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Biochemical indicators of condition, nutrition and nitrogen excretion in caribou

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Abstract: Urinary urea nitrogen to creatinine ratios (UUC mg/mg), urinary N^{τ}-methylhistidine to creatinine ratios (UN^{τ}-MHC μmol:μmol), serum urea nitrogen concentrations (SUN mg/dl), and serum N^{τ}-methylhistidine concentrations (N^{τ}-MH nmol/ml) were compared with physical measures of body composition in adult female barren-ground caribou (*Rangifer tarandus groenlandicus*) from the Bathurst and Southampton Island herds during late winter. Body weight and UUC were used to estimate urinary urea nitrogen (urea-N) excretion in free ranging caribou. Only mean UUC reflected differences in fat reserves between populations. None of the biochemical indicators were directly related to body composition. However, elevated UUC were only observed in caribou with depleted fat reserves as demonstrated by low kidney fat index (KFI<40) and/or reduced femur marrow fat (FMF<80). UUC greater than 0.25 were indicative of undernourished animals with depleted fat reserves. SUN and UN^{τ}-MHC showed no clear relationship with fat reserves. The mean estimated daily urea-N excretion for adult female caribou in late winter was extremely low (0.11±0.01SE g urea-N/day, n=76, range=0.011-0.510). The results of my study suggest that UUC can be used to detect nutritionally stressed caribou with depleted fat reserves on lichen winter ranges.

Key words: *Rangifer*, urea, urine, serum

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Introduction

Physical condition and nutritional status are important parameters in assessing the demography of caribou (*Rangifer tarandus*) populations (Messier *et al.*, 1988; Couturier *et al.*, 1990). Body size and the level of fat reserves have been shown to affect productivity and recruitment through effects on fecundity and neonatal calf survival (Dauphiné, 1976; Thomas, 1982; Reimers, 1983; White, 1983; Crête *et al.*, 1993). Historically, indices of condition have been taken from direct carcass measurements. Body measurements, tissue weights, and standard fat measurements were identified as useful indicators of physical condition (Adamczewski *et al.*, 1987a; Huot, 1988; Allaye-Chan, 1991). All of these measurements required either killing or at least handling the animals. The nutritional status of animals has often been inferred from condition analyses given that undernutrition will result in depletion of body reserves. Unfortunately, condition indicies provide little information about current nutritional status.

Recently, several researchers have focused on the use of urinary urea nitrogen to creatinine ratios (UUC) to investigate nutritional status and indirectly assess condition in wild ungulates (DelGiudice & Seal, 1988; DelGiudice *et al.*, 1989; 1991a; 1991b; Cool, 1992). Collection and analysis of urine from snow avoids stress due to capture or harvesting animals, which is of particular importance in the assessment of low density or endangered populations. Elevated UUC have been documented in undernourished white-tailed deer (*Odocoileus virginianus*) (DelGiudice *et al.*, 1987; DelGiudice & Seal, 1988), moose (*Alces alces*) (Cool, 1992), and wapiti (*Cervus elaphus*) (DelGiudice *et al.*, 1991a; DelGiudice *et al.*, 1991b). The management value of UUC was demonstrated by DelGiudice & Seal (1988) who were able to classify white-tailed deer into three categories: early undernutrition, prolonged-reversible undernutrition and prolonged-irreversible undernutrition.

The use of UUC as an indicator of nutritional status depends on the increased excretion of urea nitrogen (urea-N) in response to accelerated catabolism of endogenous proteins. Catabolism of fat and protein reserves is typical of over wintering northern ungulates when energy intake is limited. In most cases of undernutrition, fat reserves are

mobilized preferentially and the rate of endogenous protein catabolism increases as fat reserves become depleted (Torbit *et al.*, 1985; DelGiudice *et al.*, 1987). In some situations, particularly with reindeer and caribou consuming low protein lichen diets, nitrogen intake can be limiting despite ample digestible energy (Steen, 1968; Nieminen & Heiskari, 1989). Steen (1968) suggested that reindeer on a lichen diet must catabolize endogenous protein to provide a supply of amino acids for protein synthesis and nitrogen for rumen microbes, even when energy intake allows them to accumulate fat.

Although UUC have been used to classify nutritional status and to indirectly assess body composition, only one study has been conducted to determine if changes in UUC reflect body composition. In black-tailed deer (*O. hemionus sitkensis*), UUC did not consistently reflect individual animal body composition (Parker *et al.*, 1993). The primary objective of my study was to determine if urine and serum nutritional indices reflected body composition in caribou in the spring. Specifically, two urinary indices, UUC and urinary N^{τ}-methylhistidine (N^{τ}-MH) to creatinine ratios (UN^{τ}-MHC), and two serum indices, serum urea-N concentrations (SUN) and serum N^{τ}-MH concentrations (SN^{τ}-MH), were compared to proportions of fat and muscle in harvested caribou. UN^{τ}-MHC and SN^{τ}-MH were included in the analysis because N^{τ}-MH excretion has been shown to be an indicator of endogenous myofibrillar protein degradation in some species (Harris & Milne, 1981; Long *et al.*, 1988). SUN was evaluated because DelGiudice & Seal (1988) found elevated SUN in malnourished deer.

The methodology of my study also permitted an evaluation of nitrogen conservation in over wintering caribou. Caribou consuming a mainly lichen diet with very low (<3%) crude protein (Scotter, 1965; Scotter, 1967; Thomas & Hervieux, 1986) must minimize urinary nitrogen loss to conserve muscle mass. Urinary excretion of urea-N is typically the most significant source of urinary nitrogen loss (Dukes, 1947), therefore, nitrogen conservation was assessed by looking at urinary urea-N excretion.

Methods

Sampling protocol

During late winter and spring in 1990, 1991 and 1992 (February through May), 55 adult, 13 yearling and 6 calf caribou were collected from the Bathurst caribou herd winter range and 48 adult, 23 yearling and 4 calf caribou were collected from Southampton Island. The diet of Southampton Island and mainland caribou consists mainly of lichen during this period (Ouellet, 1992; Thomas & Hervieux, 1986). Animals were shot by native hunters who were instructed on the sex of animals to harvest but to otherwise take animals at random. Immediately after death, a blood sample was taken by slicing through the carotid artery and jugular vein in the lower neck. A urine sample was collected direcdy as it drained from the animal or from the snow. The animals were then taken to a central location where fresh weights and carcass measurements were made. Maximum depth of backfat was measured along an incision 45° forward from the base of the tail. Kidney fat index (KFI) was determined by dividing the weight of Riney fat by the weight of the kidney and multiplying by 100 (Riney, 1955). The femur and gastrocnemius muscle were collected and frozen. Femur marrow fat (FMF) was determined using the dry weight method corrected for mineral content (Neiland 1970). Animals were classified as being in poor condition if KFI was less than 30 or FMF was less than 50% (Thomas 1982). Gastrocnemius weight was determined after removal of the superficial digital flexor and tendons. Blood samples were centrifuged upon returning to camp and serum was retained. Samples were frozen at -10°C (urine and serum at -20°C) until analyzed in the laboratory.

Indicator muscle, bone, and fat measurements were used to estimate the weight of muscle, bone and fat in each carcass using the equations determined for caribou by Adamczewski *et al.* (1987a). To adjust for differences in frame size between animals of different ages, estimated muscle and fat weights were standardized to bone weights to give muscle to bone ratios (MUSBONE) and fat to bone ratios (FATBONE).

Chemical analyses

Creatinine concentrations (mg/dl and µmol/ml) in serum and urine were determined using a colorimetric method based on the Jaffé reaction (Sigma Diagnostics, St. Louis MO). Urinary and serum concentrations of urea-N (mg/dl) were determined using a colorimetric urea assay kit based on the diacetyl monoxime reaction (Sigma Diagnostics, St. Louis MO). Urine and serum samples were analyzed for N^{τ}-MH (µmol/ml) using high performance liquid chromatography (HPLC) (Scott *et al.*, 1993). Samples were deproteinized with 0.200 ml of 3.0M $HClO_4$, centrifuged at 3000 rpm for 15 minutes, and analyzed using a Varian Model 5500 Liquid Chromatograph with a Varian 2070 spectrofluorometer detector and a Varian 9090 auto analyzer (Varian Canada, Calgary AB). Separations were done on a 15 cm x 4.6 mm 3 micron reverse phase column (Supelco Inc., Bellefonte PA). Standard quality control procedures were run on all analyses.

Urinary creatinine excretion is strongly correlated with muscle weight and is highly consistent wit-

hin species (Vestergaard & Leverett, 1958; Kertz *et al.*, 1970; Chetal *et al.*, 1975; Forbes & Bruining, 1976). Therefore, creatinine coefficients from reindeer were used to estimate urea-N excretion from caribou based on the ratio of urea to creatinine in urine and body weight using the formula:

TTLUREA = ((CREATCO * WT)/UCREAT * UUREA)/1000

where TTLUREA= total daily urea-N excretion (g), CREATCO = creatinine coefficient (16.16 mg/kg/day) determined from lean adult female reindeer (Case, unpublished data), WT = body weight (kg), UCREAT = urine creatinine concentration (mg/dl) and UUREA = urine urea-N concentration (mg/dl).

Statistical analyses

Differences between variable means for sex and location were analyzed using least squares analysis of variance (PROC GLM) (SAS, 1988).

Results

None of the animals harvested on Southampton Island were classified as being in poor condition based on KFI or FMF. In contrast, 39% (34 of 87) of the Bathurst caribou harvested had a KFI less than 30 and 6% (4 of 70) had a FMF less than 50%. These differences in fat reserves are reflected in the significant ($P<0.0001$) differences in FATBONE ratios observed for both males and females (Fig. 1). Bathurst caribou had significantly ($P<0.05$) larger MUSBONE ratios indicating a larger muscle mass.

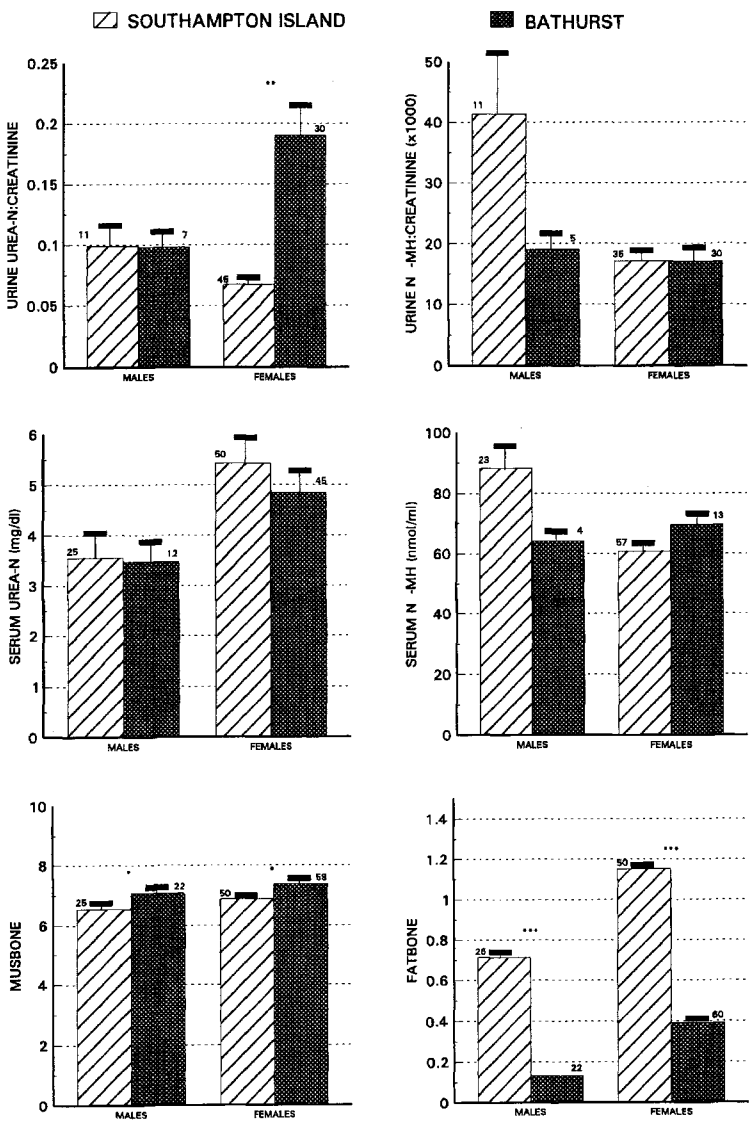

Fig. 1. Herd and sex differences in urine urea-N:creatinine, urine N^{τ}-MH:creatinine, serum urea-N, serum N^{τ}-MH, muscle:bone (MUSBONE) and fat:bone (FATBONE) in caribou harvested during late winter (mean±SE). (*$P<0.05$, **$P<0.001$, ***$P<0.0001$).

Herd differences in fatness were reflected in UUC for female caribou; Bathurst females excreted significantly more urea-N than Southampton Island females (Fig. 1). Although the differences were not significant, SUN showed a trend towards being lower in Bathurst female caribou. UN^{τ}-MHC and SN^{τ}-MH were similar for Bathurst and Southampton Island females and Bathurst males. Southampton Island males had higher UN^{τ}-MHC and serum N^{τ}-MH concentrations although the differences were not significant ($P>0.05$). Six of the males on Southampton Island had serum N^{τ}-MH concentrations in excess of 100 nmol/ml.

UUC, SUN and UN^{τ}-MHC were plotted against KFI and FMF to investigate relationships between the biochemical indicators and body condition (Fig. 2). Elevated UUC were only observed with depleted fat reserves while SUN and UN^{τ}-MHC showed no clear relationship with either KFI or FMF.

The mean estimated daily urea-N excretion for adult caribou from both study areas in late winter/spring was 0.11±0.01 SE g (n=76 range=0.011-0.510). Adult female caribou on the Bathurst range with UUC less than 0.25 excreted slightly more urea-N (0.14±0.02 g/day) than the average estimate; caribou with UUC greater than 0.25 excreted even more (0.38±0.08 g/day).

Discussion

Herd comparisons

The lower fat reserves in Bathurst caribou, as indicated by FATBONE ratios, may reflect a number of ecological differences between the two herds. Southampton Island caribou typically have higher fat reserves in the fall than the mainland herds

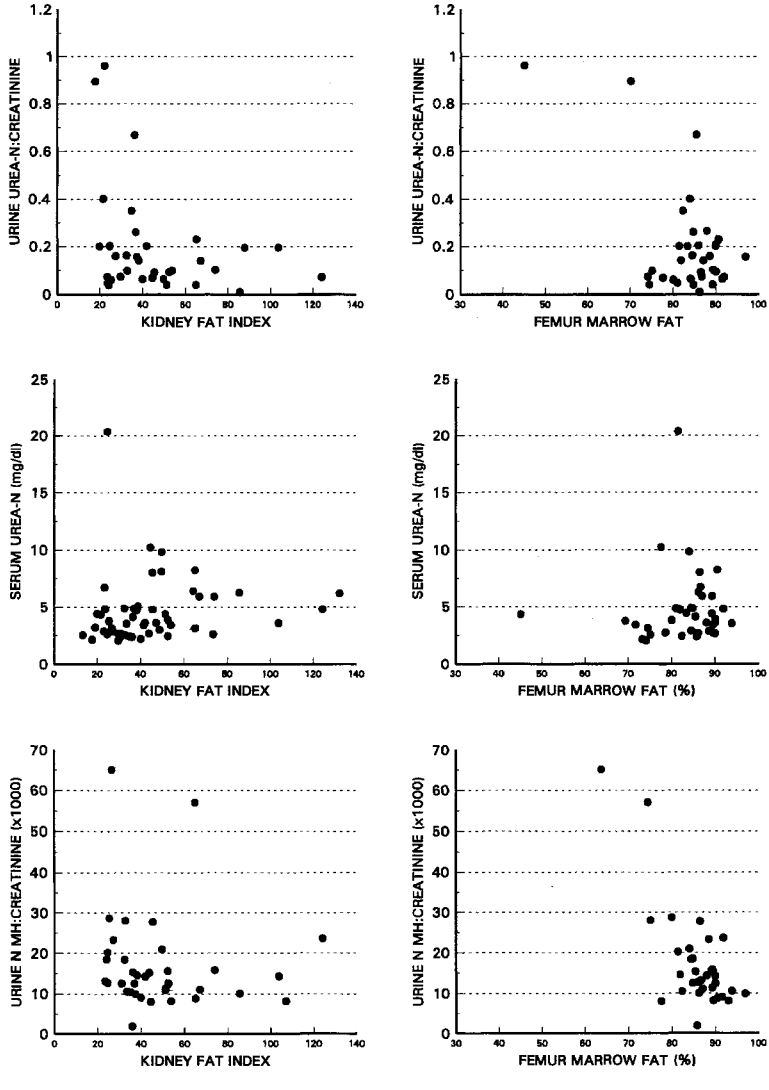

Fig. 2. Urine urea-N:creatinine, serum urea-N and urine N^{τ}-MH:creatinine versus kidney fat index and percent femur marrow fat in adult female Bathurst caribou in late winter.

(Ouellet, 1992). Bathurst caribou could also be expected to have higher over winter nutritional demands resulting from migration to winter ranges and predator avoidance because Southampton Island caribou do not migrate and have no predators. Forage quality and availability could also be important, however, no comparative range or snow pack studies have been conducted.

The elevated UUC observed in female Bathurst caribou are consistent with undernourished animals and suggest that some of the animals were either catabolizing protein or eating a higher protein forage (DelGiudice & Seal, 1988). The first explanation is the more likely one, because the study area was still 100% snow covered and no new high protein vegetation was available. DelGiudice & Seal (1988) also observed elevated SUN in extremely undernourished animals, which were not encountered in this study. The lack of elevated UUC in Bathurst males would suggest that these animals were not experiencing undernutrition; possibly because they have no gestational demands. However, the sample size was small because it was difficult to collect urine from harvested males.

The elevated serum N^{τ}-MH concentrations and UN^{τ}-MHC in Southampton Island males relative to Bathurst males suggests there is a difference between the two herds. Increased excretion of N^{τ}-MH has been associated with either starvation or growth in rats and cattle (Nishizawa *et al.*, 1977; Wassner *et al.*, 1977; Jones *et al.*, 1990). Fat levels would suggest that the animals were not experiencing prolonged undernutrition however, animals could have been experiencing short-term undernutrition at the time of collection. Growth also cannot be ruled out. Ouellet (1992) observed that males on Southampton Island grew through the winter.

Biochemical indicators of body composition

Plotting UUC from adult female Bathurst caribou in the spring versus KFI and FMF indicates that caribou with UUC greater than 0.25 had depleted body reserves (Fig. 2). All of the caribou with UUC greater than 0.25 had KFI less than 40 and all but 2 would have been classified as in poor condition using Thomas' (1982) criteria of KFI less than 30. The two animals with the lowest FMF also had the highest UUC.

DelGiudice & Seal (1988) classified white-tailed deer with UUC below 4.0 as in early undernutrition, UUC between 4 and 23 as in prolonged-reversible undernutrition and UUC over 23 as indicative of prolonged-irreversible undernutrition. As all the UUC values from the harvested caribou in my study were below 1, DelGiudice & Seal's (1988) classification would suggest that no animals were undernourished. This discrepancy highlights the need for caution in extrapolating between species.

It should be noted that although all caribou with UUC greater than 0.25 had depleted fat reserves, not all caribou with low KFI and low FMF had high UUC. A similar pattern was observed in Sitka black-tailed deer where UUC was compared with fat reserves determined using tritiated water (Parker *et al.*, 1993). The reason for this is because KFI and FMF depend on past nutrition while UUC reflects current nutrition (DelGiudice *et al.*, 1990). It is possible that caribou with low fat reserves could still be obtaining sufficient energy in the diet. This would result in low UUC even though they would be classified as being in poor condition based on their fat reserves.

The only other study that compared UUC to fat levels was limited to analysis of winter killed wapiti (DelGiudice *et al.*, 1991a). The animals had UUC in excess of 70 and FMF <10%. None of the Bathurst caribou had reached this state and their undernutrition was likely reversible.

DelGiudice & Seal (1988) also suggested that SUN could be used to classify the phases of undernutrition with SUN <20 mg/dl indicating early undernutrition, SUN from 20 to 40 mg/dl indicating prolonged-reversible undernutrition, and SUN over 40 mg/dl indicating prolonged-irreversible undernutrition. In my study, SUN did not correspond as well as UUC to fat levels, although the only animal with elevated SUN also had a high UUC and a low KFI.

Although UN^{τ}-MHC showed no clear relationship with either KFI or FMF, it remains possible that in later stages of malnutrition excretion of N^{τ}-MH would increase, as has been observed in starving rats (Wassner *et al.*, 1977). However, once animals are severely malnourished monitoring N^{τ}-MH would have no advantages over UUC or visual classification of condition, and would be more expensive.

Nitrogen conservation in over wintering caribou

Urea-N excretion is best evaluated based on dietary nitrogen intake. The late winter diet of Bathurst caribou is primarily terrestrial lichen (Thomas & Hervieux, 1986) with a nitrogen content of approximately 4 g/kg (Scotter, 1965). Assuming an apparent digestibility of 75% (Thomas & Kroeger, 1980) lichens would provide approximately 3 g N/kg. Therefore, the mean daily urinary loss of urea-N observed in animals with UUC greater than 0.25 (0.38 g/day) could be made up by ingesting 125 g of lichen.

The low excretion of urea-N in wild caribou, even in those with elevated UUC, is evident when

contrasted with adult female reindeer which excreted an average of 7.9 g urea-N/day (n=3) on a low protein (7.9% Crude Protein [CP]) pelleted diet, and reindeer which excreted an average of 26.6 g urea-N/day on a high protein diet (18.8% CP) (Case, unpublished data). Cattle on a 12% CP diet excreted >28 g urea-N/day but were able to reduce this to less than 2.5 g urea-N/day when fed a 4% CP diet and deprived of water (Livingston *et al.*, 1962). Captive caribou fed a simulated winter diet excreted an average of 18.0 g urea-N/day (Wales *et al.*, 1975).

Hove & Jacobsen (1975) reported reindeer maintained on a lichen diet reabsorbed an average of 93% of urea filtered at the glomerulus. Calculations from their figures indicated that the animals were excreting an average of 0.091 g urea-N/day, which is within the range observed in wild caribou. It is likely, therefore, that the caribou from the Bathurst and Southampton Island herds were also reabsorbing >90% of filtered urea.

The only other large ungulate for which comparable abilities to reduce nitrogen loss in urine has been documented is the camel. Schmidt-Nielsen *et al.* (1957) reported that a camel grazed in the sandy desert for 4 weeks then maintained on a low N diet of dates and hay for an additional 17 days with no access to water reduced urea-N excretion to less than 0.3 g/day. Wapiti and white-tailed deer, which have a well documented ability to recycle a large proportion of urea into the rumen, still excreted in excess of 1.9 g urea-N/day when feed very low protein diets (Robbins *et al.*, 1974; Mould & Robbins, 1981).

Conclusion

The results of my study suggests that UUC can be used to monitor the nutritional status of free ranging caribou on lichen winter ranges and that analysis of urine in snow can be used to conduct physiological assessments caribou, as has been demonstrated in deer (DelGiudice *et al.*, 1989) and wapiti (DelGiudice *et al.*, 1991c). The observation that UUC did not increase above 0.25 until fat reserves were being depleted (KFI<40) suggests that this value could be used to distinguish individual caribou which have both experienced prolonged undernutrition in late winter/spring and remain undernourished. UUC will not detect animals in poor condition which are well nourished, nor will they detect animals in good condition which have only recently experienced undernutrition. This, however, is not a problem as animals in either of these situations are not at immediate risk of starvation or reduced productivity.

Further data are needed from caribou in very poor condition to determine the UUC values for animals with severe or prolonged undernutrition. None of the animals collected during my study would have been expected to die of malnutrition. It would be expected that UUC would continue to increase as the severity and period of undernutrition increased. Data are also needed from caribou populations which are not consuming predominantly lichen diets during winter.

The ability of caribou to reduce urea-N loss in urine may be a function of reduced water flux rate in winter (Cameron & Luick, 1972). The effect is that a larger proportion of urea-N remains available for recycling into the rumen. Further investigation is needed to assess the relative and combined benefit of reduced urea-N loss and increased urea recycling in caribou.

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