Bathurst Caribou Health and Condition Monitoring 2007-2009

Brett Elkin, Bruno Croft & Jan Adamczewski

Government of the Northwest Territories Environment & Natural Resources

1. Introduction

Health and condition monitoring of the Bathurst caribou herd was conducted over a two year period between September 2007 and April 2009. Assessments were done using standardized protocols developed by the CircumArctic Rangifer Monitoring and Assessment Network (CARMA 2008), which are used to monitor caribou herds across the circumpolar Arctic. These protocols include key health and condition indicators and procedures developed from previous research on caribou and other cervid species (Langvatn 1977, Huot and Picard 1988, Chan-McLeod et al. 1995) and newly developed protocols based on community and hunter based evaluations (Kofinas et al. 2003; Lyver and Gunn 2004). There are 3 levels of CARMA sampling protocols that provide different levels of monitoring depending on information needs required for understanding trends and making management decisions.

For this work on the Bathurst herd, intensive Level 3 protocols were used to establish a comprehensive baseline of information on a wide range of condition, body size and health indices that can be used to assess current status and monitor changes over time. Ongoing monitoring of select key indicators could be done annually to monitor trends using less intensive community-based Level 1 or Level 2 hunter sampling, with more intensive Level 3 sampling at five year intervals or when an issue or concern is identified and/or specific additional information is required.

2. Sample & Data Collection

Health and condition monitoring was done at four time periods between September 2007 and April 2009. Fall and late winter were targeted for sampling given their value in monitoring condition, reproductive and health parameters at key times of the year that provide insight into the potential role of condition on reproduction and survival. Fall sampling focused on both mature males and females, and late winter collections focused primarily on mature females. Samples were collected in conjunction with community hunts or in collaboration with local hunters, and meat provided to local communities.

Samples were collected as follows:

1) Mackay Lake, September 7-13, 2007. Samples and measurements were taken from caribou harvested during a fall hunt by the Yellowknives Dene. A total of 51 caribou were sampled (17 adult cows, 17 adult bulls, 3 yearlings, 14 calves).

2) Beaverlodge Lake, March 11-14, 2008. Samples and measurements were taken from 38 caribou harvested in conjunction with Tlicho hunters (26 adult cows, 2 adult bulls, 1 yearling, 9 calves).

3) Lac de Gras, September 9-11, 2008. Samples and measurement were taken from 31 caribou harvested caribou in conjunction with hunters from the Yellowknives Dene (12 adult cows, 13 adult males, 1 yearling, 5 calves).

4) Strachan Lake, April 4-6, 2009. Samples and measurements were taken from caribou harvested in conjunction with Tlicho hunters from Gameti. A total of 30 caribou were sampled (28 adult cows, 1 adult bull, 1 calf).

3. Animal Information and Body Size

Overall body size and muscle mass can provide insight into growth, nutritional plane and condition of caribou, and influence reproduction and survival (Ringberg et al 1981). Caribou undergo extreme fluctuations in body mass and composition in adapting to their highly seasonal environments (Chan-McLeod et al. 1995). There can be seasonal differences in whole body weight (Bergerud 1978), and differences between age and sex classes (Dauphne 1976; Bergerud 1978). Females generally gain weight during the late summer through early winter, stabilize or decline over winter, and are lowest during early summer because of the energetic cost of the last winter's pregnancy and lactation. Males gain most weight from summer until the beginning of the rut, and mature prime males can lose up to 25% of their weight during the rut (Bergerud 1978). Their weight stabilizes after the rut, and winter conditions can influence subsequent changes in weight.

For the Bathurst caribou, measurements of body size and mass included full body weight, carcass weight, body length, chest girth, and foot length. Indicator bones can be used to assess body size and bone mass, and included measurements of metatarsus length and weight, and jaw measurements (diastema, anterior jaw length, posterior jaw length, total jaw length). Bone density is being assessed to examine the effects of lactation on bone density. Age was determined for each caribou using both a field estimate based on size & appearance, tooth wear, and laboratory tooth cementum analysis.

Body Weights:

Total body weights for both adult cows and bulls were within the reported range for barren-ground caribou, and similar between sampling periods between the two years. Body weights for mature cows and bulls were somewhat higher in September 2008 compared to September 2007, consistent with higher body condition in both males and females for the same time period. This difference in weight may in part reflect a difference in body fat content between years with body condition being lower in fall of 2007.

- September 2007 Adult Cows: Average 86.3 kgs (range 71.2 – 106.1)

  Adult Bulls: Average 119.6 kgs (range 95.3 – 140.6)

  Calves: Average 37.2 kgs (range 33.6 – 45.4)

- March 2008 Adult Cows: Average 85.88 kgs (range 77 – 99)

  Calves: Average 46.7 kgs (range 39-65)

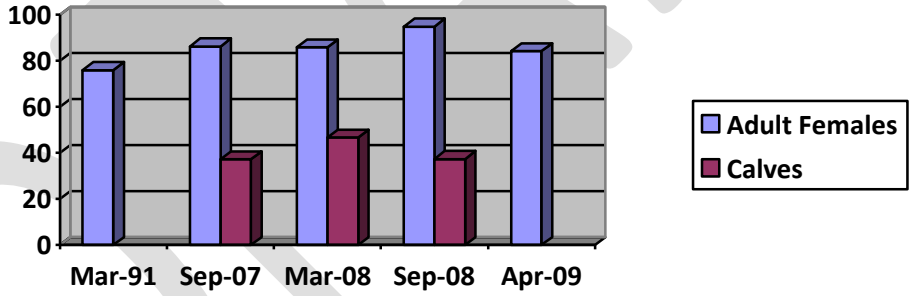
- September 2008 Adult Cows: Average 94.9 kgs (range 77-116)

  Adult Bulls: Average 141.5 kgs (range 95.5 – 159.5)

  Calves: Average 37.3 kgs (range 31.5 – 41.0)

- April 2009 Adult Cows: Average 84.2 kgs (range 67 – 106)

Figure 1: Body Weight (kilograms)
Bathurst Caribou 2007-2009



Protein & Nitrogen Balance:

Levels of protein can vary seasonally, with the summer and early fall (June to September being the primary time for deposition of body protein in breeding females (Chan-McLeod et al. 1999). Individual muscles (such as the gastrocnemius and peroneus) can be weighed to estimate lean body mass (total body mass minus fat) (Ringberg *et al*. 1981; Adamczewski *et al*. 1987; Chan-McLeod *et al.* 1995) which gives an estimate of an animal's protein status and reserves. These indicator muscles can be used as an index of the levels and seasonal changes in total muscle mass and body protein, and the weight of the peroneus muscle was taken for all caribou as part of this work.

A new technique is also being evaluated in caribou to look at trends in protein or nitrogen (N) balance of an individual animal or of a group of animals using samples of feces and urine on snow. The technique looks at stable isotope ratios of 15N/14N in blood or

fecal/urine samples, and can assess the likelihood that an animal is in positive or negative nitrogen balance at the time of sampling (Barboza and Parker 2006). Nitrogen balance can compared with protein reserves and used to track the source of N (diet *vs*. body protein mobilization) used by the cow for fetal growth and development (Parker *et al*. 2005). Maternal protein reserves entering winter and the availability of dietary protein for cows during the winter are thought to strongly affect fetal development and birth weight in caribou (Allaye-Chan 1991; Gerhart *et al*.1996; Parker *et al*. 2005). Paired animal and snow urine/fecal samples collected from this Bathurst caribou work are being assessed to evaluate the potential use of this non-invasive sampling technique (work in progress).

4. Body Condition

Overall energy reserves play an important role in the survival and productivity of caribou, and the level of fat reserves in the fall relates to the probability of conception in adult females (Koffinas et al. 2002, 2003; Adamczewski et al. 1987; Lyver and Gunn 2004). Body fat reserves are an effective measure of caribou condition, and can be used to compare a herd between seasons or years to detect differences or trends. Caribou may have large seasonal changes in body condition, and cows can lose >90% of their fat over winter. Maximum fatness in non-breeding females is seen in late fall, while breeding females tend to be fattest in late winter (Chan-McLeod et al. 1995). Different body fat reserves are mobilized preferentially when an animal uses stored energy reserves: back fat stores are used first, followed by kidney fat, with bone marrow fat being the last to be used. At low fat levels, there is little difference in back fat or kidney fat indices, and bone marrow fat is the most sensitive indicator of remaining fat stores (Harder and Kirkpatrick 1994).

Overall fatness/body condition can be assessed by several methods, including depth of back fat, kidney fat weight, percent of fat in the bone marrow, and visual condition scores. All of these measures were used to assess the Bathurst herd in this work.

Back Fat

Back fat levels in bulls were high in both years, indicating they were in good condition going into the rut. In adult females there was some variability between the two years and seasons. Back fat levels in adult females in fall 2008 and April 2009 were good and considered in the range expected for the time of year. Back fat levels for adult cows in fall 2007 were low (consistent with kidney fat index and hunter score results), though March back fat levels later that winter improved and were in the expected range for that time of year.

- September 2007 Cows: Average 3.75 mm (range 0 - 15)

  Bulls: Average 30.41 mm (range 0 - 51)

- March 2008 Cows: Average 12.5 mm (range 1.5 - 26)
- September 2008 Cows: Average 29.83 mm (range 25 - 39)

  Bulls: Average 42.85 mm (range 5.5 – 55)
- April 2009 Cows: Average 6.56 mm (range trace – 23)
-

Figure 2: Fall Back Fat Thickness (mm)
Bathurst Caribou

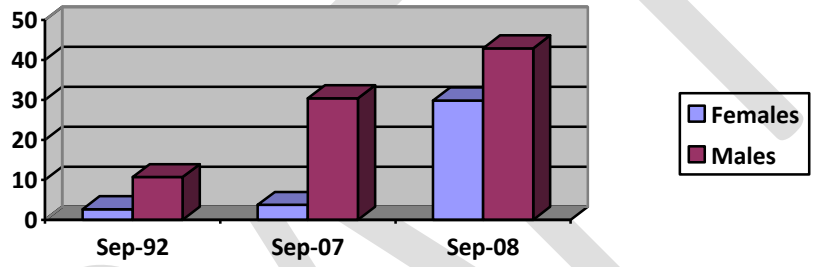
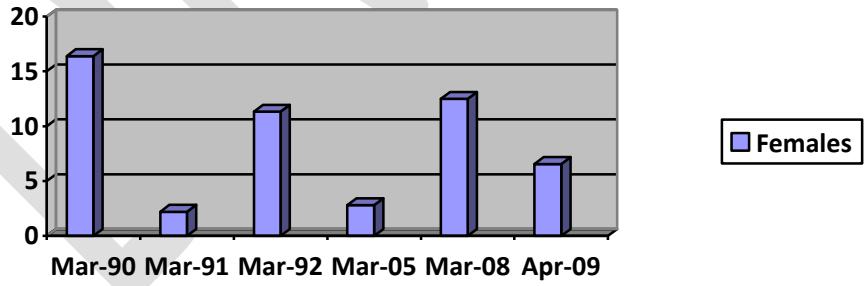


Figure 3: Spring Back Fat Thickness (mm)
Bathurst Caribou



Kidney Fat Index

Kidney fat index (KFI) is a widely used measure used as an indicator of abdominal fat reserves (Harder and Kirkpatrick 1994). Kidneys from the Bathurst caribou were evaluated using a standardized technique to provide a ratio of the weight of the kidney fat to the weight of the kidney X 100; the KFI is reported as a percentage and can be >100%. The amount of kidney fat was variable within and between sampling periods, with all animals having some amount of kidney fat stores.

- September 2007 Cows: Average 21.3% (range 9.2 - 44.1%)

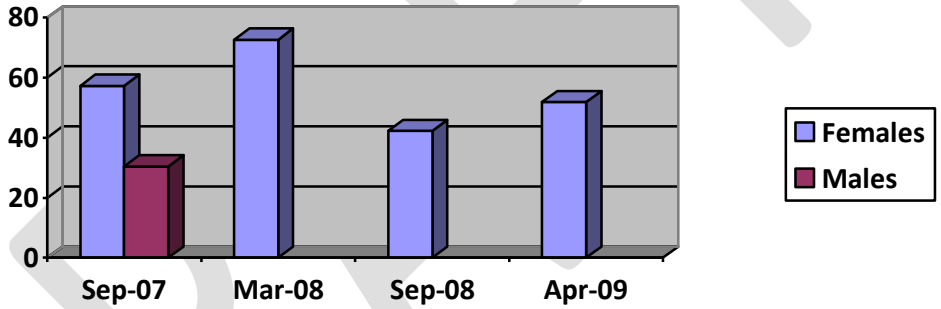
  Bulls: Average 57.3% (range 15.6 – 134.1%)

- March 2008 Cows: Average 72.6% (range 41.7 – 133.5%)

- September 2008 Cows: Average 42.2% (range 11.8 – 75.4%)

- April 2009 Cows: Average 51.8% (range 31.1 – 115.6%)

Figure 4: Kidney Fat Index (%)
Adult Female & Male Bathurst Caribou



Marrow Fat

Bone marrow fat reserves are the last fat source depleted in animals in poor nutritional condition, and Mech and DelGiudice (1985) suggested that loss of any of this fat reserve is indicative of poor body condition. The percentage of bone marrow made up of fat was assessed quantitatively by standard techniques (Harder and Kirkpatrick 1994) in late winter samples from adult females. Levels of bone marrow fat content were high in both late winter 2008 and 2009, indicating these energy reserves had not been significantly utilized.

- March 2008 Average 93.36% (89.53-98.75)

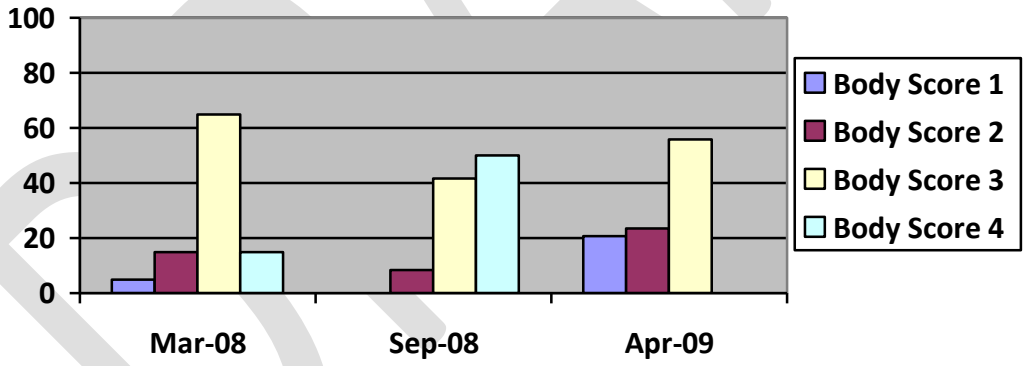
- April 2009 Average 92.85% (79.41-96.02)

Hunter Scores

An assessment of the body condition of each caribou was done by hunters using a subjective condition score ranked from 1 (poor) to 4 (excellent). Hunter assessments suggested caribou were generally in generally good body condition for the age, sex and time of year, with a range in condition scores for each sampling interval. There was some difference between the distribution of body scores for adult females in late winter of the two years, with 80% of cows in late winter 2008 falling into the top two condition scores, while 56% of cows in late winter 2009 falling into the same categories (consistent with back fat and KFI indices).

- March 2008 Cows: Average 2.9 out of 4
- September 2008 Cows: Average 3.4 out of 4 Bulls: Average 3.8 out of 4
- April 2009 Cows: Average 2.6 out of 4

Figure 5: Hunter Condition Scores for Adult Females (% of animals in each category)



5. Pregnancy & Reproductive Measurements

Caribou rely on high-quality forage on their summer range for reproduction, growth and survival (Miller 2003). The age of first conception in caribou is related to body size and fat reserves of females. Although most cows conceive after 2 years of age, some will conceive as yearlings if they are in good body condition (Dauphine 1976; Parker 1981). In general, females over 2 years of age are fertile and can breed if in good body condition, with pregnancy rates of about 80% or greater (Bergerud 1978). Insufficient build-up of fat reserves over summer and early fall can result in a failure to conceive. The chief cause of reproductive failure in caribou is a failure to conceive (Dauphine 1976), and insufficient build-up of fat reserves by cows over the summer and early fall may at least partly explain fluctuations in pregnancy rates (Russell et al. 1998; Cameron et al. 1991, 1993; Thomas

and Broughton 1978). Poor body condition in females may also result in intrauterine mortality (Skoog 1968; McGowen 1966; Neiland et al. 1968), a light fetus (Adamczewski et al. 1987), contribute to calf mortality at birth or shortly thereafter, or result in inadequate production of milk during lactation.

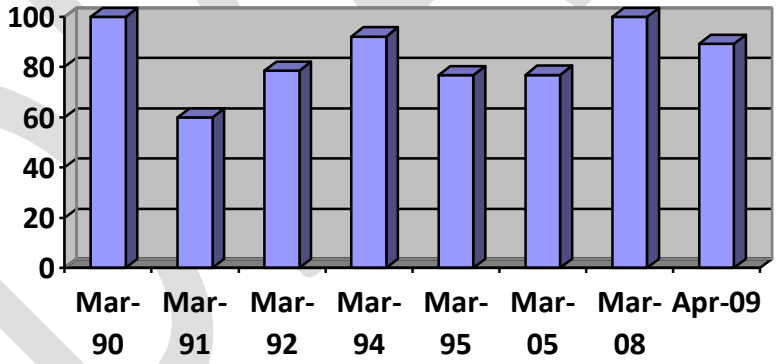
Several measures of reproductive performance were assessed in this work, including pregnancy rates, fetus size (length and weight), and fall lactation rates for adult cows.

Pregnancy Rates

Pregnancy rates for Bathurst caribou were determined in late winter by the presence of a fetus. Pregnancy rates were high in both years, though somewhat lower in April 2009 (89%) compared to March 2008 (100%). The levels for both years are similar to or above levels seen in the early to mid 1990's.

- March 2008 Adult Cows: 26/26
- April 2009 Adult Cows: 25/28

Figure 6: Late Winter Pregnancy Rates (% Pregnant)
Adult Female Bathurst Caribou



Fetus Size

The rut and calving are highly synchronous in caribou (Dauphine and McLure 1974), with a gestation length estimated at 227-229 days (Bergerud 1978). The condition of breeding females in the fall may influence the timing of parturition (Adams and Dale 1998), and delayed conception has been attributed to a decline in condition of breeding females (Skogland 1990). Fetus size can give an estimate of date of conception, and some insight into condition of breeding females.

Fetus sizes for Bathurst caribou in late March 2008 and April 2009 were within expected ranges for weight and length for the time of year. It is important to note that the differences in size between 2008 and 2009 reflect sampling date, which was done 24 days later in the year (during a time of rapid fetal growth) in 2009.

- March 2008 (n=26) Fetus weight: average 1135 grams (SD 241)

  Fetus Length: average 31.1 centimetres (SD 2.4)

- April 2009 (n=25) Fetus weight: average 2160 grams (SD 404)

  Fetus Length: average 42.6 centimetres (SD 3.3)

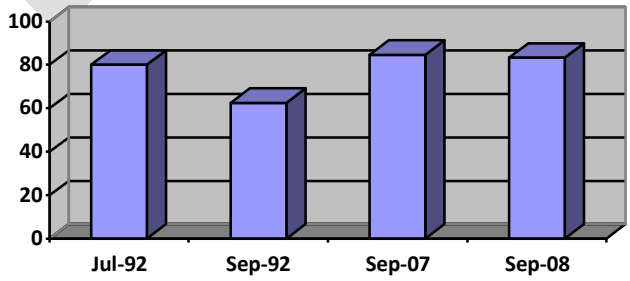
Lactation

Documenting lactation status is important because of the relationship between condition, lactation, and calf survival. The ability and strategy for nursing or weaning a calf will influence both its survival and cow productivity in the following year (Russel and White 2000, White et al. 2000). Lactation status can be determined by the presence and type of milk in the cow's udder. Clear liquid obtained from the udder indicates that weaning has just occurred, concentrated milk (>25% dry matter) indicates that weaning is occurring, and dilute milk (<25% dry matter) indicates active lactation that may continue over winter (White *et al*. 2000). All adult cows were examined to see if the mammary gland was developed, and if so, what type of milk was present.

The percentage of adult Bathurst cow's actively lactating milk in September of 2007 and 2008 was assessed as an indication of how many animals were still nursing a calf.

- September 2007 Adult Cows: 11/13
- September 2008 Adult Cows: 10/12

Figure 7: Adult Cows Lactating In Fall (%)



6. Contaminants

A wide range of naturally occurring and anthropogenic contaminants have been detected in the environment and in wildlife in northern Canada (Braune et al. 1999). Contaminant levels were monitored in most major barren-ground caribou herds across the north during the 1990's under the Northern Contaminants Program to provide a baseline of what types and levels of contaminants are present, to help understand their source, and consider their significance to caribou. Herds including the Bathurst were tested for a wide range of metals, organchlorine compounds and radionuclides, but most were found at very low levels (Elkin and Bethke 1995). Ongoing monitoring of select herds is being done to assess any change in the levels or types of contaminants over time.

Contaminant testing of the Bathurst herd was done in 2005 (bulls) and 2006 (cows). A total of 31 elements were tested, and levels of all elements were low and considered to be background levels and not of concern for caribou health. Levels of most metals remained similar to levels detected in 1992. A number of elements required for normal functioning of an animal (eg. copper, selenium and zinc) were found within normal ranges, though copper was lower in both males and females in 2005/2006 than in 1992/93. Toxic elements (eg. arsenic, cadmium, and mercury) were low and similar to previous levels. A number of elements differed in levels between males and females (eg. lead, mercury, cadmium, copper), and may reflect different metabolic demands in females.

Cadmium concentrations ranged from 5.9 to 71.0 ug/g, which is consistent with levels found in other caribou herds across the north and similar to levels detected in 1992. Renal cadmium has been shown to increase with age in various mammals, including caribou (Gamberg and Scheuhammer, 1994). Lead levels were higher in 2006 than in 2005 ($P<0.001$ using a Kruskal-Wallis One Way Analysis of Variance on Ranks), though still at low levels. This may reflect differences in gender, time, or possible local point sources. Renal arsenic and mercury concentrations were also somewhat higher in 2006 than in 2005, but still at low levels at both time periods. There is some evidence that mercury may be increasing in some parts of the environment, which may be the result in part from atmospheric input from global mercury emissions and a naturally occurring cycle of mercy flux in the Arctic environment (Poissant et al. 2008). Even the highest mercury level measured in this study (2.3 ug/g wet weight) is far below the threshold level of 30 ug/g (ppm) wet weight cited by Scheuhammer (1991) at which effects might be expected to occur.

Monitoring contaminants in the Bathurst herd over time is warranted to assess any potential changes in the levels or types of contaminants, provide additional insight into possible gender differences in levels of some elements, monitor the levels of essential elements required by caribou, and track levels of key elements including mercury.

Table 1. Element concentrations in Bathurst caribou kidneys (μg/g dry weight; X+SD) in 2005 and 2006, compared to baseline levels in 1992.

Year	1992				2005	2006
Season	Fall/Winter		Spring/Summer		Fall/Winter	Fall/Winter
Gender	F	M	F	M	M	F
N	11	9	5	5	23	25
Arsenic	NM	NM	NM	NM	0.1±0.0	0.2±0.1
Cadmium	4.4±4.0	6.7±6.3	13.4±8.3	7.0±1.4	18.4±8.8	29.3±18.1
Copper	48.2±24.8	59.8±55.0	36.8±4.0	81.3±27.4	21.6±3.1	16.2±3.6
Lead	0.1±0.1	0.1±0.1	0.2±0.0	0.1±0.1	0.1±0.1	0.3±0.1
Mercury	2.4±1.4	2.4±1.1	3.9±2.1	3.1±1.3	1.8±0.5	5.3±1.8
Selenium	NM	NM	NM	NM	3.5±0.5	3.6±0.9
Zinc	112.7±25.5	116.6±16.7	160.7±67.0	116.0±18.5	103.0±21.8	86.7±18.6

7. Diseases and Parasites

Infectious diseases and parasites can influence the health of caribou (Huot and Beaulieu 1985), as well as their resilience to environmental change. Climate is also considered to be an important factor in determining the diversity and abundance of some pathogens, as well as patterns of disease they cause (Kutz et al 2009), and host-parasite systems may be sensitive indicators of climate change (Hoberg 2008). A number of different disease and parasites are endemic in caribou throughout the circumpolar arctic, though our understanding of the current pathogen fauna of all caribou herds and the effect/significance of these organisms is incomplete. The Bathurst herd is a key herd under the Circum Arctic Rangifer Monitoring and Assessment Network (CARMA 2008), and disease and parasite monitoring is done by the GNWT, its community partners, and a number of university-based research collaborators. Monitoring is done regularly on the Bathurst herd to establish a current baseline of the types and levels of existing diseases and parasites in the herd, begin to assess their potential implications for caribou health, identify diseases that can affect people, look for possible new or emerging pathogens (eg. CWD), and monitor for changes in the levels or types of diseases and parasites over time.

Several of the specific diseases and parasites being monitored include:

Brucellosis: Brucellosis (*Brucella suis biovar 4*) has been reported for all major barren-ground caribou herds in northern Canada (Forbes 1991), though actual levels of infection

vary between herds. Serological testing of the Bathurst herd in the early 1990's (which indicates exposure to the organism, and not necessarily disease) found antibodies to Brucella in 1% of 529 animals tested. In the current work, no clinical cases were detected in this study (blood testing results pending). Brucellosis can affect the leg joints and reproductive organs of caribou, though the significance of this disease at a population level is not known. Brucellosis is an important zoonotic disease. A new technique is being developed to be able to test for brucellosis and other diseases using blood samples collected on filter paper (frozen or air dried) as a tool to facilitate community-based monitoring (Curry 2009).

Gastrointestinal Parasites: A number of parasites have been reported in the gastrointestinal tract (abomasums and intestines) of caribou, and it has been recognized that some of these parasites can have important sub-clinical effects including local tissue damage, protein and blood loss, inappetance, and reductions in body condition (Stein et al. 2002). Preliminary results for the September 2007 caribou found abomasal worms in 77.6% of the animals, with a mean intensity of 140 worms/caribou. Effects of these parasites will depend on both the prevalence and intensity of infection. Strains of some parasites like *Giardia* may be zoonotic, warranting monitoring of the prevalence and strains of these parasites found in caribou (work ongoing).

Lung Parasites: A number of parasites can be found in the lungs of caribou, and in some conditions may cause clinical disease. *Dictyocaulus* lungworms are found in the airways of the lungs primarily in young (yearling) caribou, while adults appear to develop some immunity to the parasite. Hydatid cysts (*Echinococcus granulosus*) can be found in caribou lungs (3.6 – 6.7% of animals in this study); the cysts do not appear to impact caribou health and are not a direct human health concern, but if fed to dogs the cysts develop into a tapeworm who's eggs do pose a zoonotic concern.

Tissue Parasites: *Besnoitia* is common in apparently healthy caribou (~40% affected in current work; 64% in a 1994 study), but occasionally can cause clinical disease; current research is underway looking at tissue distribution of cysts and possible effect on male fertility. *Toxoplasma* can have impacts on reproductive success in some species, and some strains may be zoonotic (35% seroprevalence in 1993; current results pending). *Taenia krabbei* forms small white cysts in caribou muscle that are intermediate stages of a tapeworm found in wild canids, but does not appear to have an impact on caribou health.

Warbles: Warbles (*Hypoderma tarani*) are a common parasite of caribou found in herds across northern Canada and Alaska (>90% of Bathurst caribou affected in current study). Adult warble flies lay eggs on the legs of caribou, which hatch into larvae that penetrate the skin and migrate to the back of the caribou where they overwinter. The warbles themselves can affect caribou by causing allergenic responses, nutritional demands and secondary infections (Dietrich and Has 1981). Summer fly harassment has also been suggested to have a significant impact on caribou energetics by diverting the time caribou spend foraging during the summer when nutritional requirements of caribou are high (Thomas and Kiliaan 1998; Toupin et al. 1996). The intensity of warble infestation in an animal may relate to the amount of fly harassment and local effects exerted by the parasite.

Preliminary parasite results are presented in Table 1, while additional laboratory testing is still underway and results will be reported when completed. Additional work is being done by university collaborators to further document the pathogens themselves, and attempt to determine the ecology and potential effects of some of these organisms (research ongoing). The types and levels of organisms detected in this work can be considered natural endemic diseases and parasites for caribou in the Bathurst herd and other northern caribou herds.

Table 2: Summary of Preliminary Parasite Test Results for Bathurst Caribou, Presented as Percentage (%) of Animals Affected.

	September 2007	March 2008	September 2008	April 2009
External Parasites				
Besnoitia	47.1%	39.5%	41.9%	TBD
Nose Bots	not visible	2.6%	not visible	3.3%
Warbles	not visible	94.7% ave. 52 (0-198)	not visible	93.3% ave. 45 (0-148)
Lung Parasites				
Echinococcus	6.7%	2.6%	6.5%	3.3%
Lungworm	0%	0%	0%	0%
Liver Parasites				
Taenia hydatigena	25.5%	50%	32.3%	36.7%
Muscle Parasites				
Sarcocystis	pending	pending	pending	pending
Taenia krabbei	0%	2.6%	6.5%	3.3%
Toxoplasmosis	5.9%	pending	pending	pending
GI Parasites				
Cryptosporidium	3.9%	0%	0%	0%
Eimeria	3.9%	38%	0%	24.1%
Giardia	5.9%	0%	0%	0%
Moniezia	3.9%	10.8%	7.1%	3.4%
Nematodirus	9.8%	10.8%	14.3%	0%
Trichostrongyles	29.4%	0%	60.1%	13.8%
Dorsal Spined Larvae	5.9%	29.7%	0%	34.5%

8. Future Monitoring

The sampling conducted from September 2007 through April 2009 provided a solid baseline of information on the health, condition and contaminant exposure in Bathurst caribou. Ongoing monitoring of select key indicators should be done to monitor trends over time, and to detect any significant changes or new issues. Where possible, this should be done using less intensive community-based Level 1 or Level 2 sampling by community hunters, with more intensive Level 3 sampling at five year intervals or when an issue or concern is identified and/or specific additional information is required.

9. References

Adamczewski, J.Z., C.C. Gates, R.J. Hudson, and M.A. Price. 1987. Seasonal changes in body composition of mature female caribou and calves (*Rangifer tarandus groenlandicus*) on an Arctic island with limited winter resources. Canadian Journal of Zoology 65: 1149-1157.

Adams, L.G. and B.W. Dale. 1998. Timing and synchrony of parturition in Alaskan caribou. Journal of Mammalogy 19:287-294.

Allaye-Chan, A.C. 1991. Physiological and ecological determinants of nutrient partitioning in caribou and reindeer. Ph.D. thesis, University of Alaska, Fairbanks, AK. 135 pp.

Barboza, P.S. and K.L. Parker. 2006. Body protein stores and isotopic indicators of N balance in female reindeer (*Rangifer tarandus*) during winter. Physiol. Biochem. Zool. 79:628-644.

Bergerud, A.T.1978. Caribou. Pages 83-101 in J.L. Schmidt and D.L. Gilbert, eds. Big game of North America: Ecology and management. Stackpole, Harrisburg, PA.

Braune, B., D. Muir, B. DeMarche, M. Gamberg, K. Poole, R. Currie, M. Dodd, W. Duschenko, J. Eamer, B. Elkin, M. Evans, S. Grundy, C. Hevert, R. Johnstone, K. Kidd, B. Koenig, L. Lockhart, H. Marshall, K. Reimer, J. Sanderson and L. Shutt. 1999. Spatial and temporal trends of contaminants in Canadian arctic freshwater and terrestrial ecosystems: a review. Science of the Total Environment 230:145-207.

Cameron, R.D., W.T. Smith, and S.G.Fancy. 1991. Comparative body weights of pregnant/lactating and non-pregnant female caribou. Proceedings of North American Caribou Workshop 4:109-114.

Cameron, R. D., W. T. Smith, S. G. Fancy, K. L. Gerhart, and R. G. White. 1993. Calving success of female caribou in relation to body weight. Canadian Journal of Zoology 71:480-486.

Chan-McLeod, A., R. G. White, and D. E. Russell. 1995. Body mass and composition indices for female barren-ground caribou. Journal of Wildlife Management 59:278-291.

Circum Arctic Rangifer Monitoring and Assessment (CARMA) Network. 2008. Rangifer Health and Body Condition Monitoring Manual. Edited by A. Gunn and W. Nixon. 54 Pages.

Curry, P. 2009. Caribou herds and arctic communities: exploring a new tool for caribou health monitoring. InfoNorth. Arctic Institute of North America

Dauphine, T.C., Jr. 1976. Biology of the Kaminuriak population of barren-ground caribou. Part 4. Growth, reproduction, and energy reserves (Report Series 38). Canadian Wildlife Service.

Dauphine, T.C., Jr., and R.L. McClure. 1974. Synchronous mating in Canadian barren-ground caribou. Journal of Wildlife Management 38:54-66.

Dieterich, R.A. and G.E. Haas. 1981. Warbles. Pages 179-182. In R.A. Dieterich ed. Alaskan wildlife diseases. Institute of Arctic Biology, University of Alaska, Fairbanks.

Elkin, B.T. and R.W. Bethke. 1995. Environmental contaminants in caribou in the Northwest Territories. Science of the Total Environ 160/161:307-322.

Forbes, L.B. 1991. Isolates of Brucella suis biovar 4 from animals and humans in Canada, 1982-1990. Canadian Veterinary Journal 32:686-689.

Gamberg, M. and A.M. Scheuhammer. 1994. Cadmium in caribou and muskoxen from the Canadian Yukon and Northwest Territories. Science of the Total Environment 143:221-234.

Gerhart, K. L., R.G. White, R. D. Cameron, and D.E. Russell. 1996. Body composition and nutrient reserves of arctic caribou. Canadian Journal of Zoology 74:136-146.

Harder, J.D. and R.L. Kirkpatrick. 1994. Physiologic methods in wildlife research. Pages 275-306. In: Research and management techniques for wildlife and habitats. Edited by T.A. Bookhout. The Wildlife Society, Bethesda, Maryland. 740 pp.

Hoberg, E.P., L. Polley, E.J. Jenkins, S.J. Kutz, A.M. Veitch and B.T. Elkin. 2008. Integrated approaches and empirical models for investigation of parasitic diseases in northern wildlife. Emerging Infectious Diseases 14:10-17.

Huot, J. and M. Beaulieu. 1985. Relationship between parasite infection levels and body fat reserves in George River caribou in spring and fall. Proceedings of the Second North American Caribou Workshop, Oct 1985, Val Morin, Québec. McGill Subarctic Research Paper 40:317-327.

Huot, J. and G. Picard. 1988. A simplified method for assessment of caribou body composition. Journal of Wildlife Management 42:606-609.

Kofinas, G., P. Lyver, D. Russell, R. White, A. Nelson, and N. Flanders. 2003. Towards a protocol for community monitoring of caribou body condition. Rangifer Special Issue 14: 43-52.

Kofinas, G., D.E. Russell, and R.G. White. 2002. Monitoring caribou body condition: workshop proceedings. Canadian Wildlife Service Technical Report Series No. 396. Ottawa, ON. 31 pp.

Kutz, S.J., E.J. Jenkins, A.M. Veitch, J. Ducrocq, L. Polley, B. Elkin and S. Lair. 2009. The Arctic as a model for anticipating, preventing, and mitigating climate change impacts on host-parasite interactions. Veterinary Parasitology 163:217-228.

Langvatn, R. (Editor) 1977. Criteria of physical condition, growth and development in Cervidae. Nordic Council for Wildlife Research, Stockholm, Sweden.

Langvatn, R. and S. D. Albon. 2005. Resistance to abomasal nematodes and individual genetic variability in reindeer. Molecular Ecology 14:4159.

Lyver, P.O.B and A. Gunn. 2004. Calibration of hunters' impressions with female caribou body condition indices to predict probability of pregnancy. Arctic 57:233-241.

McGowan, T.A. 1966. Caribou studies in north-western Alaska. Proceedings of the Western Association of State Game and Fish Commissioners 46:57-66.

Mech, L.D. and G.D. DelGuidice. 1985. Limitations of the marrow-fat technique as an indicator of condition. Wildlife Society Bulletin 13:204-206.

Miller, F.L. 2003. Caribou. In: Wild mammals of North America: biology, management, and conservation, Second Edition. Edited by F.A. Feldhamer, B.C. Thompson and J.A. Chapman. The John Hopkins University Press, Baltimore, Maryland. Pp. 965-997.

Neiland, K.A., J.A. King, B.E. Huntley, and R.O Skoog. 1968. The diseases and parasites of Alaskan wildlife populations, Part 1: Some observations on brucellosis in caribou. Bulletin of the Wildlife Disease Association 4:27-36.

Parker, GR. 1981. Physical and reproductive characteristics of an expanding woodland caribou populations (*Rangifer tarandus caribou*) in northern Labrador. Canadian Journal of Zoology 59:1929-1940.

Parker, K.L., P.S. Barboza, and T.R. Stephenson. 2005. Protein conservation in female caribou (*Rangifer tarandus*): effects of decreasing diet quality during winter. Journal of Mammalogy 86:610-622.

Poissant, L., H.H. Zhang, J. Canario and P. Constant. 2008. Critical review of mercury fates and contamination in the arctic tundra ecosystem. Science of the Total Environment 400:173-211.

Ringberg, T., R.G. White, D.F. Holleman, and J.R. Luick. 1981. Prediction of carcass composition in reindeer (*Rangifer tarandus tarandus* L.) by use of selected indicator bones and muscles. Canadian Journal of Zoology 59:583-588.

Russell, D.E. and R.G. White. 2000. Surviving the north – a conceptual model of reproductive strategies in arctic caribou. Rangifer Special Issue 12:67.

Russell, D.E., R.D. Cameron, R.G. White, and K.L. Gerhart. 2000. Mechanisms of summer weight gain in northern caribou herds. Rangifer Special Issue 12:148 (abstract).

Russell, D.E., K.L. Gerhart, R.G. White, and D. van de Wetering. 1998. Detection of early pregnancy in caribou: evidence for embryonic mortality. Journal of Wildlife Management 62:1066-1075.

Scheuhammer AM. 1991. Effects of acidification on the availability of toxic metals and calcium to wild birds and mammals. Environmental Pollution 71:329-375.

Skogland, T. 1990. Density dependence in a fluctuating wild reindeer herd: maternal vs. offspring effects. Oecologia 84:442-450.

Skoog, R.O. 1968. Ecology of the caribou (*Raniger tarandus granti*) in Alaska. Dissertation, University of California at Berkley, Berkley.

Stien, A., R.J. Irvine, E. Ropstad, O. Halvorsen, R. Langvatn, and S.D. Albon. 2002. The impact of gastrointestinal nematodes on wild reindeer: experimental and cross-sectional studies. Journal of Animal Ecology 71:937.

Thomas, D.C. and E. Broughton. 1978. Status of three Canadian caribou populations north of 70 winter 1977 (Progress Notes 85). Canadian Wildlife Service.

Thomas, D.C. and H.P.L. Kiliaan. 1998. Fire-caribou relationships: (1) Physical characteristics of the Beverly herd, 1980-87 (Technical Report Series 309). Canadian Wildlife Service.

Toupin, B., J. Huot and M. Manseau. 1996. Effect of insect harassment on the behaviour of the Riviere George caribou. Arctic 49:375-382.

White, R.G., K.L. Gerhart, D.E. Russell, and D. van de Wetering. 2000. Composition of milk during lactation. Rangifer Special Issue 12:148 (abstract).