*Journal of Wildlife Diseases*, 46(4), 2010, pp. 1096–1107


# SERUM BIOCHEMISTRY, SEROLOGY, AND PARASITOLOGY OF BOREAL CARIBOU (*RANGIFER TARANDUS CARIBOU*) IN THE NORTHWEST TERRITORIES, CANADA

**Deborah Johnson,[1,6] N. Jane Harms,[2,7] Nicholas C. Larter,[3] Brett T. Elkin,[4] Henry Tabel,[5] and Guojian Wei[5]**

[1] Department of Environment and Natural Resources, Government of the Northwest Territories, Box 900, Fort Smith, Northwest Territories X0E 0P0, Canada
[2] Department of Veterinary Pathology, Western College of Veterinary Medicine, University of Saskatchewan, 52 Campus Drive, Saskatoon, Saskatchewan S7N 5B4, Canada
[3] Department of Environment and Natural Resources, Government of the Northwest Territories, Box 240, Fort Simpson, Northwest Territories Z0E 0N0, Canada
[4] Department of Environment and Natural Resources, Government of the Northwest Territories, 500-5102 50th Avenue, Yellowknife, Northwest Territories X1A 3S8, Canada
[5] Department of Microbiology, Western College of Veterinary Medicine, University of Saskatchewan, 52 Campus Drive, Saskatoon, Saskatchewan S7N 5B4, Canada
[6] Current address: 2231 Clarence Avenue South, Saskatoon, Saskatchewan S7J 1L6, Canada
[7] Corresponding author (email: naomi.harms@usask.ca)

ABSTRACT: Boreal caribou (*Rangifer tarandus caribou*) are an ecologically and culturally important wildlife species and now range almost exclusively in the boreal forests of Canada, including the Northwest Territories, northern Alberta, and British Columbia. Boreal caribou are threatened throughout their Canadian range because of direct and indirect natural and anthropogenic factors. In the Northwest Territories, however, they have a continuous range that overall has not yet been subjected to the same degree of anthropogenic habitat fragmentation and degradation that has occurred elsewhere in Canada. To monitor the health of boreal caribou populations and individuals, we collected blood from 104 adult, female boreal caribou captured between March 2003 and February 2006 and measured serum biochemical parameters. Serum creatinine was higher in pregnant than in nonpregnant caribou. Several biochemical parameters differed among years, but they tended to be similar to those reported for reindeer. Serum antibodies were found to an alphaherpesvirus, *Toxoplasma gondii*, and to the *Mycobacterium avium* subspecies *paratuberculosis* in 37.5, 2.9, and 1.3% of boreal caribou, respectively. Fecal samples were collected from 149 boreal caribou, and *Cryptosporidium* sp. oocysts, *Giardia* sp. cysts, trichostrongyle ova, dorsal-spined nematode larvae, cestode ova, and *Eimeria* sp. were found. *Trypanosoma* sp. was detected in the blood of 72.1% of boreal caribou. *Eimeria* sp., *Cryptosporidium* sp., and *Giardia* sp. have not been previously reported in boreal caribou.

*Key words:* Boreal caribou, clinical chemistry, Northwest Territories, parasitology, *Rangifer tarandus caribou*, serology.

## INTRODUCTION

Boreal caribou (*Rangifer tarandus caribou*) currently occur almost exclusively in Canada and are dispersed throughout the boreal forest from the Northwest Territories to Labrador. Unlike barren-ground caribou, which are gregarious and undertake large-scale migrations, boreal caribou are solitary animals that are widely dispersed throughout their range (Stuart-Smith et al., 1997). Boreal caribou are designated as threatened in Canada (Committee on the Status of Endangered Wildlife in Canada, 2002). Industrial development and large-scale anthropogenic disturbances in boreal caribou habitat have been implicated in range and population declines via increased hunting, habitat fragmentation and loss, and linear barriers to movement such as roads (Weclaw and Hudson, 2004; Vors et al., 2007). Viral, bacterial, and parasitic diseases can also affect the boreal caribou population by increasing susceptibility to predation, hunting, and accidents, as well as by causing direct mortality (Lagrue et al., 2007; Miller et al., 2008). Little is known about the prevalence of disease agents in boreal caribou, although there is considerable concern regarding the possible introduction and effect of diseases, such

as chronic wasting disease, and parasites, including *Parelaphostrongylus tenuis*. In addition to the paucity of infectious disease data, there are no reports of basic health parameters, such as serum biochemistry analytes and serum cortisol levels, in these animals. Baseline data on existing diseases in boreal caribou are necessary to evaluate potential effects of existing and emerging diseases on populations and individuals and to determine appropriate management strategies. Blood parameters of many species of wildlife are examined to assess the physical condition and health status of individual animals and are useful for assessing disease status, nutrition and habitat quality, and effects of environmental stressors (Hanks, 1981). The method of capture used when collecting blood samples may have a substantial effect on certain serum constituents (Marco and Lavin, 1999) and should be taken into consideration when evaluating serum biochemistry of free-ranging animals.

Blood and fecal samples were collected from adult boreal caribou captured in the northern boreal forest of Canada as part of an ongoing study on the population ecology of boreal caribou conducted by the Government of the Northwest Territories. Our objective was to document boreal caribou health parameters, including serum biochemistry, serum cortisol levels, serologic evidence of exposure to a suite of viral and bacterial pathogens, presence and type of fecal parasites, and presence of *Trypanosoma* sp. parasites in blood.

## MATERIALS AND METHODS

### Collection and preparation of samples

Adult, female boreal caribou ($n=139$) were captured using the helicopter net-gun method in the study area in the southern Northwest Territories, Canada (Fig. 1), from March 2003 through February 2009. Boreal caribou were captured in March to April 2003 ($n=18$), March to April and December 2004 ($n=35$), March 2005 ($n=29$), January to February 2006 ($n=28$), January 2007 ($n=15$), February 2008 ($n=6$), and February 2009 ($n=8$). Because boreal caribou populations in the Northwest Territories, Canada, are contiguous with those in northern Alberta and British Columbia, Canada, several animals were captured within 110 km south of the Northwest Territories border (Fig. 1). In the net-gun capture method, an animal is located, pursued for <1 min, maneuvered into position from the air, and entrapped by a net shot from the net gun. The helicopter lands, and captured caribou are hobbled, placed in sternal recumbency, examined briefly, and fitted with a radio collar. Blood taken from the cephalic vein of 104 caribou captured between 2003 and 2006 was allowed to clot, was centrifuged at 1,000 × G for 10 min, and the serum was frozen at −20 C. Feces were collected from the rectum of 120 caribou and stored in Whirl-Pak bags (Nasco, Fort Atkinson, Wisconsin, USA) at −20 C. Additional fecal samples ($n=29$) were collected opportunistically from groups of boreal caribou in the vicinity of Trout Lake, Northwest Territories, Canada (60°30′N, 120°14′W) on seven occasions between February 2005 and January 2009. None of these groups were equipped with radio collars, so they were determined not to have been sampled previously. The fecal samples were collected from the ground and could not be linked to a specific individual.

### Serum analysis

Sera were analyzed (Prairie Diagnostic Services [PDS], Saskatoon, Saskatchewan, Canada) using a Hitachi 912 analyzer ($n=100$; Boehringer Mannheim Corporation, Indianapolis, Indiana, USA), for sodium, potassium, bicarbonate, anion gap, calcium, magnesium, phosphorus, urea, creatinine, glucose, total bilirubin, γ-glutamyltransferase (GGT), creatine kinase (CK), aspartate aminotransferase (AST), total protein, globulin, albumin, albumin/globulin ratio, and sorbitol dehydrogenase (SDH), and with an Immunlite analyzer ($n=103$; Siemens Medical Solutions Diagnostics, Los Angeles, California, USA) for serum cortisol and progesterone. Serum progesterone was used to determine the pregnancy status of caribou because serum progesterone has been reported to be elevated in pregnant reindeer (*Rangifer tarandus tarandus*; Ropstad et al., 2005). Boreal caribou with a serum progesterone level of >1 ng/ml were considered to be pregnant.

The presence of *Mycobacterium avium* subsp. *paratuberculosis* antibody was assessed using an antigen-absorbed enzyme-linked immunosorbent assay (ELISA; IDEXX, Westbrook, Maine, USA) on serum ($n=76$) according to the manufacturer's recommendations.

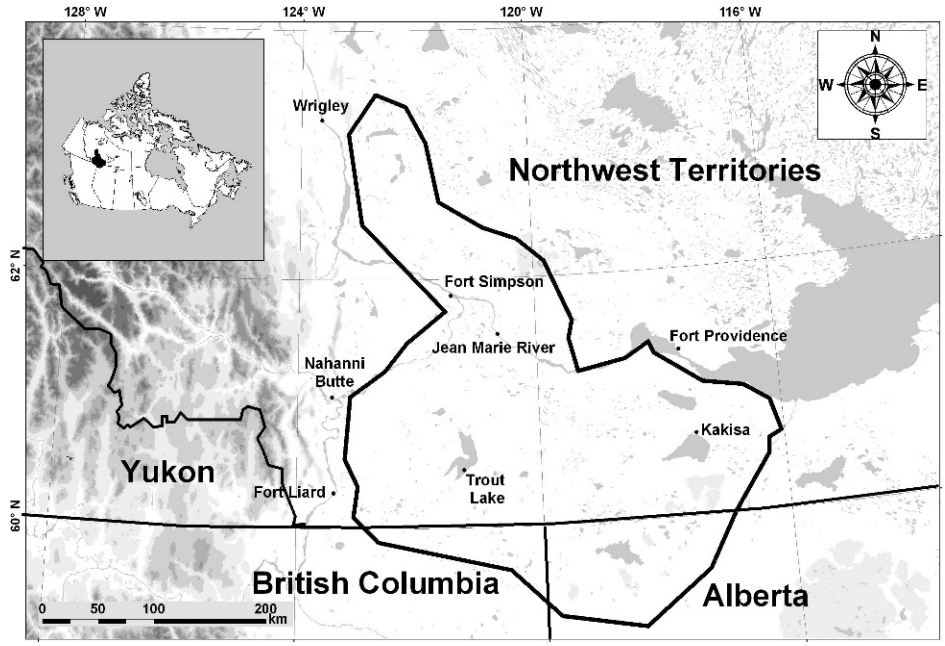


FIGURE 1. Map of the study area in northern Canada where boreal caribou were captured, 2003–2009. Map in the upper left corner is a map of Canada showing the location of the study area.

This test has not been validated for use in caribou. Positive animals had a sample to positive ratio (S/P) of 0.25 or greater. Serum-neutralization was used to assess the occurrence of *Bovine parainfluenza 3* ($n=103$), *Bovine viral diarrhea virus* (BVDV; $n=103$), and *Bovine herpesvirus 1* (BoHV-1; $n=104$) antibodies (field strain, Singer type I strain, and field strain, respectively). These tests are used by the laboratory routinely in cattle but have not been validated for use in caribou. Prevalence of serum antibody to *Toxoplasma gondii* ($n=104$) was determined using an indirect agglutination test (Wampole Laboratories, Princeton, New Jersey, USA) using a cutoff value of 1:64 per manufacturer's instruction. There is no information available on the specificity and sensitivity of this test for the diagnosis of toxoplasmosis in caribou. Sera ($n=43$) were tested for antibodies to *Brucella* sp. (Animal Disease Research Institute, Lethbridge, Alberta, Canada) using buffered-plate antigen, complement fixation, and tube agglutination tests (Stemshorn, 1985; Stemshorn et al., 1985).

### Trypanosome isolation

Blood samples from boreal caribou in 2003 ($n=17$), 2004 ($n=30$), and 2005 ($n=21$) were collected into tubes containing ethylenediaminetetraacetic acid (EDTA). Cultures for trypanosomes were done as described by Lefebre et al. (1997), with the following modifications: The blood was centrifuged at 400 × G for 30 min at 5 C. The buffy coat was collected into a 15-ml tube, and erythrocytes were lysed with the addition of 9 ml of sterile, distilled water. After end-over-end mixing of the tube for 15 sec, 1 ml 10× phosphate-buffered saline (PBS) was added. The supernatant was removed after centrifugation at 400 × G for 10 min. The remaining white blood cells were resuspended in 2 ml of complete RPMI-1640 medium (Sigma Aldrich, St. Louis, Missouri, USA) supplemented with penicillin, streptomycin and L-glutamine, and 10% heat-inactivated fetal bovine serum, containing 5 μg phytohemagglutinin/ml. This suspension was added to 96-well culture plates with 200-μl wells. Eight duplicates per sample were cultured at 37 C in an atmosphere containing 5% $CO_2$. Cultures were checked daily for the presence of parasites under an inverted microscope.

### Fecal sample analysis

Fecal samples were examined at PDS ($n=65$) and Bow Valley Research Inc. (Calgary, Alberta, Canada; $n=84$) for *Giardia* sp. cysts and *Cryptosporidium* sp. oocytes by a sucrose gradient (Olsen et al., 1997). Samples were also analyzed at PDS ($n=57$) using a

TABLE 1. Serum biochemical parameters for free-ranging, adult, female boreal caribou captured in 2003–2006 by net gun in northern Canada.[a]

| Parameter | Range (central 95%) | Mean | Median | SD |
|---|---|---|---|---|
| Sodium (mmol/l)[b] | 93.3–169.9 | 143.36 | 146 | 13.65 |
| Potassium (mmol/l)[b] | 3.00–7.95 | 4.53 | 4.3 | 1.15 |
| Chloride (mmol/l)[b] | 55–106.33 | 90.92 | 94 | 11.9 |
| Bicarbonate (mmol/l)[b] | 3.53–17.43 | 8.66 | 8 | 3.55 |
| Calcium (mmol/l)[b] | 1.64–3.15 | 2.59 | 2.64 | 0.29 |
| Phosphorus (mmol/l) | 0.73–2.53 | 1.72 | 1.73 | 0.42 |
| Magnesium (mmol/l)[b] | 0.62–1.40 | 1.09 | 1.11 | 0.14 |
| Urea (mmol/l)[b] | 1.05–4.34 | 1.98 | 1.8 | 0.81 |
| Creatinine (μmol/l) | 122.68–294.13 | 211.79 | 211.5 | 39.97 |
| Glucose (mmol/l) | 4.06–12.95 | 8.27 | 8.1 | 2.43 |
| Total bilirubin (μmol/l) | 0.53–5 | 2.51 | 3 | 0.96 |
| GGT (U/l)[b] | 6.53–84.9 | 24.39 | 20 | 17.07 |
| CK (U/l)[b] | 95.73–1613.8 | 439.41 | 286 | 914.75 |
| AST (U/l)[b] | 42.05–162.65 | 81.6 | 77 | 25.69 |
| Total protein (g/l)[b] | 45.05–86.33 | 70.73 | 71 | 8.76 |
| Albumin (g/l)[b] | 27.58–46 | 38.56 | 39 | 3.97 |
| Globulin (g/l) | 17.05–44.95 | 32.17 | 32 | 6.39 |
| Albumin/globulin ratio[b] | 0.881–1.77 | 1.24 | 1.21 | 0.28 |
| SDH (U/l)[b] | 4.16–11.38 | 4.13 | 4 | 3.08 |
| Cortisol (mmol/l)[b] | 64.2–362.6 | 169.93 | 161 | 65.04 |

[a] GGT = γ-glutamyltransferase; CK = creatine kinase; AST = aspartate aminotransferase; SDH = sorbitol dehydrogenase.

[b] Not normally distributed.

Wisconsin double centrifugal-floatation procedure with saturated sucrose as the floatation medium (Cox and Todd, 1962) for nematode and cestode ova and *Eimeria* sp. oocysts. Helminth eggs were phenotypically identified as trichostrongyle-type ova or *Moniezia* sp. ova. Fecal samples ($n=84$) were analyzed at Bow Valley Research for nematode and cestode ova using a double centrifugal-floatation technique (Cox and Todd, 1962). Protostrongylid larvae and dorsal-spined larvae were detected using the Baermann technique (Forrester and Lankester, 1997) at PDS ($n=57$) and the centrifugal-floatation procedure at Bow Valley Research ($n=84$).

### Statistical analysis

Statistical analysis was undertaken using Statistix 8 (Analytical Software, Tallahassee, Florida, USA). A Kruskal-Wallis test was used to compare serum biochemistry values among years, and a significant result was followed by an all-pairwise comparison on the mean ranks. Data were analyzed for normality using the Shapiro-Wilks test, and biochemistry values are presented as the central 95% fraction (Solberg, 1987), mean, median, and standard deviation, determined with Stata Version 10 (StataCorp, College Station, Texas, USA). SPSS Statistics 16.0 (SPSS Inc., Chicago, Illinois, USA) was used to compare serologic test results and fecal parasite loads among years. These data were analyzed with a Fisher's exact test or a $\chi^2$ test. Statistical significance was set at if $P \leq 0.05$.

## RESULTS

All sampled caribou appeared healthy when examined in the field. Serum biochemistry analytes are presented in Tables 1 and 2. The mean±SD serum progesterone in caribou determined to be pregnant ($n=93$) was 6.18±2.44 ng/ml, compared with 0.4±0.3 ng/ml in caribou determined not to be pregnant ($n=10$). Creatinine was higher in pregnant than in nonpregnant animals ($P=0.022$), but there were no other differences between analytes from pregnant and nonpregnant caribou. Preliminary statistical analysis detected several interyear differences in biochemical parameters; therefore, interyear variation was examined (Table 2). Cortisol was significantly higher in 2003

TABLE 2. Serum biochemical parameters for free-ranging, adult, female boreal caribou captured by net gun during March to April 2003, March to April 2004, March 2005, and January to February 2006, in northern Canada.[a,b]

| | Capture date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | March–April 2003 ($n$=15) | | March–April 2004 ($n$=28) | | March 2005 ($n$=29) | | January–February 2006 ($n$=28) | |
| Parameter | Mean±SD | Median | Mean±SD | Median | Mean±SD | Median | Mean±SD | Median |
| Sodium (mmol/l)[c] | 145.47±2.9 B | 145.0 | 148.36±2.48 A | 148.0 | 137.14±18.27 B | 145.0 | 143.68±16.0 B | 144.0 |
| Potassium (mmol/l)[c] | 5.39±1.96 A | 4.7 | 4.23±0.93 B | 4.0 | 4.18±0.72 AB | 4.2 | 4.72±0.88 A | 4.5 |
| Chloride (mmol/l)[c] | 93.73±2.4 | 94.0 | 93.75±1.97 | 94.0 | 86.59±18.74 | 95.0 | 91.07±10.78 | 62.5 |
| Bicarbonate (mmol/l)[c] | 7.13±2.9 | 6.0 | 7.32±2.61 | 7.0 | 9.97±4.47 | 8.0 | 9.46±2.96 | 10.0 |
| Calcium (mmol/l)[c] | 2.70±0.21 | 2.7 | 2.60±0.21 | 2.6 | 2.52±0.34 | 2.7 | 2.59±0.33 | 2.6 |
| Phosphorus (mmol/l) | 1.53±0.33 | 1.6 | 1.85±0.34 | 1.9 | 1.69±0.52 | 1.8 | 1.74±0.41 | 1.7 |
| Magnesium (mmol/l)[c] | 1.08±0.11 | 1.0 | 1.11±0.09 | 1.1 | 1.03±0.18 | 1.1 | 1.13±0.15 | 1.2 |
| Urea (mmol/l)[c] | 2.91±0.76 A | 2.9 | 1.92±0.96 B | 1.8 | 1.67±0.55 B | 1.6 | 1.84±0.51 B | 1.7 |
| Creatinine (μmol/l) | 223.27±28.5 A | 225.0 | 236.61±39.42 A | 234.5 | 207.79±34.83 AB | 215.0 | 184.96±33.91 B | 189.0 |
| Glucose (mmol/l) | 8.39±1.79 AB | 9.0 | 7.51±2.28 B | 7.4 | 7.51±2.15 B | 7.2 | 9.76±2.53 A | 10.1 |
| Total bilirubin (μmol/l) | 2.2±1.15 AB | 2.0 | 3.04±0.88 A | 3.0 | 2.03±0.82 B | 2.0 | 2.64±0.78 AB | 3.0 |
| GGT (U/l)[c] | 22.07±7.69 | 22.0 | 27.21±24.09 | 20.5 | 19.31±5.86 | 19.0 | 28.07±19.21 | 19.5 |
| CK(U/l)[c] | 369.6±194.48 AB | 333.0 | 828.82±1672.52 A | 398.5 | 264.38±126.48 B | 246.0 | 268.68±107.29 B | 238.5 |
| AST (U/l)[c] | 95.27±26.06 | 85.0 | 79.11±26.44 | 72.0 | 75.97±21.66 | 72.0 | 82.61±27.15 | 77.0 |
| Total protein (g/l)[c] | 69.27±8.28 | 68.0 | 73.29±4.01 | 73.0 | 68.93±9.99 | 69.0 | 70.82±10.72 | 70.0 |
| Albumin (g/l)[c] | 37.53±2.83 | 38.0 | 39.75±2.12 | 40.0 | 37.14±4.66 | 38.0 | 39.39±4.67 | 40.0 |
| Globulin (g/l) | 31.73±6.45 | 32.0 | 33.54±4.32 | 33.0 | 31.79±6.74 | 31.0 | 31.43±7.72 | 31.0 |
| Albumin/globulin ratio[c] | 1.22±0.23 | 1.2 | 1.21±0.20 | 1.2 | 1.20±0.22 | 1.2 | 1.32±0.4 | 1.3 |
| SDH (U/l)[c] | 3.0±3.04 B | 2.0 | 3.68±4.1 B | 4.0 | 5.62±2.35 A | 5.0 | 3.64±1.95 B | 4.0 |
| Cortisol (mmol/l)[c] | 215.2±31.7 A | 214.0 | 139.25±45.6[d] B | 144.5 | 138.3±44.24 B | 140.0 | 215.07±76.79[e] A | 197.0 |

[a] GGT = γ-glutamyltransferase; CK = creatine kinase; AST = aspartate aminotransferase; SDH = sorbitol dehydrogenase.

[b] Means within a row followed by different capital letters are significantly different from each other ($P \leq 0.05$).

[c] Not normally distributed.

[d] For cortisol, $n$=32.

[e] For cortisol, $n$=27.

TABLE 3. Serology and parasitology test results for free-ranging, adult, female boreal caribou from northern Canada.[a]

| Disease agent | Method | No. positive/ No. examined | % |
|---|---|---|---|
| *Mycoplasma avium* subsp. *paratuberculosis* | Antigen-absorbed ELISA[b] | 1/76 | 1 |
| Bovine herpesvirus 1 (BHV-1) | Serum-neutralizing test[b] | 39/104 | 37.5 |
| Bovine viral diarrhea virus (BVD) | Serum-neutralizing test[b] | 0/103 | 0.0 |
| Bovine parainfluenza virus 3 (PI3) | Serum-neutralizing test[b] | 0/103 | 0.0 |
| *Toxoplasma gondii* | Indirect agglutination test[b] | 3/104 | 2.9 |
| *Brucella* sp. | Buffered-plate antigen test[b] | 0/43 | 0.0 |
| *Brucella* sp. | Standard tube agglutination test[b] | 0/43 | 0.0 |
| *Brucella* sp. | Complement fixation[b] | 0/43 | 0.0 |
| Trichostrongyle-type ova | Centrifugal-floatation[c] | 87/141 | 61.7 |
| *Eimeria* sp. oocysts | Centrifugal-floatation[c] | 7/141 | 5.0 |
| *Moniezia* sp. ova | Centrifugal-floatation[c] | 5/141 | 3.5 |
| Dorsal-spined larvae | Centrifugal-floatation[c] | 8/141 | 5.7 |
| *Protostrongylid* sp. larvae | Centrifugal-floatation[c] | 0/57 | 0 |
| *Giardia* sp. cysts | Sucrose gradient[c] | 3/149 | 2.0 |
| *Cryptosporidium* sp. oocysts | Sucrose gradient[c] | 2/149 | 1.3 |
| *Mycoplasma avium* subsp. *paratuberculosis* | Culture[c] | 0/83 | 0 |
| *Trypanosoma* sp. | Culture[d] | 49/68 | 72 |

[a] ELISA = enzyme-linked immunosorbent assay.

[b] Sample was serum.

[c] Sample was feces.

[d] Sample was buffy coat.

and 2006 than in 2004 and 2005 ($P<0.0001$). Sodium was significantly higher in 2004 compared with all other years ($P=0.0001$), and potassium was higher in 2003 and 2006 than in 2004 ($P=0.003$). Urea was significantly higher in 2003 than in all other years ($P<0.0001$), and creatinine was higher in both 2003 and 2004 than in 2006 ($P<0.0001$). Caribou in 2006 had higher serum glucose than in 2004 and 2005 ($P=0.002$). Creatine kinase was higher in 2004 than 2005 and 2006 ($P=0.007$), total bilirubin was higher in 2004 compared with 2005 ($P=0.0004$), and SDH was significantly higher in 2005 compared with all other years ($P=0.0001$).

No boreal caribou had antibodies to BVDV or to *Bovine parainfluenza virus 3* (Table 3). All sera tested for antibodies to *Brucella* sp. using complement fixation, buffered-plate antigen, and standard tube agglutination tests were also negative. Antibodies to *Mycobacterium avium* subsp. *paratuberculosis* was found in 1% (1/76) of the animals. Exposure to *Toxoplasma gondii* was demonstrated in 2.9% (3/104) of the caribou. Animals found positive had titers between 1:256 and 1:512. Fourteen sera with equivocal results on the indirect agglutination test were considered negative. Antibodies to BHV-1 were detected in 37.5% (39/104) of boreal caribou with titers ranging from 1:6 to 1:152. There was no significant difference in antibody prevalence among years.

*Mycobacterium avium* subsp. *paratuberculosis* was not isolated on fecal culture ($n=83$), including the single animal that was antibody-positive (Table 3). *Eimeria* spp. oocysts were detected in 7/141 (5.0%) fecal samples. Trichostrongyle-type ova were detected in 87/141 (61.7%), dorsal-spined larvae were found in 8/141 (5.7%), and cestode ova were detected in 5/141

(3.5%) fecal samples. *Giardia* sp. cysts were found in 3/149 (2.0%) and *Cryptococcus* sp. oocysts were detected in 2/149 (1.3%) fecal samples. Protostrongylid larvae were not detected. There was no difference among years in the proportion of fecal samples with *Moniezia* sp. ova ($P>0.05$). A greater proportion of samples collected in 2003 had dorsal-spined larvae in fecal samples than in all other years, except 2006. The proportion of samples with trichostrongyle-type ova was significantly higher in 2004 than in all other years, and a greater proportion of samples were positive for trichostrongyle-type ova in 2005 and 2006 than in 2008 and 2009.

*Trypanosoma* sp., morphologically resembling organisms of the subgenus *Megatrypanum* (Lefebvre et al., 1997), were detected in 49/68 (72%) of the caribou blood samples. There was no significant difference between the prevalence of *Trypanosoma* sp. in samples collected in 2003 and 2004 or 2005, but a higher prevalence was found in 2005 compared with 2004.

## DISCUSSION

We report the first serum biochemistry values for boreal caribou in northern Canada. Several studies have evaluated changes in hematologic and biochemical serum values caused by nutrition, season, age, and pregnancy status in reindeer (Nieminen, 1980; Soveri et al., 1992) and in barren-ground caribou (McEwan, 1968), but no similar studies, to our knowledge, have been carried out for boreal caribou.

### Serum biochemistry

Serum creatinine levels in boreal caribou in our study area were comparable to those reported in reindeer (Nieminen, 1980). Creatinine levels were higher in pregnant caribou compared with nonpregnant animals. Nieminen (1980) reported no difference between creatinine measured during and after pregnancy in reindeer; however, elevated serum creatinine has been reported in pregnant cattle during the third to seventh month of pregnancy, which may be associated with muscular damage in the dam (Tainturier et al., 1984). Serum creatinine concentrations were lowest in boreal caribou captured in 2006. Because creatinine levels can change seasonally in wild ruminants (Sakkinen et al., 2001), these levels may reflect the late winter capture of these boreal caribou as opposed to capture in early spring. Serum calcium, magnesium, and phosphorus values of boreal caribou are comparable to values for adult, female reindeer (Nieminen, 1980). Serum albumin concentration reported here are comparable to those reported for adult reindeer and calves (Nieminen, 1980; Soveri et al., 1992).

Blood urea nitrogen concentration was greater in boreal caribou in 2003. Urea concentration in serum can be used, in conjunction with other clinical pathology data, as an indicator of renal function, and it also fluctuates with nutritional status and diet (Lopez-Olvera et al., 2006). The mean urea concentration presented here is much lower than that reported for adult female reindeer (Nieminen, 1980) but is comparable to that of reindeer calves in late winter and early spring (Soveri et al., 1992) and wild red deer (*Cervus elaphus*; Marco and Lavin, 1999).

Cellular damage to skeletal, cardiac, or smooth muscle myocytes increases serum CK activity (Stockham and Scott, 2002). The differences detected in serum CK among years may be due, in part, to enzymatic induction because of capture and handling. Therefore, reporting an accurate reference interval for free-ranging boreal caribou is difficult. The reference interval reported here for the combined data is extremely wide, and the standard deviation is large, consistent with other studies evaluating serum chemistry values in captured wild ungulates (Marco and Lavin, 1999).

In this study, all boreal caribou were

captured using the net-gun method, so variation in biochemical values because of the use of different capture methods was avoided. The method of capture, however, may be reflected in changes in certain serum biochemical parameters of wildlife and should be taken into consideration when evaluating or comparing serum chemistry from different groups or among studies. Differences in serum parameters from wild ungulates captured by physical or chemical means have been reported in several species of wild ungulates, including red deer (Marco and Lavin, 1999) and white-tailed deer (*Odocoileus virginianus*; Wesson et al., 1979). Marco and Lavin (1999) reported significant elevations in serum ALT, total protein, albumin, sodium, and chloride in red deer captured by physical means compared with those from deer that were chemically immobilized. Physically restrained, "untrained" chital deer (*Axis axis*) had elevated serum AST and CK levels, which were attributed to muscle damage sustained by "excited" deer that were not used to handling (Chapple et al., 1991). Physical handling and restraint of wild animals elevates serum cortisol levels (Sakkinen et al., 2004), and serum cortisol levels depend on the method of capture, previous experience of the animals, age, and sex (Morton et al., 1995). Serum glucose values reported here are higher than those reported for reindeer calves and adults and for pregnant domestic cattle and are comparable with those of wild, physically captured red deer (Nieminen, 1980; Tainturier et al., 1984; Soveri et al., 1992; Marco and Lavin, 1999). The elevated values may be due to the hyperglycemic effects of catecholamines and glucocorticoids released during capture (Spraker, 1993). Higher glucose levels in caribou compared with other ruminants may also be a characteristic that facilitates survival in harsh winter conditions (Nieminen, 1980).

Although a comparison of the effects of capture method on serum biochemical parameters was not a goal of this study, parameters that may be affected by the methods of physical capture are highlighted here. These values should be treated as specific to physically captured boreal caribou because it is essential to take into account the method of capture when evaluating or comparing these parameters with caribou captured or restrained using other methods.

### Serology

The prevalence of antibodies to BHV-1 in caribou from the Northwest Territories (37.5%) is similar to that of boreal caribou in Alberta (52%; Tessaro et al., 2005) and Saskatchewan (55%; Jordon et al., 2003), Canada. Boreal caribou in the Northwest Territories are exposed to either BHV-1 or another virus antigenically similar to BHV-1. Antibodies to BHV-1 also have been reported in woodland caribou (*Rangifer tarandus caribou*) in Quebec, Canada (Elazhary et al., 1981), and Alaska, USA (Dieterich, 1981). The identity of the herpesvirus(es) responsible for production of antibodies in these populations of caribou remains unknown. Tessaro et al. (2005) isolated an alphaherpesvirus from elk (*Cervus elaphus*), but determined that the herpesvirus infection in boreal caribou in Alberta, Canada, was unlikely to be either BHV-1 or elk herpesvirus and hypothesized that there may be a caribou-specific alphaherpesvirus in the Canadian woodland caribou population.

Infection with *Mycobacterium avium* subsp. *paratuberculosis* has been reported in many wild ruminants including elk and bison (*Bison bison*; Crawford et al., 2006; Sibley et al., 2007). *Mycobacterium avium* subsp. *paratuberculosis* was not cultured from any boreal caribou fecal samples, and only a few acid-fast rods were seen on one fecal smear. Acid-fast staining of fecal samples has low sensitivity and specificity, and the sensitivity of fecal culture varies because the rate and quantity of shedding may change over time (Manning, 2001). Given the accuracy of the tests currently

available, the ability to detect exposure to or infection with the organism in boreal caribou is lacking. However, potential exposure to *M. avium* subsp. *paratuberculosis* and the possible effects of infection on the health of boreal caribou should be investigated further.

#### Parasitology

Clinical disease associated with *Toxoplasma gondii* has not been reported in free-ranging caribou (Kutz et al., 2001); however, experimental infection of reindeer caused acute, severe, and fatal hemorrhagic enteritis (Oksanen et al., 1996), and fatal transplacental toxoplasmosis has been reported in a naturally infected reindeer (Dubey et al., 2002). *Toxoplasma gondii* poses a potential public health risk for humans handling or consuming raw meat from infected animals, and further study of definitive hosts for this parasite in northern ecosystems, as well as the host range, distribution, and intensity of infection in boreal caribou, is needed.

*Eimeria* sp. has not been reported in boreal caribou in the Northwest Territories, Canada, although several species of *Eimeria* have been detected in wild Icelandic reindeer (Gudmundsdottir and Skirnisson, 2006). We detected *Eimeria* sp. oocysts in fecal samples from boreal caribou in this study, but because we did not characterize the oocysts further, we do not known if the *Eimeria* spp. are one or more of the already identified species. *Cryptosporidium* sp. infection has been reported in a number of wild cervids, including moose (*Alces alces*), red deer and elk, roe deer (*Capreolus capreolus*), white-tailed deer (Hamnes et al., 2006), and caribou (*Rangifer tarandus granti*) from Alaska, USA (Siefker et al., 2002). We found *Cryptosporidium* sp. oocysts in boreal caribou, indicating caribou are exposed to *Cryptosporidium* sp. in the southern portion of their range in the Northwest Territories, Canada. *Giardia* sp. cysts were recovered from boreal caribou in this study, and this is the first report of *Giardia* in boreal caribou. Molecular studies were not performed on the *Giardia* sp. or *Cryptosporidium* sp. isolates, and further genotyping of isolates from boreal caribou would be useful.

Trichostrongylidae, including *Nematodirus* sp., *Ostertagia* sp., and *Teladorsagia* sp., have been recognized in *Rangifer* sp., and although the intensity of some infections is suspected to be sufficient to adversely influence host productivity, this has yet to be substantiated (Hoberg et al., 2001). The presence of trichostrongyle-type ova in boreal caribou fecal samples indicates that *Ostertagia gruehneri*, *Teladorsagia boreoarcticus*, or both, are present in boreal caribou in the Northwest Territories, Canada. Both parasites are known to occur in populations of barren-ground caribou (Hoberg et al., 2001), but this is the first report of these parasites in boreal caribou.

Protostrongylid nematodes cause recognized disease syndromes in ungulates and have been implicated in the declines in wildlife populations (Kutz et al., 2007). In North America, five genera of protostrongylids parasitize artiodactyls: *Elaphostrongylus*, *Parelaphostrongylus*, *Muellerius*, *Umingmakstrongylus*, and *Varestrongylus* (Jenkins et al., 2005; Kutz, et al., 2007), and all produce characteristic dorsal-spined larvae. Larvae of *Parelaphostrongylus odocoilei*, a muscle worm, have been identified in this population of boreal caribou (Jenkins et al., 2005). In addition, *P. odocoilei* has been isolated from boreal caribou in several locations in Alberta, and *P. andersoni* has been found in barren-ground caribou in the Northwest Territories and in caribou in Labrador, suggesting that these parasites are widespread in woodland caribou of central and north-central Canada (Gray and Samuel, 1986; Lankester and Hauta, 1989; Jenkins et al., 2005; Kutz et al., 2007). Although *P. odocoilei* is most likely responsible for the protostrongylid larvae seen in these caribou, concurrent or mixed infection

cannot be ruled out without further molecular diagnostics.

The cestode ova found in the boreal caribou in this study were identified as *Moniezia* sp. Anoplocephalid tapeworms appear to have little effect on the health of infected animals (Elliott, 1986); however, heavy infections may cause unthriftiness and mild digestive disturbances (Radostits et al., 2000). *Moniezia* sp. has been reported previously in *Rangifer* spp. in Canada and Europe (Fruetel and Lankaster, 1989).

Similar to boreal caribou in Alberta, Canada (Lefebvre et al., 1997), we found a high prevalence of trypanosomes in boreal caribou from the Northwest Territories, Canada. *Trypanosom*a sp. belonging to the subgenus *Megatrypanum* have been described in wild cervid species, including reindeer (Kingston et al., 1982) and woodland caribou (Lefebvre et al., 1997). *Trypanosoma* sp. identified in cervids appears to be distinct from the megatrypanosome of bovids (*Trypanosoma theileri*) and has been designated *Trypanosoma cervi* (Kingston and Morton, 1975; Kingston et al., 1982; Lefebvre et al., 1997). To date, no evidence of pathogenicity caused by infection with *Megatrypanum* has been noted in any cervid species (Kingston et al., 1982; Lefebvre et al., 1997).

We report the first serum biochemistry values, to our knowledge, for boreal caribou, as well as baseline disease data for boreal caribou in the Northwest Territories, Canada. Serum biochemistry values are an important measure of health in animals and may be altered depending on factors such as nutritional status, disease, life history, stress, and capture. Wildlife health parameters—such as serum biochemistry parameters—are valuable when evaluating the potential impact of existing or emerging diseases on populations or individuals. Similarly, baseline data on exposure to, or infection with, potentially pathogenic or zoonotic organisms are essential when assessing the health of a wildlife population. The presence of several previously unreported parasites in these caribou, as well as evidence of exposure to an unknown herpesvirus and to *Toxoplasma gondii*, emphasizes the need for further health and disease monitoring in boreal caribou.

## ACKNOWLEDGMENTS

We thank J. Campbell, B. Wagner, E. Jenkins, and G. Wobeser at the University of Saskatchewan for their helpful comments during the preparation of this manuscript. We acknowledge the support of the Ka'a'gee Tu First Nation (Kakisa, Northwest Territories, Canada), the Sambaa K'e Dene Band (Trout Lake, Northwest Territories, Canada), the Fort Simpson Métis and the Liidlii Kue First Nation (Fort Simpson, Northwest Territories, Canada), the Katlodeeche First Nation and the West Point First Nation (Hay River, Northwest Territories, Canada), the Jean Marie River First Nation and the Pehdzeh Ki First Nation (Wrigley, Northwest Territories, Canada), and the Nahanni Butte Dene Band and the Acho Dene Koe Band (Fort Liard, Northwest Territories, Canada). We also thank the Sambaa K'e Dene Band and the Diversified Environmental Services and Helicopter Wildlife Management for assistance with sample collection. Funding for this project was provided by the Government of the Northwest Territories and by the Cumulative Impact Monitoring Program (Department of Indian Affairs and Northern Development).

## LITERATURE CITED

Chapple, R. S., A. W. English, R. C. Mully, and E. E. Lepherd. 1991. Haematology and serum biochemistry of captive unsedated chital deer (*Axis axis*) in Australia. Journal of Wildlife Diseases 27: 396–406.

Committee on the Status of Endangered Wildlife in Canada. 2002. COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario, 98 pp.

Cox, D. D., and A. C. Todd. 1962. Survey of gastrointestinal parasitism in Wisconsin dairy cattle. Journal of the American Veterinary Medical Association 15: 706–709.

Crawford, G. C., M. H. Ziccardi, B. J. Gonzaales, L. M. Woods, J. K. Fischer, E. J. Manning, and J. A. Mazet. 2006. *Mycobacterium avium* subspecies *paratuberculosis* and *Mycobacterium avium* subsp. *avium* infections in a tule elk

(*Cervus elaphus nannodes*) herd. Journal of Wildlife Diseases 42: 715–723.

DIETERICH, R. 1981. Respiratory viruses. *In* Alaskan wildlife diseases. R. A. Dieterich (ed.). University of Alaska Press, Fairbanks, Alaska. pp. 28–29.

DUBEY, J. P., B. LEWIS, K. BEAM, AND B. ABBITT. 2002. Transplacental toxoplasmosis in a reindeer (*Rangifer tarandus*) fetus. Veterinary Parasitology 110: 131–135.

ELAZHARY, M. A. S. Y., J. L. FRECHETTE, A. SILIM, AND R. S. ROY. 1981. Serological evidence of some bovine viruses in the caribou (*Rangifer tarandus caribou*) in Quebec. Journal of Wildlife Diseases 17: 609–612.

ELLIOT, D. C. 1986. Tapeworm (*Moniezia expansa*) and its effect on sheep production: The evidence reviewed. New Zealand Veterinary Journal 34: 61–65.

FORRESTER, S. G., AND M. W. LANCESTER. 1997. Extracting protostrongylid nematode larvae from ungulate feces. Journal of Wildlife Diseases 33: 511–516.

FRUETEL, M., AND M. W. LANKESTER. 1989. Gastrointestinal helminths of woodland and barren ground caribou (*Rangifer tarandus*) in Canada, with key to species. Canadian Journal of Zoology 67: 2253–2269.

GRAY, J. B., AND W. M. SAMUEL. 1986. *Parelaphostrongylus odocoilei* (Nematoda: Protostrongylidae) and a protostrongylid nematode in woodland caribou (*Rangifer tarandus caribou*) of Alberta, Canada. Journal of Wildlife Diseases 22: 48–50.

GUDMUNDSDOTTIR, B., AND K. SKIRNISSON. 2006. The third newly discovered *Eimeria* species (Protozoa: Eimeriidae) described from wild reindeer, *Rangifer tarandus*, in Iceland. Parasitological Research 99: 659–662.

HAMNES, I. S., B. GJERDE, L. ROBERTSON, T. VIKOREN, AND K. HANDELAND. 2006. Prevalence of *Cryptosporidium* and *Giardia* in free-ranging wild cervids in Norway. Veterinary Parasitology 141: 30–41.

HANKS, J. 1981. Characterization of population condition. *In* C. W. Fowler and T. D. Smith (eds.). Dynamics of large mammal populations. John Wiley and Sons, New York, New York. pp. 47–73.

HOBERG, E. P., A. A. KOCAN, AND L. G. RICKARD. 2001. Gastrointestinal strongyles in wild ruminants. *In* Parasitic Diseases of Wild Mammals. 2nd Edition, W. M. Samuel, M. J. Pybus, and A. A. Kocan (eds.). Iowa State University Press, Ames, Iowa. pp. 228–278.

JENKINS, E. J., G. D. APPLEYARD, E. P. HOBERG, B. M. ROSENTHAL, S. J. KUTZ, A. M. VEITCH, H. M. SCHWANTJE, B. T. ELKIN, AND L. POLLEY. 2005. Geographic distribution of the muscle-dwelling nematode *Parelaphostrongylus odocoilei* in North America, using molecular identification of first-stage larvae. Journal of Parasitology 91: 574–584.

JORDON, L. T., W. J. RETTIE, AND S. V. TESSARO. 2005. Evidence of herpesvirus in woodland caribou in Saskatchewan. Journal of Wildlife Diseases 39: 216–220.

KINGSTON, N., AND J. K. MORTON. 1975. *Trypanosoma cervi* sp. n. from elk (*Cervus canadensis*) in Wyoming. Journal of Parasitology 61: 17–23.

———, ———, AND R. DIETERICH. 1982. *Trypanosoma cervi* from Alaskan reindeer, *Rangifer tarandus*. Journal of Protozoology 29: 588–591.

KUTZ, S. J., B. T. ELKIN, AND J. P. DUBEY. 2001. Prevalence of *Toxoplasma gondii* antibodies in barren-ground caribou (*Rangifer tarandus groenlandicus*) from the Canadian arctic. Journal of Parasitology 87: 439–442.

———, I. ASMUNDSSON, E. P. HOBERG, G. D. APPLEYARD, E. J. JENKINS, K. BECKMEN, M. BRANIGAN, L. BUTLER, N. B. CHILTON, D. COOLEY, B. ELKIN, F. HUBY-CHILTON, D. JOHNSON, A. KUCHBOEV, J. NAGY, M. OAKLEY, L. POLLEY, R. POPKO, A. SCHEER, M. SIMARD, AND A. VEITCH. 2007. Serendipitous discovery of a novel protostrongylid (Nematoda: Metastrongyloidea) in caribou, muskoxen, and moose from high latitudes of North America based on DNA sequence comparison. Canadian Journal of Zoology 85: 1143–1156.

LAGRUE, C., N. KALDONSKI, M. J. PERROT-MINNOT, S. MOTREUIL, AND L. BOLLACHE. 2007. Modification of hosts' behavior by a parasite: Field evidence for adaptive manipulation. Ecology 88: 2839–2847.

LANKESTER, M. W., AND P. L. HAUTA. 1989. *Parelaphostrongylus andersoni* (Nematoda: Protostrongylidae) in caribou (*Rangifer tarandus*) of northern and central Canada. Canadian Journal of Zoology 67: 1966–1975.

LEFEBVRE, M. F., S. S. SEMALULU, A. E. OATWAY, AND J. W. NOLAN. 1997. Trypanosomiasis in woodland caribou of northern Alberta. Journal of Wildlife Diseases 33: 271–277.

LOPEZ-OLVERA, J. R., I. MARCO, J. MONTANE, AND S. LAVIN. 2006. Haematological and serum biochemical values of southern chamois (*Rupicapra pyrenaica*). Veterinary Record 158: 479–484.

MANNING, E. J. B. 2001. *Mycobacterium avium* subspecies *paratuberculosis*: A review of the current knowledge. Journal of Zoo and Wildlife Medicine 32: 293–304.

MARCO, I., AND S. LAVIN. 1999. Effect of the method of capture on the haematology and blood chemistry of red deer (*Cervus elaphus*). Research in Veterinary Science 66: 81–84.

MCEWAN, E. H. 1968. Haematological studies of barren-ground caribou. Canadian Journal of Zoology 46: 1031–1036.

MILLER, M. W., H. M. SWANSON, L. L. WOLF, F. G.

QUARTARONE, S. L. HUWER, C. H. SOUTHWICK, AND P. M. LUKACS. 2008. Lions and prions and deer demise. PLoS One 3: 1–7.

MORTON, D. J., E. ANDERSON, C. M. FOGGIN, M. D. KOCK, AND E. P. TIRAN. 1995. Plasma cortisol as an indicator of stress due to capture and translocation in wildlife species. Veterinary Record 136: 60–63.

NIEMINEN, M. 1980. Nutritional and seasonal effects on the haematology and blood chemistry in reindeer (*Rangifer tarandus tarandus* L.). Comparative Biochemistry and Physiology 66: 399–413.

OKSANEN, A., K. GUSTAFSSON, A. LUNDEN, J. P. DUBEY, P. THULLIEZ, AND A. UGGLA. 1996. Experimental *Toxoplasma gondii* infection leading to fatal enteritis in reindeer (*Rangifer tarandus*). The Journal of Parasitology 82: 843–845.

OLSEN, M. E., C. L. THORLAKSON, L. DESELLIERS, D. W. MORCK, AND T. A. MCALLISTER. 1997. *Giardia* and *Cryptosporidium* in Canadian farm animals. Veterinary Parasitology 68: 375–381.

RADOSTITS, O. M., C. GAY, D. C. BLOOD, AND K. W. HINCHCLIFF. 2000. Diseases caused by helminth parasites: Nematode diseases of the alimentary tract. *In* Veterinary medicine: A textbook of the diseases of cattle, sheep, pigs, goats and horses. 9th Edition. W.B. Saunders Company Ltd., Philadelphia, Pennsylvania. pp. 1339–1386.

ROPSTAD, E., V. VEIBERG, H. SAKKINEN, E. DAHL, H. KINDAHL, O. HOLAND, J. F. BECKERS, AND E. ELORANTA. 2005. Endocrinology of pregnancy and early pregnancy detection by reproductive hormones in reindeer (*Rangifer tarandus tarandus*). Theriogenology 63: 1775–1788.

SAKKINEN, H., A. STEIN, O. HOLAND, K. HOVE, E. ELORANTA, S. SAARELA, AND E. ROPSTAD. 2001. Plasma urea, creatinine, and urea:creatinine ratio in reindeer (*Rangifer tarandus tarandus*) and in Svalbard reindeer (*Rangifer tarandus platyrhynchus*) during defined feeding conditions and in the field. Physiology and Biochemical Zoology 74: 907–916.

———, J. TORNBERG, P. J. GODDARD, E. ELORANTA, E. ROPSTAD, AND S. SAARELA. 2004. The effect of blood sampling method on indicators of physiological stress in reindeer (*Rangifer tarandus tarandus*). Domestic Animal Endocrinology 26: 87–98.

SIBLEY, J. A., M. R. WOODBURY, G. D. APPLEYARD, AND B. T. ELKIN. 2007. *Mycobacterium avium* subspecies *paratuberculosis* in bison (*Bison bison*) from northern Canada. Journal of Wildlife Diseases 43: 775–779.

SIEFKER, C., L. G. RICKARD, G. T. PHARR, J. S. SIMMONS, AND T. M. O'HARA. 2002. Molecular characterization of *Cryptosporidium* sp. isolated from northern Alaskan caribou (*Rangifer tarandus*). Journal of Parasitology 88: 213–216.

SOLBERG, H. E. 1987. Approved recommendation (1987) on the theory of reference values, 5: Statistical treatment of collected reference values—Determination of reference limits. Clinica Chimica Acta 170: S13–S32.

SOVERI, T., S. SANKARI, AND M. NIEMINEN. 1992. Blood chemistry of reindeer calves (*Rangifer tarandus tarandus*) during the winter season. Comparative Biochemistry and Physiology 102A: 191–196.

SPRAKER, T. 1993. Stress and capture myopathy in artiodactyls. *In* Zoo and wild animal medicine: Current therapy. 3rd Edition, M. E. Fowler (ed.). W.B. Saunders, Philadelphia, Pennsylvania. pp. 481–488.

STEMSHORN, B. W. 1985. Bovine brucellosis—Diagnosis and eradication. Canadian Veterinary Journal 26: 35–39.

———, L. B. FORBES, M. D. EAGLESOME, K. H. NIELSEN, F. J. ROBERTSON, AND B. S. SAMAGH. 1985. A comparison of standard serological tests for the diagnosis of bovine brucellosis in Canada. Canadian Journal of Comparative Medicine 49: 391–394.

STOCKHAM, S. L., AND M. A. SCOTT. 2002. Proteins. *In* Fundamentals of veterinary clinical pathology. Iowa State University Press, Ames, Iowa. pp. 251–276.

STUART-SMITH, A. K., C. J. A. BRADSHAW, S. BOUTIN, D. M. HERBERT, AND A. B. RIPPIN. 1997. Woodland caribou relative to landscape patterns in northeastern Alberta. Journal of Wildlife Management 61: 622–633.

TAINTURIER, D., J. P. BRAUN, A. G. RICO, AND J. P. THOUVENOT. 1984. Variations in blood composition in dairy cows during pregnancy and after calving. Research in Veterinary Science 37: 129–131.

TESSARO, S. V., D. DEREGT, E. DZUS, C. ROHNER, K. SMITH, AND T. GABOURY. 2005. Herpesvirus infection in woodland caribou in Alberta, Canada. Journal of Wildlife Diseases 41: 803–805.

VORS, L. S., J. A. SCHAEFER, B. A. POND, A. R. ROGERS, AND B. R. PATTERSON. 2007. Woodland caribou extirpation and anthropogenic landscape disturbance in Ontario. Journal of Wildlife Management 71: 1249–1256.

WECLAW, P., AND R. J. HUDSON. 2004. Simulation of conservation and management of woodland caribou. Ecological Modelling 177: 75–94.

WESSON, J. A., P. F. SCALON, R. L. KIRKPATRICK, H. S. MOSBY, AND R. L. BUTCHER. 1979. Influence of chemical immobilization and physical restraint on steroid hormone levels in blood of white-tailed deer. Canadian Journal of Zoology 57: 768–776.

*Submitted for publication 15 September 2009.*
*Accepted 25 April 2010.*