does not indicate 0% body fat (e.g., caribou with no rump fat could have up to 5.76% body fat based on the linear equation used to estimate body fat from rump fat). At very low levels of rump fat, it also can be difficult to determine the difference between muscle fascia and fat on ultrasound images depending on field conditions (e.g., sun may limit the visibility of the screen), observer experience, and resolution of the ultrasound screen. It may be more correct to interpret low values of rump fat as a range in condition (e.g., caribou with 0.10 cm of rump fat have <6.1% body fat), but investigators would have difficulty comparing samples with descriptive statistics. With few exceptions (see set point discussion above), reclassifying individuals in our sample this way would not effect our general conclusions: pregnant females had thicker rump fat than non-pregnant females and ultrasonography appears to be a valuable tool for assessing relative condition of woodland caribou. Chan-McLeod *et al.* (1995) documented large variation in percent body fat for animals with no rump fat (approx 3–14%, min–max), using measurements made manually on carcasses and not with ultrasonography. It is possible, therefore, that we also could have underestimated

percent body fat for animals with little or no rump fat. As recommended by Cook *et al.* (2002), an estimation of body fat probably should combine ultrasound measurements of rump fat with body condition scores (Gerhart *et al.*, 1996b) to increase utility of the technique across the full range of body conditions (approx 0–25% body fat). Second, fat deposition and pregnancy rates vary with age. Because young animals must meet the demands of growth, younger animals deposit less fat and generally have lower pregnancy rates than adults (Dauphiné, 1976; Heard *et al.*, 1997; Thomas & Kiliaan, 1998). Researchers should attempt to either age animals within their samples or incorporate this as a source of bias in their estimates of condition.

The positive relationship between probability of pregnancy and body fat in *Rangifer* spp. is well documented (Dauphiné, 1976; Cameron *et al.*, 1991; Gerhart *et al.*, 1996a; Heard *et al.*, 1997; Thomas & Kiliaan, 1998) and has been useful for evaluating nutritional condition of individual animals and populations. The importance of body condition in *Rangifer* spp. though has been discussed almost exclusively relative to fluctuations in populations of Arctic barren-ground caribou. In contrast, research on populations of woodland caribou has focused typically on habitat fragmentation and predation risk, and indices of body condition have received little attention. Consequently, there are few data reported that index the condition of woodland caribou and we recommend that more studies quantify nutritional condition as an integrator of the food-predation-environment trade-off. The relationship between body reserves and the probability of pregnancy may be similar among woodland and barren-ground subspecies and/or ecotypes, but variation in biotic (e.g., vegetation, snow conditions, seasonal distribution of predators and other ungulates) and abiotic factors (e.g., topography) as well as associated annual and seasonal energetic costs, suggest that there may be differences in nutrient partitioning strategies (e.g., magnitude of fat deposition). We were unable to make direct comparisons of our measurements of rump fat with those of Arctic populations because back fat of barren-ground animals mostly was measured manually and at different locations on animal carcasses. Ultrasonography with standardized protocols is now being used to determine thickness of rump fat in both live barren-ground and woodland caribou for captive (Parker *et al.*, 2005; Barboza & Parker, 2006) and wild (E. Jones, unpublished data from British Columbia; M. Oakley, unpublished data from Yukon; this study) populations.

Recognizing that the deposition and mobilization of fat varies with age (Dauphiné, 1976; Heard *et al.*, 1997), previous demands of reproduction (Chan-

McLeod *et al.*, 1994), and across the winter season (Thomas & Kiliaan, 1998; Chan-McLeod *et al.*, 1999), ultrasonography can be used as a non-invasive technique in the field to assist in evaluating nutritional condition of caribou. Similar to data collected from carcass evaluations in previous studies on barren-ground caribou (e.g., Dauphiné, 1976; Thomas & Kiliaan, 1998), the non-pregnant woodland caribou in our sample had less rump fat than pregnant individuals. Although these data are within general thresholds of percent body fat needed for pregnancy in caribou (Crête *et al.*, 1993; Ouellet *et al.*, 1997), additional studies should quantify the environmental and physiological parameters that affect rates of fat and protein deposition and catabolism for individuals within a population. In addition to ultrasound measurements of rump fat, body condition scores [described in Gerhart *et al.* (1996b) and developed for elk by Cook *et al.* (2002)] and estimates of body protein would help to quantify maternal investment towards calf production and the ecological strategies used to address energetic and protein demands for reproduction and survival.

Acknowledgements

Funding was provided by the Muskwa-Kechika Trust Fund, the Northern Land Use Institute at the University of Northern British Columbia, and the British Columbia Ministry of Environment. We thank R. B. Woods and B. C. Culling for their skills in animal capture and handling, and our pilots, A. W. Moore and C. Allen, for their flying expertise. We are indebted to J. B. Ayotte and A. B. D. Walker for assistance in the field and M. Oakley for the shared use of the ultrasound machine. We thank T. Stephenson for providing us his data on thickness of rump fat and percent body fat as well as drawings on establishing measurement locations on caribou. We also thank an anonymous reviewer and T. Stephenson for providing insightful comments on an earlier version of this manuscript.

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