Biodiversity and springtime patterns of egg production and development for parasites of the Chisana Caribou herd, Yukon Territory, Canada

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Abstract: We investigated the biodiversity and springtime patterns of parasite egg/oocyst and larval production from feces and parasite development in the environment for the Chisana caribou herd in the southwest Yukon Territory, Canada from 29 March to 14 June 2006. Fecal samples from 50 adult cows that were housed in a temporary enclosure within the herd's natural range at Boundary Lake, Yukon Territory were collected and analyzed during 5 sampling periods. A minimum of 6 parasite genera were recovered: eggs of Trichostrongylidae species (most likely *Ostertagia gruehneri* and *Teladorsagia boreoarcticus*), *Marshallagia* sp., Anoplocephalidae cestodes, and *Skrjabinema* sp.; oocysts of *Eimeria* spp.; and dorsal-spined first-stage protostrongylid larvae, including *Parelaphostrongylus andersoni*. Prevalence of Trichostrongylidae spp. eggs in fresh fecals was at or near 100% throughout the sampling period, however, the median intensity increased significantly from 8 to 34 eggs per gram (epg) at the peak of calving and then decreased to 12 epg 2 weeks post-calving (P = 2.83e-07). Three plots of feces collected from these animals were established outside of the enclosure on 4 May 2006 and monitored every 10 days to investigate patterns of parasite development under natural conditions. The total number of Trichostrongylidae spp. (eggs + larvae) in fecal plots did not change over time, but as the number of larvae increased, egg counts decreased. The presence of other parasite species in the fecal plots remained constant over time. This study is the first to document the parasite diversity for the Chisana caribou herd and to examine the development and survival of eggs and larvae in feces throughout the spring and early summer.

Key words: climate change, development rates, fecal plots, *Ostertagia gruehneri*, periparturient rise, Protostrongylidae, *Rangifer*, Trichostrongylidae, woodland caribou.

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Introduction

The Chisana woodland caribou herd (*Rangifer tarandus caribou*) of the western Yukon Territory and the Wrangell-St. Elias area of Alaska (Fig. 1) is one of several threatened caribou populations in Canada. Between 1989 and 2003, the population has declined from 1800 to less than 700 (Yukon Government, 2007) and calf recruitment has been extremely low (less then 6 calves per 100 cows per year since 1990) (Gross, 2005). In 1979, hunting was restricted to bulls and a mere 1% to 2% of the population was removed annually. By 1991, the number of reproductive bulls in the herd was below the management objective and hunting was stopped via voluntary compliance (Gross, 2005). Despite management efforts, the Chisana caribou herd is listed as "at risk" in the Yukon (Yukon Government, 2007).

Predation and adverse weather conditions have been identified as the primary causes of poor calf recruitment and high adult mortality within the Chisana herd, with 89% of the documented mortality due to predation (Gardner, 2003; Gross, 2005). The factors underlying poor recruitment and high predation are still not well understood. Parasites are important pathogens of wildlife and negatively impact body condition, reproductive success (reduced conception rates, abortions, still births, and weak calves), and increase susceptibility to predation (Anderson, 1980; Hudson *et al.*, 1992; Crawford *et al.*, 2000; Albon *et al.*, 2002; Stien *et al.*, 2002; Soldati *et al.*, 2004). Potentially exacerbating the role of parasites in northern wildlife is the climatic warming trends which are pronounced at northern latitudes (Hassol, 2004; Alley *et al.*, 2007). Climate change is likely to have a profound impact on the development and survival of the free-living stages of many parasite species (Kutz *et al.*, 2005). Slight changes in the temperature and/or relative humidity of the parasite's environment may cause significant changes in the time required for development to the infective stage, as well as the rate of mortality at each developmental stage (Berberian & Mizelle, 1957; Ciordia & Bizzell, 1963; Pandey, 1972; Beveridge *et al.*, 1989; Pandey *et al.*, 1989). Conditions experienced by the free-living stages may also influence the behaviour and/ or infectivity of the parasite at later stages (Ciordia *et al.*, 1966; Armour & Duncan, 1987).

As an initial step to understand the role of parasites in the Chisana herd an investigation of the biodiversity and springtime patterns of parasite production and development was performed in spring 2006 (March-June). Fecal egg, oocyst and larval counts were determined in individual animals over an 11 week period and development and survival rates of these parasites in the environment were also investigated.

Methods

Study animals

Fifty pregnant cows, ranging from 2 to >10 years of age, from the Chisana caribou herd were captured by net gun from a helicopter between 29 March and 4 April 2006. The cows were outfitted with individually numbered radio-collars and were housed in a temporary enclosure within their natural range at Boundary Lake, Yukon Territory (61°39'00"N, 140°50'25"W) (Fig. 1) until being released 14 June 2006. The enclosure was approximately 10 hectares and it was surrounded by a 2.5 m geocloth fence that served as a visual barrier. In addition, the outer perimeter was surrounded by a 4-wire electric fence to deter predators. Natural forage in the enclosure was supplemented with a commercial pelleted reindeer ration (15% CP: Unifeed, Okotoks, Alberta) and moistened lichens (*Cladina* spp.) collected throughout the southern Yukon Territory the previous autumn by volunteers. The caribou were fed twice daily and rations were adjusted depending upon the amount of feed remaining from the previous feeding. Calves were born between 20 May 2006 and 4 June 2006, with an 88% success rate.

Springtime patterns of parasite production

Fecal samples were collected from all but one adult female caribou at the time of capture (Week 1: 29 March to 4 April) (n=49) and then from as many animals as possible over 4 one week periods (Week 5: 28 April to 5 May; Week 7: 12-19 May; Week 8: 20-26 May; and Week 10: 2-9 June). The area directly surrounding 13 feeders was raked clear of feces immediately prior to feeding to prevent contamination. Caribou were monitored daily during scheduled feeding periods (09:00 and 20:00) from a high stand located near the feeding area and all fecal depositions were recorded. Collection of fecal samples occurred after all caribou had dispersed from the feeding area, no more

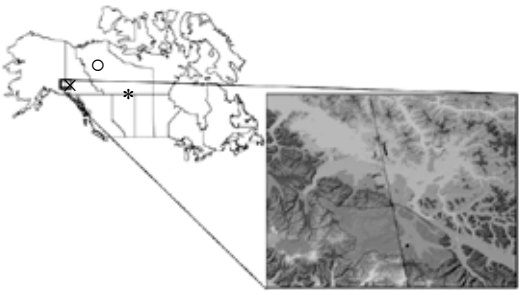

Fig. 1. Map of the Chisana caribou range expanding from the Wrangle-St. Elias mountain range of Alaska, USA into the south west corner of the Yukon, Canada. Location of the temporary enclosure at Boundery Lake, Yukon (61°39'00"N, 140°50'25" W) indicated by the black circle. Locations of Haines Junction, YT (×), Forth Smith, NT (*), and Lennie Lake, NT (○) also indicated on map. (Reproduced with permission from Layne Adams and Gretchen Roffler, USGS - Alaska Sience Center).

than 2 hours after deposition. Individual caribou were only sampled once per week and 37 of the 50 cows were sampled more than once throughout the project. Fecal samples from the caribou calves were opportunistically collected and were not identified to individual. Samples were stored in sealable plastic bags and kept at 0 to10 °C in a refrigerator at camp for an average of 6 days until analyzed. Samples collected during Week 7 were stored for 10-17 days because of logistical restraints. Prolonged storage at this temperature was not adequate to prevent egg hatching within stored samples, however, the field conditions prohibited any alternative storage methods. As a consequence, Trichostrongylidae spp. larvae were recovered from many of the "fresh" samples.

Laboratory facilities were established in Haines Junction, Yukon Territory at the Yukon Government Conservation Officers Office. All fecal samples were analyzed for parasite eggs and oocysts using a modified Wisconsin double centrifuge technique (Egwang & Slocombe, 1982) and for larvae using a modified quantitative beaker Baermann technique (Forrester & Lankester, 1997). For the Wisconsin technique, 4 g of each sample were analyzed, the water-fecal mixture was strained through a single layer of cheesecloth instead of a tea strainer, and samples were centrifuged for 10 minutes. For the Baermann technique, 5 g of each sample were analyzed, a single layer of cheesecloth was used instead of tissue paper, and samples were decanted to 25 mL, centrifuged, decanted again to 2 mL (using a Pasteur pipette), and 3 x 100 µL aliquots analyzed. Identification of eggs and larvae were based on morphological characteristics. Samples of Protostrongylidae spp. first-stage dorsal-spined larvae (DSL) and Trichostrongylidae spp. larvae were collected in 95% ethanol for DNA sequencing to determine species through molecular analysis at a later date. Results are reported for eggs, oocysts, and larvae per gram of feces wet weight.

For comparative purposes we include data from late winter/spring fecal surveys of woodland caribou that we previously collected from 2002 to 2005 in collaboration with the governments of the Yukon and Northwest Territories (Table 1). For these surveys, fresh feces were collected either from the ground or directly from the rectum and frozen at -10 °C to -20 °C for up to 4 months prior to analysis by Baermann and Wisconsin as described above. Freezing of the samples likely damaged a proportion of the parasite eggs, reducing the total numbers recovered during analysis, therefore the results of earlier studies are not directly comparable to the results of the current study.

Plot experiments

To investigate development and survival patterns of parasites in the environment, fecal plots were established outside of the caribou enclosure. The 12 m x 30 m study site was located in a montane shrub and herb community that was mostly flat, except for a small

rise in the northeast corner. The ground was moist with little standing water; the northeast corner was well-drained and much drier than the rest of the site. Three fecal samples (70, 73 and 122 grams) with high counts of Trichostrongylidae spp. collected from three different caribou during Week 5 were used to establish fecal plots. These were randomly placed in the study site on 4 May 2006. Four temperature probes (Onset HOBO data loggers ®, Onset Computer Corporation, Bourne, MA) were also randomly distributed in the study site to measure ambient temperature at ground level every 30 minutes throughout the study period.

To establish time zero parasite counts for each plot, subsamples were removed before plot establishment. Subsequent samples were removed at 10, 20, and 30 days post-establishment. Subsamples were analyzed for eggs and larvae upon return to the lab at Haines Junction. Trichostrongylidae spp. larvae were not identified to stage of development (L1, L2, L3) and are reported as total counts. For the time zero samples, delay in time between collection and analysis, together with challenges in maintaining the fecals at cool temperatures resulted in some Trichostrongylidae spp. eggs hatching during storage and larvae being recovered from the fresh samples. These would have been at the egg stage when the fecal plots were established, so they are recorded as eggs in our data.

Fecal samples lost moisture (and approximately 2/3 of their initial weight) during the sampling period; therefore, results for the plot experiment are reported per pellet instead of per gram. Baermann and Wisconsin analyses were done in duplicate for each of the 3 plots during each sampling period, except for those collected on Day 30.

Statistical analysis

The R statistical package [The Free Software Foundation, Inc., Boston, MA, USA] was used for all analyses. Change in parasite intensity over time for the fresh fecal collections was compared using the Kruskal Wallis rank sum test and for the fecal plot experiments using either ANOVA or the Kruskal Wallis rank sum test (statistical significance was set at $P = 0.05$ for all analyses). For some of the parasite species found in this study, the sample size of infected individuals was too small for meaningful statistical comparisons.

Results

Springtime patterns of parasite production

A total of 120 fecal samples were analyzed. Six types of parasite eggs/oocysts/larvae were found (Table 1) – Trichostrongylidae spp. (not including morphologically identifiable genera such as *Marshallagia* sp.), *Marshallagia* sp., Anoplocephalidae cestodes, *Eimeria* spp., *Skrjabinema* sp., and Protostrongylidae spp., including *Parelaphostrongylus andersoni* (Kutz *et al.*, 2007). A sample of Trichostrongylidae spp. was sequenced by the Agricultural Research Centre, United States Department of Agriculture, Beltsville, MD during this project and was identified as *Ostertagia gruehneri*. Previous sequencing of larvae from this herd also identified *O. gruehneri*, as well as low levels of *Teladorsagia boreoarcticus* (Kutz, unpubl. data). It was therefore assumed that the Trichostrongylidae eggs recovered during this project were a mixture consisting predominantly of *O. gruehneri* but including some *T. boreoarcticus*, the eggs and free-living larval stages of which are indistinguishable (Belem *et al.*, 1993; Hoberg *et al.*, 2001). No parasite eggs or oocysts were recovered from the sampled newborn caribou calves ($n = 7$).

The Trichostrongylidae spp. were the most common in each sampling period, both in terms of prevalence and intensity (Table 1; Figs. 2-3). The median intensity of infection significantly increased during Week 8 (34 epg) (n=8) coinciding with the start of calving. Two weeks later (Week 10) the intensity decreased

Table 1. Prevalence (P) and median intensity (I) and (range) of parasites per gram of wet feces found in woodland caribou (*Rangifer tarandus caribou*). *n* = number of adult female caribou sampled.

			'other' Trichostrongylidae (eggs)	*Marshallagia* (eggs)	Cestode (eggs)	*Eimeria* (oocysts)	*Skrjabinema* (eggs)	Protostrongylidae (DSL)
Current Study – Chisana, YT March-April 2006	Week 1: (29 March - 4 April)	*n* = 49	P = 95.9 I = 8.00 (0.25-71)	P = 0.00	P = 2.04 I = 0.50 (0.5)	P = 20.4 I = 0.50 (0.25-2.8)	P = 0.00	P = 30.6 I = 7.60 (0.07-44)
	Week 5: (28 April - 5 May)	*n* = 31	P = 100 I = 15.3 (1.0-62)	P = 0.00	P = 6.45 I = 4.25 (1.5-7.0)	P = 0.00	P = 0.00	P = 29.0 I = 8.87 (1.1-30)
	Week 7: (12 May - 19 May)	*n* = 13	P = 100 I = 27.9 (7.3 - 135)	P = 7.69 I = 1.00 (1.0)	P = 15.4 I = 9.63 (3.5-16)	P = 0.00	P = 15.4 I = 1.00 (0.3-1.8)	P = 7.69 I = 5.0 (5.0)
	Week 8: (20 May - 26 May) (start and peak of calving)	*n* = 8	P = 100 I = 34.2 (16-60)	P = 0.00	P = 25.0 I = 3.13 (2.0-4.3)	P = 12.5 I = 81.5 (81.5)	P = 12.5 I = 0.25 (0.25)	P = 25.0 I = 8.53 (1.1-1.6)
	Week 10: (2 June - 9 June)	*n* = 19	P = 100 I = 12.0 (0.25-24)	P = 0.00	P = 31.6 I = 4.13 (1.5-12)	P = 5.26 I = 4.25 (4.25)	P = 0.00	P = 31.6 I = 4.17 (1.1-18)
Previous Studies	Chisana, YT (May 2005)	*n* = 10	P = 100 I = 15.7 (0.4-45)	P = 0.00	P = 20.0 I = 1.40 (1.40)	P = 0.00	P = 0.00	P = 10.0 I = 1.40 (1.4)
	Chisana, YT (May-June 2003)	*n* = 7	P = 100 I = 73.5 (38-123)	P = 0.00	P = 0.00	P = 0.00	P = 0.00	P = 42.9 I = 2.50 (0.5-32)
	Chisana, YT (May-June 2003)	*n* = 24	P = 79.2 I = 3.60 (0.6-41)	P = 0.00	P = 0.00	P = 4.17 I = 0.40 (0.4)	P = 0.00	P = 29.2 I = 0.60 (0.2-2.2)
	Fort Smith, NT (March 2002)	*n* = 31	P = 100 I = 6.60 (0.6-27)	P = 0.00	P = 9.68 I = 3.20 (2.4-43)	P = 19.4 I = 3.00 (0.6-71)	P = 0.00	P = 9.68 I = 0.40 (0.2-5.0)
	Lennie Lake, NT (May 2002)	*n* = 18	P = 83.3 I = 2.2 (0.4-9.2)	P = 0.00	P = 0.00	P = 0.00	P = 0.00	P = 27.8 I = 1.00 (0.2-34)

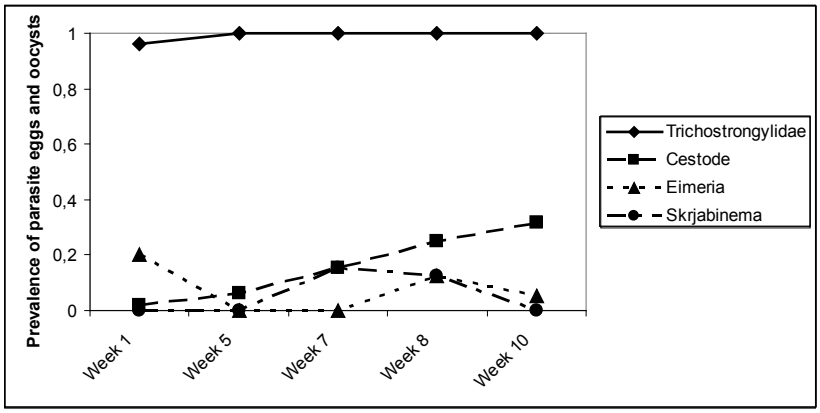

Fig. 2. Prevalence of four parasite egg and oocyst types recovered from pregnant caribou of the Chisana herd.

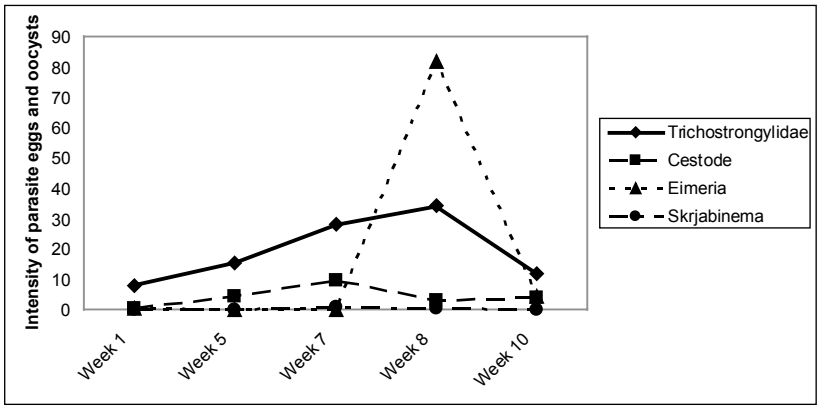

Fig. 3. Intensity of four parasite egg and oocyst types recovered from pregnant caribou of the Chisana herd.

(12 epg) (*n*=19). Intensity at Week 8 was significantly higher than other weeks, except for Week 7 (28 epg) (*n*=13), one week prior to the first calf being born (Kruskal Wallis; df = 4; *P* = 2.83e-07).

Only a single *Marshallagia* sp. egg was recovered from a single individual, therefore this species was not included in any analyses.

Eimeria spp. oocysts, *Skrjabinema* sp. eggs, and cestode eggs were recovered from one-third or less of the cows in each sampling period and were not recovered during all sampling periods (Table 1; Figs. 2-3). The intensity of *Eimeria* spp. oocysts peaked in Week 8 (82 oocysts/g (opg)), however, oocysts were only recovered from a single cow during this sampling period. The prevalence of *Skrjabinema* sp. remained less than 2% and intensity was below 1 epg.

The prevalence of cestode eggs gradually increased throughout the study period from 2% to 32% (Fig. 2); the mean intensity ranged from 1 to 10 epg (Table 1) with a peak in Week 7 (10 epg) (Fig. 3).

Protostrongylidae spp. DSL were recovered from approximately 30% of the cows sampled, except in Week 7 when prevalence dropped (Table 1). Intensity of DSL was low and relatively constant across sampling periods (Kruskal Wallis; df = 4; *P* = 0.713). Both prevalence and intensity decreased at Week 7 (8%; 5 epg), however, the decrease may be the result of an extended period of sample storage and may not reflect actual changes in parasite production in the caribou fecal samples.

Plot experiments

The fecal samples analyzed in the fecal plots contained eggs of Trichostrongylidae spp. and

Table 2. Median (M) or mean (m) number and (range) of parasite eggs and larvae per pellet in the fecal plots originally collected from pregnant caribou of the Chisana herd.

	4-May (Day 0)	14-May (Day 10)	24-May (Day 20)	3-Jun (Day 30)
Trichostrongylidae Eggs*	M = 28.4 (15-42)	M = 5.50 (0.0-32)	M = 0.00 (0.0-0.71)	M = 0.00 (0.0-2.7)
Trichostrongylidae Larvae*	M = 0.00 (0.0)	M = 3.17 (0.0-21)	M = 31.9 (5.0-62)	M = 0.00 (0.0-29)
Cestodes Eggs	m = 1.46 (0.0-7.0)	m = 1.42 (0.0-6.3)	m = 2.15 (0.0-8.4)	m = 1.42 (0.0-4.3)
Protostrongylidae DSL	M = 12.9 (0.0-30)	M = 5.17 (0.0-11)	M = 5.00 (2.3-43)	M = 9.70 (6.3-19)

* indicates a significant change in intensity over time.

cestodes, as well as larvae of Protostrongylidae spp. and Trichostrongylidae spp..

There was no significant difference in the mean number of all combined development stages of Trichostrongylidae spp. (eggs + larvae) over time (ANOVA; df = 3; P = 0.174) (Table 2). There was an exponential decrease in the median number of Trichostrongylidae spp. eggs over time (Kruskal Wallis; df = 3; P = 0.00443) with an 80% decline within the first 10 days. The median number of larvae increased significantly to 32 larvae/pellet at Day 20 (Kruskal Wallis; df = 3; P = 0.00602) and then declined by Day 30 when larvae were recovered from only one of the three experimental plots.

There were no significant changes in the number of cestode eggs (ANOVA; df = 3; P = 0.967) or DSL (Kruskal Wallis; df = 3; P = 0.563) recovered from the plots over time (Table 2).

Ambient soil surface temperatures were re-

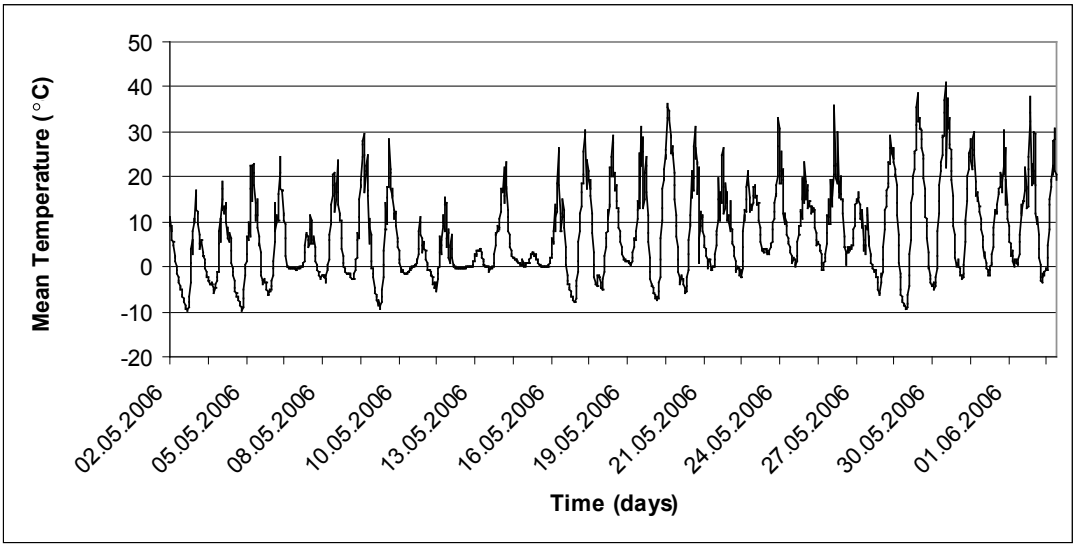

Fig. 4. Mean soil-surface temperatures recorded by four probes every 30 minutes from 2 May to 3 June 2006 on spring grazing ground of Chisana caribou.

corded every 30 minutes at four locations within the study area and demonstrated variation throughout the day (Fig. 4) and across the site. Soil-surface temperatures ranged from a minimum of -12.4 °C (5 May 2006) to a maximum of 55.6 °C (20 May 2006) with a mean daily temperature throughout the study period of 7.14 °C.

Discussion

Parasite diversity and springtime patterns of egg production

All six types of parasites found in the Chisana caribou herd have been previously recorded in caribou. The Trichostrongylidae spp. were by far the most prevalent parasite recovered, and had the highest intensity. The other five types of parasites (*Marshallagia* sp., Anoplocephalidae cestodes, *Eimeria* spp., *Skrjabinema* sp., and Protostrongylidae spp., including *Parelaphostrongylus andersoni*) were only recovered from a small proportion of the sample population and were all at low levels of intensity.

In general, the intensity of parasite infection (as measured by the number of parasite epg of feces) increased prior to calving, reaching its peak in Week 8 when the majority of caribou calves were born. There was a dramatic reduction in the number of eggs shed following the peak of calving, particularly of Trichostrongylidae spp. This trend supports the hypothesis of a periparturient rise in the intensity of parasite infections prior to calving, which is possibly caused by increased stress levels and/or the relaxation of an acquired immune response by pregnant females (Skerrett & Holland, 2001; Cattadori *et al.*, 2005). The periparturient rise indicated in this study has not been reported before in *R. tarandus*, however it is a common phenomenon that has been found across a variety of host and parasite species (Irvine *et al.*, 2000; Skerrett & Holland, 2001; Cattadori *et al.*, 2005).

A single trichostrongylid larva recovered from the Chisana caribou herd was sequenced and identified as *O. gruehneri* (Agricultural Research Center, United States Department of Agriculture, Beltsville, MD). It is probable that *T. boreoarcticus* were also present, but undetected in the current study, as both of these species are commonly reported in *Rangifer* in North America (Fruetel & Lankester, 1989; Hoberg *et al.*, 1999; 2001) and *T. boreoarcticus* has previously been recorded in this herd (S. Kutz, unpubl. data).

Trichostrongylidae spp. are common gastrointestinal nematodes found in ruminants, both domestic and wild (Hoberg *et al.*, 2001). Subclinical effects of Trichostrongylidae spp., such as changes in foraging behaviour, host physiology, and body weight have been documented in domestic, semi-domestic, and wild ruminants (Anderson, 1980; Forbes *et al.*, 2000; Hoberg *et al.*, 2001; Albon *et al.*, 2002; Stien *et al.*, 2002; Gunn & Irvine, 2003; Morgan *et al.*, 2005). These parasites, especially *O. gruehneri*, have a wide distribution throughout age and sex classes of sampled herds (Fruetel & Lankester, 1989).

The intensity of Trichostrongylidae spp. in the Chisana herd (8 to 34 epg) is low and well below the typical egg counts associated with clinical disease in domestic animals. In fact, domestic sheep often have fecal egg counts ranging from several hundred to several thousand epg without showing clinical signs of disease (Colvin *et al.*, 2008).

Marshallagia sp. was only recovered from a single individual. *Marshallagia marshalli* intensity in Svalbard reindeer (*R. t. platyrhynchus*) usually peaks in the spring and prevalence increases with host age, however, it has been shown that worm burdens can vary with year and location (Cote *et al.*, 2005). It is surprising that *Nematodirus* spp. were not found in the Chisana herd as they are a common parasite of caribou; however, the prevalence of *Nematodirus* spp. declines with host age (Beaudoin *et al.*,

1970). The youngest adult caribou sampled in this study was two years of age and the sampled calves were too young to have acquired a gastrointestinal parasite infection from the environment. Neither *Marshallagia* nor *Nematodirus* were recovered from our previous studies of woodland caribou in Canada (Table 1).

Several different genera of cestodes have previously been recorded in North American *Rangifer*, including *Moniezia*, *Taenia*, *Echinococcus*, and *Avitellina* (Halvorsen, 1986; USDA, 2002). *Moniezia* and *Avitellina*, of the family Anoplocephalidae, are the only cestodes reported to live as adults and produce eggs in the gastrointestinal tract of *Rangifer*; however, the cestode eggs recovered during this study were likely *Moniezia* spp. based on morphological characteristics. *Moniezia* spp. found in the small intestine of many domestic and wild ruminants are relatively non-pathogenic as adults, similar to other Anoplocephalids (Bowman, 1995).

The *Eimeria* spp. oocysts found in the Chisana herd were not identified to species, however, 5 species of *Eimeria* (*E. arctica, E. mayeri, E. muhlensi, E. taradina*, and *E. rangiferis*) and one species of *Isospora* (*Isospora rangiferis*) have been reported in *R. tarandus* (reviewed in Gudmundsdottir & Skirnisson, 2006). *Eimeria* is a protozoan parasite that infects the gastrointestinal tract of a wide range of vertebrate hosts, although individual parasite species tend to be more host-specific (Bowman, 1995). The most common symptom of infection with *Eimeria*, or other coccidians, is chronic diarrhea, making the diagnosis of coccidiosis challenging. Immunity to coccidiosis is protective but incomplete, resulting in a decrease in prevalence and intensity with host age.

The prevalence and intensity of *Eimeria* spp. in the Chisana herd were both very low and it is not likely to be a significant pathogen in the herd at this time. Other studies have reported spring prevalence of 6 to 13% in reindeer (reviewed in Gudmundsdottir & Skirnisson, 2005) and our previous surveys reported a prevalence of 0 to 13% (Table 1). Intensity of *Eimeria* spp. ranged from 1 to 82 opg; however, the majority of counts were less than 5 opg, with 82 opg being recovered from a single individual during one sampling period. In domestic animals, prevalence can range from 30 to 50% (Bowman, 1995) and exponentially higher levels of intensity have been reported in reindeer calves (Oksanen *et al.*, 1990).

Skrjabinema sp. has been previously identified in caribou from Canada (Fruetel & Lankester, 1989). This parasite is a nematode of the large intestine and is considered harmless in sheep and goats (Bowman, 1995). Once again, both the prevalence and intensity of this parasite were low and *Skrjabinema* is unlikely to be a significant parasite within this herd.

Protostrongylidae spp. have been previously recovered from caribou throughout North America, including *Parelaphostrongylus tenuis*, *P. odocoilei*, *P. andersoni*, and *Elaphostrongylus rangiferi*, as well as a newly discovered, undescribed species of protostrongylid (reviewed in Kutz *et al.*, 2007). Two samples were sequenced from the Chisana herd, one in 2003 (Kutz *et al.*, 2007) and one in 2006, and both were identified as *P. andersoni*. Although not identified in this herd, it is possible that *P. odocoilei* may also be present in the Chisana herd. The prevalence for *P. odocoilei* in woodland caribou has been recorded at 28% for well-established parasite populations (Gray & Samuel, 1986) and the prevalence for Protostrongylidae spp. was 10 to 43% in woodland caribou from our previous studies (Table 1). The prevalence of Protostrongylidae spp. for this study of the Chisana herd ranged from 8 to 32%.

Protostrongylidae are parasitic nematodes that infect the central nervous system and muscles of their definitive hosts (Jenkins *et al.*, 2005; Huby-Chilton *et al.*, 2006). The effect of the parasite on the host individual is depen-

dent upon both the parasite and host species, and can range from little to no effect to severe neurological disorders. Previous studies have shown that the time of year and host age both affect the mean intensity of DSL in caribou (Ball *et al.*, 2001).

Parasite recovery from plot experiments

The plot experiment was established to monitor the development and survival of free-living Trichostrongylidae spp. under natural conditions. Although parasite development and survival within the plots were only monitored for one month, this project provides a valuable comparative baseline for the development and survival of Trichostrongylidae spp. in the Arctic and Sub Arctic.

Conditions at the time of fecal deposition are critical to egg hatching rates, as evidenced by the 80% decline in the number of Trichostrongylidae spp. eggs within the first 10 days. The decline in Trichostrongylidae spp. eggs was associated with an increase in the number of larvae recovered from the plots, suggesting that the decline in eggs was largely the result of hatching to larvae and not mortality. Likewise, the total number of Trichostrongylidae spp. (eggs + larvae) recovered from the plots did not change significantly over time, suggesting that mortality of the parasites was limited under the present conditions at Boundary Lake, YT. Previous studies in temperate regions have demonstrated a much higher rate of mortality of approximately 90% for other trichostrongylids (Uriarte & Grüner, 1984). Work by Beveridge *et al.* (1989) has shown that nematodes are highly adapted to the climate conditions of their region, therefore, research completed in temperate regions may not be directly applicable to Arctic and Sub Arctic parasites.

There were only minor differences in the number of cestode eggs and protostrongylid DSL recovered from the plots over time. The insignificant decrease in intensity of DSL samples collected during Day 10 may have been associated with sample storage conditions and length of time (15 days). Both parasite types require intermediate hosts to develop (arthropod or gastropod, respectively) (Bowman, 1995; Jenkins *et al.*, 2005), therefore, any decrease in the total number could be attributed to either mortality or transmission to an intermediate host.

Although this research was limited in scope (i.e. temporally limited to a single calving season and sample collection limited to a small proportion of the total population), it is the first to document the biodiversity and springtime patterns of parasite production for the Chisana caribou herd, including a periparturient rise in parasite egg production. This project has also provided the necessary framework to begin to understand the survival and development of *Rangifer* parasites under natural conditions in the SW Yukon. Defining the biodiversity of the parasite fauna and the development and survival rates of free-living stages is essential to better understand the role of parasites in regulating wildlife populations. In addition, this work provides a baseline of comparison for future work that can be used to address the impact(s) of climate change on the development and survival of specific parasite species.

It is very difficult to clearly define the effects of climate change on parasites because of the current paucity of knowledge regarding many parasite life histories and the variability in climate change projections with regards to spatial differences, as well as the amplitude of change for both temperature and precipitation. However, it is likely that a warmer climate will lead to 1) increased development and transmission rates for many parasites, 2) relaxation of overwintering restrictions (i.e. increased winter temperatures that may lead to increased parasite winter survival and/or transmission), and 3) changes to host susceptibility to infection (Harvell *et al.*, 2002; Kutz *et al.*, 2002; Kutz *et*

al., 2004; Kutz *et al.*, 2005; Altizer *et al.*, 2006; Jenkins *et al.*, 2006; Hoberg *et al.*, 2008). Further quantitative laboratory and field-based research can build on the results presented here to develop conceptual and mechanistic models to understand the transmission dynamics of parasites in free-ranging caribou populations. Such studies should not only focus on the effects of temperature on development and survival of nematodes, but also on the effects of relative humidity and extreme environmental conditions (i.e. freezing, desiccation, extreme heat), particularly for northern adapted parasite species. A thorough understanding of the development and survival of free-living stages of parasites will aid in predicting rates of transmission under different climate conditions.

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Parasitters artssammensetning og forløp av eggproduksjon og parasittutvikling om våren hos Chisanavillreinen i Yukon, Canada

Abstract in Norwegian / Sammendrag: I en periode fra 29. mars til 14. juni 2006 tok vi prøver fra reinmøkk og undersøkte artsammensetning, egg/oocysteproduksjon og parasittutvikling i et område sørvest i Yukon, Canada, der Chisana caribou'en holder til. Møkkprøver fra 50 voksne simler, holdt i en midlertidig inngjerding i det naturlige beiteområdet ved Bondary Lake, ble samlet og analysert i løpet av fem prøveperioder. Parasitter fra minst seks slekter ble funnet: materialet omfattet egg av Trichostrongylidae-arter (mest sannsynlig *Ostertagia gruehneri* og *Teledorsagia boreoarcticus*), *Marshallagia*-art, Anaplocephalidae-bendelmark og *Skrjabinema*-art, oocyster av *Eimeria*-arter, og ryggpiggete førstestadiums Protostrongylidae-larver, bl.a. av *Parelaphostrongylus andersoni*. I ferske møkkprøver var prosentvis tilstedeværelse av Trichostrongylidae-egg nesten 100% gjennom prøveperioden, men median intensitet (parasittmengde) økte statistisk signifikant fra 8 til 34 egg per gram under kalvingens mest intense periode og avtok til 12 egg per gram to uker etter kalving. Møkk fra forsøkssimlene ble den 4. mai plassert i tre felt utenfor området der simlene ble holdt inngjerdet, og undersøkt hver tiende dag for å følge parasittutviklingen under naturlige betingelser. Det totale antall av egg + larver Trichostrongylidae i feltene forandret seg ikke; larvemengden økte samtidig som eggmengden avtok. Tilstedeværelsen av andre parasitter i feltene forble også konstant over tid. Vår studie er den første til å dokumentere parasittdiversiteten i Chisanavillreinen og å undersøke utviklingen og overlevelsen av egg og larver gjennom vår og tidlig sommer.