Fecal Surveys of Yukon Woodland Caribou Herds

3 March 1999 to 13 July 2000

Susan Kutz

Fecal Surveys of Yukon Woodland Caribou Herds, 3 March 1999 to 13 July 2000

TRC-02-01

Prepared by

Susan Kutz, DVM PhD
Research Associate, Arctic Archival Observatory
Department of Veterinary Microbiology, Western College of Veterinary Medicine, University of Saskatchewan 52 Campus Drive,
Saskatoon, SK S7N 5B4
susan.kutz@usask.ca

Prepared for

Government of Yukon, Department of Environment

17 September 2001

Fecal Surveys of Yukon Woodland Caribou Herds, 3 March 1999 to 13 July 2000

Table of Contents

Abstract

For an initial parasitological survey in Yukon mountain woodland caribou herds, 55 fecal samples from 3 herds (Finlayson (Yukon), Little Rancheria (Yukon–BC), and Nahanni (Yukon–NWT)) were gathered in late winter 1999 during other fieldwork. The samples were kept frozen until they were examined for parasites using the beaker–Baermann technique and a modified Wisconsin flotation at the Department of Veterinary Microbiology, Western College of Veterinary Medicine in Saskatoon. Dorsal-spined protostrongylid larvae, nematodirine and other trichostrongyles eggs, and *Eimeria* spp. oocysts were found in all 3 herds at a low prevalence and intensity. Cestode eggs, consistent with *Moniezia* spp. were found in the Finlayson and Rancheria herds. The parasite larvae, eggs, and oocysts found in the feces could not be identified to species, but appear to be consistent with the fauna previously described in northern caribou. The protostrongylid larvae may be *Parelaphostrongylus odocoilei, P. andersoni* or, less likely, *Elaphostrongylus rangiferi.* Within the limitations of the sampling methods, the overall prevalence and intensity of parasites in the samples from the Finlayson and Little Rancheria herds appeared to be low. The 4 samples from the Nahanni herd were insufficient to make definitive statements about their parasite loads. Further work is recommended to identify the parasites to the species level and to establish baseline values for parasites in these caribou herds.

Introduction

Parasites are important, but frequently overlooked, components of wild ruminant population ecology (Grenfell 1992, Grenfell and Gulland 1995, Hoberg et al. 2001*a*). Determining the role of parasites in population dynamics, and even in individual wild animals, is challenging because of logistical constraints and numerous other confounding factors (e.g. climate, predation, food availability) influencing wild populations (Gulland 1995). Nevertheless, there have been some excellent studies demonstrating population level effects of abomasal parasites in Soay sheep (Gulland 1992) and individual effects of abomasal parasites on reindeer (Arneberg et al. 1996, Arneberg and Folstad 1999).

In the Canadian north, where wild ruminants such as caribou, moose, and muskoxen are significant natural resources providing food and employment to local people (e.g., Gunn et al. 1991), the maintenance of healthy and sustainable wild populations is a high priority. In recent years, in an effort to better understand the role of parasites in arctic and subarctic ruminants, there has been considerable research aimed at identifying the parasite fauna of caribou, muskoxen, and Dall's sheep (Hoberg et al.1995, 1999, 2001*b*, Kutz et al. 2000*a*, 2001*a*, 2001*c*, 2001*d*). This work has been accomplished through an informal collaboration among government agencies, wildlife management groups, outfitter associations, and universities (the Research Group in Arctic Parasitology – RGAP). The focus of the research has been defining the parasite fauna, a crucial first step, for understanding

the role of parasites in ruminant populations and for assessing changes that may be associated with perturbations in climate or other environmental conditions (Hoberg 1997, Brooks and Hoberg 2000).

Of growing concern in the Arctic and Subarctic are the effects of climate change on ecosystems. Parasites are integral components of northern ecosystems and their abundance and effects on the hosts may be affected by changes in climate (Daszak et al. 2000, Hoberg et al. 2001*a*, Kutz et al. 2001*c*). Many parasites undergo development free in the environment or in invertebrate intermediate hosts before infecting another host. This stage of development is highly dependent on climatic conditions, occurring more rapidly at warmer temperatures (e.g., see Kutz et al. 2001*b*). Increasing global temperatures have the potential to change current development and transmission patterns, ultimately affecting the patterns of occurrence and disease in host populations and affecting host and geographic distributions (e.g., see Handeland and Slettbakk 1994, Lindgren et al. 2000, Kutz et al. 2001*c*). Establishing quantitative baselines are important for predicting and monitoring the potential effects of parasites on host populations under changing climatic conditions. Parasitological studies have often been initiated only when obvious poor health or mortality was evident. Such studies have much more meaning when it is possible to compare the results to data from relatively healthy animals.

Information on the parasite fauna of woodland caribou is limited (Samuel et al. 2001). In 1999, an initial parasitological survey was done on 3 mountain woodland caribou herds in the south Yukon Territory (YT) and adjacent areas of British Columbia (BC) and the Northwest Territories (NWT). Northern mountain populations such as these usually range from 200–4,000 animals and have identifiable, discrete summer alpine ranges and forested lowland winter ranges. A total of 55 fecal samples were gathered opportunistically from these herds during the course of other fieldwork. Twenty-four samples were from the Finlayson herd of approximately 4,000 (as of March 1999), which winters near Ross River, YT and summers in the Yukon's Pelly and Logan Mountains. Twenty-seven samples were from the Little Rancheria herd of approximately 1,000 (as of March 1999), which has a lowland winter range near Watson Lake, YT and in adjacent BC, and a summer range in the Cassiar Mountains in BC and YT. Four samples were from the Nahanni Herd, which winters largely in Nahanni National Park and summers in the border region between YT and NWT, near the Tungsten mine, site. This herd has not been counted, but is estimated at 1,000–2,000. The work (laboratory analyses and report preparation) described here was carried out under a contract between the author and the Western College of Veterinary Medicine (WCVM) in Saskatoon, Saskatchewan (SK), and Regional Biologist Jan Adamczewski in Watson Lake, YT.

Materials and Methods

Fecal collections

Fecal samples were gathered during census-surveys of the Little Rancheria (ca. 60°N, 129°W) and Finlayson (ca. 61° 45' N, 131° 45' W) woodland caribou herds in 1999 in late February and March, respectively. This type of census is based on delineating and counting blocks (areas) by helicopters, using a zigzag flight pattern that detects a very high proportion of caribou in the blocks (Farnell and Gauthier 1988). In late winter, woodland caribou in this region are often found on frozen lakes. In 5 such areas (Rancheria 3, Finlayson 2) where 15 or more caribou were observed, the helicopter landed after the counting was completed. Approximately a handful of fresh pellets (those that were still moist and soft) were collected from individual fecal groups. Samples were not gathered from areas where fecal material from several animals overlapped. The 4 fecal samples from the Nahanni herd were gathered during caribou net-gun captures in March 1999 in this herd's winter range in Nahanni National Park (ca. 61° 45' N, 126° 45' W).

Caribou in all 3 herds were judged to be in excellent health. Yukon woodland caribou and moose are generally thought to be kept by predators (mostly wolves) at relatively low densities compared to range capacity (Yukon Renewable Resources 1996*a*, 1986*b*).

Samples were kept cold until they could be frozen at the end of each sampling day. All samples were stored in a chest freezer at about –20°C in Watson Lake until June 2000, when they were shipped still frozen to the WCVM in Saskatoon, SK.

Fecal processing

Fecal samples were examined 13–24 July 2000 at the WCVM. Samples were analyzed using 2 techniques. The first technique, used for isolating first-stage larvae of Protostrongylidae, was the beaker–Baermann (Forrester and Lankester 1997). The second technique, used to isolate nematode and cestode eggs as well as protozoal oocysts was a modified Wisconsin flotation (Cox and Todd 1962). The technique was modified by using 10 mL of water instead of 15 mL, and by using a single layer of cheesecloth instead of a tea strainer. Results are reported as larvae, eggs, or oocysts per gram of feces wet weight.

Results

Parasites recovered on fecal flotation included gastrointestinal nematodes (nematodirines and other trichostrongyles), cestodes, and protozoa, and dorsal-spined first-stage protostrongylid larvae. There was a low prevalence (percent of animals infected) and intensity (level of infection based on positive animals only) of infection for all parasites from all locations (Table 1). A brief overview of the parasite genera found in caribou in this study, and their potential effects on the host species, is found in Appendix I.

TABLE 1: Results of fecal examinations from Yukon caribou. Prevalence is given as a percentage of the samples infected. Intensity, in parentheses, indicates the average egg, larva, or oocyst count per gram of feces (wet weight).

ID	Date	n	Proto	Trichostr	Nematodir	Cestode	Protozoa
Finalyson	19/03/99	13	8 (11)	8 (0.2)	8 (23)	8 (17)	23 (0.3)
	17/04/99	11	0	0	0	0	0
Rancheria	03/03/99	9	22 (239)	22 (0.2)	0 (NA)	0 (NA)	0 (NA)
	04/03/99	10	10 (7)	20 (0.3)	10 (6.4)	10 (3.8)	10 (0.2)
	03/04/99	8	13 (65)	13 (0.2)	13 (0.4)	0 (NA)	0 (NA)
Nahanni	13/07/99	4	25 (0.2)	0 (NA)	25 (0.2)	0 (NA)	50 (53)

Proto - Protostrongylidae first-stage larvae
Nematodir - Nematodirines, including the genera *Nematodirus* and *Nematodirella*
Trichostr - Other trichostrongylids, undifferentiated to genus
Cestode - Tapeworm eggs, most likely *Moniezia* spp.
Protozoa – Protozoan oocysts, *Eimeria* spp.

Discussion

Overview

These fecal examinations have provided a preliminary indication of the parasite status of caribou from 3 Yukon herds. Within the limitations of the fecal examinations, the relatively low parasite diversity and abundance is consistent with that found in other northern herds. However, the timing and method of sampling as well as the sample size were insufficient to assess the significance of parasites at an individual or population level. The sections that follow explore (A) the limitations of the methods used, (B) the species of parasite found in this study, in relation to other parasitological studies, (C) the intensities of the parasite infections, and (D) recommendations for further study that would build on this "first cut" evaluation.

Limitations of the sampling methods used

Fecal parasitological examinations have qualitative and quantitative limitations; results from this study must, therefore, be interpreted within these constraints. Firstly, most parasites isolated on fecal exams cannot be identified to the species level without further molecular studies, larval cultures, or adult parasite recovery. For this reason, we typically classify parasites found on fecal examination to groups, usually at the genus level, sometimes at the sub-family or family level. Further conclusions are based on the assumption that these parasites are consistent with what is typically found in that host. Secondly, fecal egg, larvae, and oocyst counts may not always reflect the actual quantity of adult parasites in the host. Egg output can be affected by many factors including season, host

immunity, parasite age and longevity, density dependent effects on parasite fecundity, fecal wet weight and fecal collection and storage protocols. These counts may provide a rough index of the parasite status of the host, but must be interpreted with caution and with knowledge of the life history of the individual parasite species. Finally, fecal counts will not reflect infections with immature or latent parasite stages, stages that are frequently responsible for considerable pathology (e.g., Type II Ostertagiasis, see Myers and Taylor 1989).

Within these constraints, the findings from the Finlayson, Little Rancheria, and Nahanni herds are discussed in relation to what has been reported in other northern caribou herds (for a recent overview see Samuel et al. 2001). Because of small sample sizes, comparisons between the sampled herds were not possible.

Parasite species

Although parasites could not be identified to species based on fecal examination, eggs, larvae, and oocysts were consistent with the literature on northern caribou (see Appendix II and Samuel et al. 2001). Definitive identification of all these species will require isolation of adult parasites followed by morphological and possibly molecular studies.

Of particular interest was the presence of dorsal-spined protostrongylid larvae in all of these herds. Protostrongylid nematodes are important pathogens of wild ungulates (Anderson 2000, Lankester 2001). Dorsal-spined protostrongylid species that have been recovered from free-ranging *Rangifer* spp. in North America include: *Parelaphostrongylus andersoni* from the Beverly herd, Northwest Territories, the George River herd, Labrador, caribou from Slate Islands, Ontario and Newfoundland, and 1 report from Alaska; *Parelaphostrongylus odocoilei* from woodland caribou in Northern Alberta; and *Elaphostrongylus rangiferi* in caribou from Newfoundland (Lankester 2001). *Parelaphostrongylus odocoilei* has recently been found in Dall's sheep in the Mackenzie Mountains, Northwest Territories (Kutz et al. 2001*d*), and is suspected in Fannin and Stone's sheep in the Yukon and British Columbia (E. Jenkins, [University of Saskatchewan, Saskatoon, SK], personal communication). Woodland caribou sympatric with the Mackenzie Mountain Dall's sheep also have a yet unidentified dorsal-spined larvae (A. Veitch [Department of Resources, Wildlife and Economic Development, {DRWED} Sahtu region, NWT], S. Kutz and B. Wagner [University of Saskatchewan, Saskatoon, SK] unpublished data).

Parelaphostrongylus andersoni and *P. odocoilei* usually do not commonly cause mortality in wild cervids, although in experimental infections with *P. odocoilei* mortalities associated with severe, parasite induced pulmonary pathology have been reported (Pybus 1983). Pulmonary damage caused by the eggs and larvae of *P. odocoilei* was the predisposing cause for the exercise-induced mortality of a 10-month-old Dall's lamb in the Mackenzie Mountains (S. Kutz, E. Jenkins, A. Veitch, unpublished data). *Parelaphostrongylus tenuis,* a related dorsal-spined protostrongylid, causes fatal neurological disease in caribou but is not maintained in caribou populations and is not found in

western North America (Lankester 2001). *Elaphostrongylus rangiferi* can cause fatal neurological disease in reindeer and caribou (Lankester 2001).

The L1 recovered from caribou in this study are probably either *P. odocoilei* or *P. andersoni.* They can be definitively identified by isolation of adult nematodes, and new molecular methods (Gajadhar et al. 2000) hold promise but are not commercially available. A third, less likely possibility is *E. rangiferi.* This nematode was introduced and established in Newfoundland with reindeer imported from Scandinavia. A failed attempt to establish a herd of these reindeer near Fort Resolution, NWT in the early half of the 20th century, resulting in the escape of some animals leaves the possibility that the *E. rangiferi* may have been introduced into native caribou populations. Other translocations of reindeer throughout the Canadian and American Arctic may also have imported this and other parasite spp. (Lankester 2001).

Parasite intensity

For all 3 herds, both the prevalence and intensity of parasitic infections were low. However, both the Finlayson and Little Rancheria herds were sampled at a time when fecal counts and adult abomasal parasites in *Rangifer* spp. are at a seasonal low (February and March). Studies on reindeer have demonstrated that the adult and fecal egg counts of *Ostertagia* spp. and *Teladorsagia* spp. are low during the winter, with peaks in intensity during the summer months (Irvine et al. 2000, Halvorsen and Bye 1999, Halvorsen et al. 1999). Preliminary studies on barrenground caribou in the Northwest Territories suggest a similar pattern (A. Gunn [DRWED, Yellowknife, NWT] and Kutz, unpublished data). The small sample size for the Nahanni herd precludes any quantitative analysis.

The prevalence of *Eimeria* spp. in both the Finlayson and Rancheria herds was low and the intensity was virtually zero. *Eimeria* spp. counts may vary throughout the year, and with host species. In domestic animals, *Eimeria* generally causes clinical disease in young animals and occasionally, in those held in confinement, there are outbreaks of clinical disease associated with severe weather during the winter months (winter coccidiosis) (Bowman 1995). Dall's sheep in the Mackenzie Mountains and muskoxen on Banks Island have high *Eimeria* spp. counts throughout the year, conversely, preliminary studies on Peary, Bluenose, and Mackenzie Mountain caribou indicate considerably lower *Eimeria* spp. counts (A. Veitch, E. Jenkins, J. Nagy [DRWED, Inuvik, NWT], A. Gunn and S. Kutz, unpublished data). Protozoan parasites are often associated with crowded conditions, and it is possible that these different patterns of infection among sheep, muskoxen, and caribou reflect the differences in host density and behaviour.

The prevalence and intensity of dorsal-spined larvae in all 3 herds is consistent with other preliminary surveys in Bluenose caribou and Mackenzie Mountain woodland caribou (J. Nagy, A. Veitch, and S. Kutz, unpublished data), but lower than that reported by Lankester and Hauta (1989) in the Beverly caribou herd (56%). *Parelaphostrongylus andersoni* has been confirmed only in the

Beverly herd and from Alaska. The identity of the dorsal-spined larvae in these other northern herds remains unknown.

Recommendations for further study

In the face of increased exploration and development as well as climate change, the importance of baseline data in Arctic and Subarctic ecosystems is coming to the forefront (e.g., see Arctic Archival Observatory http://arctos.museum.uaf.edu:8080/AAO, Northern Climate Exchange http://www.taiga.net/nce/index.html). Establishing qualitative and quantitative baseline information on potential pathogens in wildlife species will allow long term monitoring of changes in the prevalence and intensity, and in geographic and host distribution of these pathogens. Defining the parasite fauna and understanding the epidemiology is crucial for assessing impacts on host populations.

Further investigation of the parasite fauna of the caribou populations in the southern YT and adjacent NWT and BC is recommended. At a minimum, the parasite fauna should be described. Further quantitative and seasonal studies could follow to investigate the role of parasites in population dynamics of these herds.

Identification of the parasite fauna

Rationale: To identify the parasite fauna to the species level so that changes in parasite fauna over time could be recognized

Methods: This requires full post mortem and parasitological examinations to isolate and identify parasite species. If done on a large scale, parasites could be quantified and examined relative to age and sex classes, body condition, pregnancy status, etc.

Investigate seasonal patterns of parasite infection

Rationale: Assess seasonal patterns of environmental contamination and provide insight into parasite epidemiology, including development and transmission rates, pathology, and seasonal risk of exposure.

Methods: Regular seasonal fecal collections and analyses. Could include full carcass post mortems to quantify adult and larval parasite populations and assess parasite-induced pathology.

Quantitative, population level, parasite assessment

Rationale: Determine the distribution of parasites among different age and sex classes, the associated pathology, and effects on physiological condition (body condition, pregnancy, size, etc.).

Methods: Extensive whole animal parasitological examinations at a single point in time.

The above research would provide baseline information on the composition and epidemiology of the parasite fauna as well as the association of parasites with reproductive status, body condition, and other physiological parameters in these caribou populations. Subsequent long term monitoring of

parasites could then be considered. This could involve whole animal collections on a regular basis (e.g., annually or every 5 to 10 years). The greatest benefit would occur when parasitological collections were coupled with other population based research (e.g. population counts and classifications) and habitat and climatic data. It is important that standardized parasitology methods are developed (from collection and analysis to archiving of material) that allow comparisons between years.

Literature Cited

Anderson, R. C. 2000. Nematode parasites of vertebrates: their development and transmission, 2nd ed. Cambridge: C.A.B. International, University Press, Cambridge, UK. 650 pp.

Arneberg, P., and I. Folstad. 1999. Predicting effects of naturally acquired abomasal nematode infections on growth rate and food intake in reindeer using serum pepsinogen levels. The Journal of Parasitology 85:367–369.

_____, _____, and A. J. Karter. 1996. Gastrointestinal nematodes depress food intake in naturally infected reindeer. Parasitology 112:213–219.

Bowman, D. D. 1995. Georgi's Parasitology for Veterinarians. 6th ed. W. B. Saunders Company, Philadelphia, PA. 430 pp.

Brooks, D. R. and E. P. Hoberg. 2000. Triage for the biosphere: The need and rationale for taxonomic inventories and phylogenetic studies of parasites. Comparative Parasitology 67:1–25.

Cox, D. D. and A. C. Todd. 1962. Survey of gastrointestinal parasitism in Wisconsin dairy cattle. Journal of the American Veterinary Medicine Association 141:706–709.

Daszak, P., A. A. Cunningham, and A. D. Hyatt. 2000. Emerging infectious diseases of wildlife – threats to biodiversity and human health. Science 287:443–449.

Farnell, R., and D. Gauthier. 1988. Utility of the stratified random quadrat sampling census technique for woodland caribou in Yukon. Proc. 3rd N. American Caribou Workshop. Alaska Dept., Fish and Game, Juneau. Alaska, Wildlife Technical Bulletin No. 8:90–119.

Forrester, S. G., and M. W. Lankester. 1997. Extracting protostrongylid nematode larvae from ungulate feces. Journal of Wildlife Diseases 33:511–516.

Fruetel, M. and M. Lankester. 1989. Gastrointestinal helminths of woodland and barren ground caribou (*Rangifer tarandus*) in Canada, with keys to species. Canadian Journal of Zoology 67:2253–2269.

Gajadhar, A., T. Steeves-Gurnsey, J. Kendall, M. Lankester and M. Steen. 2000. Differentiation of dorsal-spined elaphostrongyline larvae by polymerase chain reaction amplification of ITD-2 rDNA. Journal of Wildlife Diseases 36:713–723.

Grenfell, B. T. 1992. Parasitism and the dynamics of ungulate grazing systems. American Naturalist 139:907–929.

_____, and F. M. D. Gulland. 1995. Introduction: Ecological impact of parasitism on wildlife host populations. Parasitology 105:493–503.

Gulland, F. M. D. 1992. The role of parasites in soay sheep (*Ovis aries* L) mortality during a host population crash. Parasitology 105:493–503.

_____. 1995. The impact of infectious diseases on wildlife populations – a review. Pages 20–51 *in* B. T. Grenfell and A. P. Dobson, editors. Ecology of infectious diseases in natural populations. Cambridge University Press, Cambridge, UK.

Gunn, A., J. Adamczewski, and B. Elkin. 1991. Commercial harvesting of muskoxen in the Northwest Territories. Pages 197–204 *in* L. A. Renecker and R. J. Hudson, editors. Wildlife production: Conservation and sustainable development. AFES Miscellaneous Publication 91-6, University of Alaska, Fairbanks, Fairbanks, Alaska, USA.

Halvorsen, O. and K. Bye. 1999. Parasites, biodiversity, and population dynamics in an ecosystem in the high arctic. Veterinary Parasitology 84:205–227.

_____, A. Stien, J. Irvine, R. Langvatn, and S. Albon. 1999. Evidence for continued transmission of parasitic nematodes in reindeer during the Arctic winter. International Journal for Parasitology 29:567–579.

Handeland, K. and T. Slettback. 1994. Outbreaks of clinical cerebrospinal elaphostrongylosis in reindeer (*Rangifer tarandus tarandus*) in Finnmark, Norway, and their relations to climatic conditions. Journal of Veterinary Medicine B 41:407–410.

Hoberg, E. P. 1997. Parasite biodiversity and emerging pathogens: A role for systematics in limiting the impacts on genetic resources. Pages 71–83 *in* K. E. Hoagland and A. Y. Rossman, editors. Global Genetic Resources: Access, Ownership and Intellectual Property Rights. Association of Systematics Collections, Washington, DC, USA.

_____, A. Kocan, and L. G. Rickard. 2001*a*. Gastrointestinal strongyles in wild ruminants. Pages 193–227 *in* W. Samuel, M. Pybus and A. Kocan, editors. Parasitic Diseases of Wild Mammals. Iowa State University Press, Ames, Iowa, USA.

_____, S. J. Kutz, J. Nagy, E. Jenkins, B. Elkin, M. Branigan, and D. Cooley. 2001*b*. *Protostrongylus stilesi* (Nematoda: Protostrongylidae): Ecological isolation and putative host-switching between Dall's sheep and muskoxen in a contact zone. Comparative Parasitology *In press.*

_____, K. J. Monsen, S. Kutz, and M. S. Blouin. 1999. Structure, biodiversity, and historical biogeography of nematode faunas in Holarctic ruminants: morphological and molecular diagnoses for *Teladorsagia boreoarcticus* n. sp. (Nematoda: Ostertagiinae), a dimorphic cryptic species in muskoxen (*Ovibos moschatus*). The Journal of Parasitology 85:910–934.

_____, L. Polley, A. Gunn, and J. S. Nishi. 1995. *Umingmakstrongylus pallikuukensis* gen. nov. et sp. nov. (Nematoda: Protostrongylidae) from muskoxen, *Ovibos moschatus*, in the central Canadian Arctic, with comments on biology and biogeography. Canadian Journal of Zoology 73:2266–2282.

Irvine, R. J., A. Stien, O. Halvorsen, R. Langvatn, and S. D. Albon. 2000. Life-history strategies and population dynamics of abomasal nematodes in Svalbard reindeer (*Rangifer tarandus platyrhynchus*). Parasitology 120:297–311.

Kralka, R. A., and W. M. Samuel. 1984. Emergence of larval *Protostrongylus boughtoni* (Nematoda: Metastrongyloidea) from a snail intermediate host and subsequent infection in the domestic rabbit (*Oryctolagus cuniculus*). Journal of Parasitology 70:457–458.

Kutz, S. J., B. Elkin, A. Gunn, and J. P. Dubey. 2000*a*. Prevalence of *Toxoplasma gondii* antibodies in muskox (*Ovibos moschatus*) sera from northern Canada. Journal of Parasitology 86:879–882.

_____, _____, D. Panayi, and J. P. Dubey. 2001*a*. Prevalence of *Toxoplasma gondii* antibodies in barren-ground caribou (*Rangifer tarandus groenlandicus*) from the Canadian Arctic. Journal of Parasitology 87:439–442.

_____, Hoberg, E. P., and Polley, L. 2000*b*. Emergence of third-stage larvae of *Umingmakstrongylus pallikuukensis* from three gastropod intermediate host species. Journal of Parasitology 86:743–749.

_____, _____, and _____. 2001*b*. *Umingmakstrongylus pallikuukensis* in gastropods: larval morphology, morphometrics and development rates. Journal of Parasitology 87:527–535.

_____, _____, and _____. 2001*c*. A new lungworm in muskoxen: an exploration in arctic parasitology. Trends in Parasitology 17:276–280.

_____, A. M. Veitch, E. P. Hoberg, B. T. Elkin, E. J. Jenkins, and L. Polley. 2001*d*. New host and geographic records for *Protostrongylus stilesi* and *Parelaphostrongylus odocoilei* (Protostrongylidae) in Dall's Sheep (*Ovis dalli dalli*) from the Mackenzie Mountains, Northwest Territories, Canada. Journal of Wildlife Diseases 37:761–774.

Lankester, M. 2001. Extrapulmonary lungworms of cervids. Pages 228–278 in W. M. Samuel, M. J. Pybus, and A. A. Kocan, editors. Parasitic Diseases of Wild Animals. Iowa State University Press, Ames, Iowa, USA.

_____, and P. L. Hauta. 1989. *Parelaphostrongylus andersoni* (Nematoda: Protostrongylidae) in caribou (*Rangifer tarandus*) of northern and central Canada. 67:1966–1975.

Lindgren, E., L. Talleklint, and T. Polfeldt. 2000. Impact of climate change on the northern latitude limit and population density of the disease-transmitting European tick *Ixodes ricinus*. Environmental Health Perspectives 108:119–123.

Myers, G. H. and R. F. Taylor. 1989. Ostertagiasis in cattle. Journal of Veterinary Diagnostic Investigation 1:195–200.

Pybus, M. 1983. *Parelaphostrongylus andersoni* Prestwood 1972 and *P. odocoilei* (Hobmaier and Hobmaier 1934) (Nematoda: Metastrongyloidea) in two cervid definitive hosts. Ph.D. Thesis, University of Alberta, Edmonton, Alberta, 185 pp.

_____, W. J. Foreyt, and W. M. Samuel. 1984. Natural infections of *Parelaphostrongylus odocoilei* (Nematoda: Protostrongylidae) in several hosts and locations. Proceedings of the Helminthological Society of Washington 51:338–340.

Samuel, W. M., M. J. Pybus, and A A. Kocan. 2001. Parasitic Diseases of Wild Animals. Iowa State University Press, Ames, Iowa, USA. 559 pp.

Yukon Renewable Resources. 1996*a*. Moose Management Guidelines. Department of Renewable Resources, Whitehorse, Yukon.

_____. 1996*b*. Woodland Caribou Management Guidelines. Department of Renewable Resources, Whitehorse, Yukon.

Appendix I Description of parasites

(summarized primarily from Bowman 1995, Anderson 2000, and Samuel et al. 2001)

Protostrongylidae:

These are strongylate nematodes of the superfamily Metastrongyloidea. The Protostrongylidae have an indirect lifecycle requiring a gastropod (slug or snail) intermediate host (IH). The adult nematodes live in the lungs, muscles, or central nervous system of their hosts. Eggs are transported by the blood stream to the lungs where they hatch into first-stage larvae (L1). These larvae are moved up the airways, swallowed and passed in the feces. Once in the environment they must penetrate into the foot tissue of a suitable IH. In the IH, they develop from L1 to the third-stage larvae (L3). This stage is infective to the definitive host (DH, mammalian host). The DH is infected either by ingesting the IH containing the L3, or by ingesting L3 that have emerged from the IH (Kutz et al. 2000*b*; Kralka and Samuel 1984). L3 migrate from the gastrointestinal tract to the lungs, muscle, or central nervous system depending on species.

There are 2 major different types of protostrongylid L1 found in northern ruminants. The first is a straight-tailed larvae, typical of the Protostrongylinae, i.e., *Protostrongylus* sp., common lungworms of bighorn and Dall's sheep. The second type has several cuticular folds in the tail and a dorsal spine projecting from the base of the tail. This is typical of the Elaphostrongylinae and Muelleriinae subfamilies. The Muelleriinae are lungworms of the Caprinae and include the genera *Muellerius, Cystocaulus* (in sheep and goats) and *Umingmakstrongylus* (only known in muskoxen). The Elaphostrongylinae include the genera *Elaphostrongylus* and *Parelaphostrongylus.* These are typically found in cervids, however, *P. odocoilei* has been described in Mountain goats (Pybus et al. 1984) and recently in Dall's sheep (Kutz et al. 2001*d*). These 'dorsal-spined' L1 generally cannot be identified to genus without the isolation of the adult nematodes or sophisticated molecular techniques (Gajadhar et al. 2000).

Gastrointestinal parasites:

The gastrointestinal nematode eggs recovered from these caribou herds are primarily strongylates that belong to the superfamily Trichostrongyloidea. These parasites have direct lifecycles; i.e. eggs are shed in the feces and must develop in the environment to third-stage larvae before they can reinfect the mammalian host. The eggs of the numerous genera in the family Trichostrongylidae cannot be easily differentiated, even to the generic level, so they are lumped as 'trichostrongyles". Most of the genera in this family hatch as first-stage larvae and then undergo 2 molts in the environment to the third stage larvae which is infective to the definitive host.

The nematodirines belong to the family Molineidae in the superfamily Trichostrongyloidea. Eggs of genera within this family also cannot be easily differentiated and are lumped as nematodirines. These

nematodes develop to the infective third stage within the egg. The eggs are resistant to freezing and desiccation, thus overwinter survival is common. In domestic animals, these parasites are most often found in the young of the year.

Moniezia sp. are tapeworms found in the small intestine. They shed segments that are passed in the feces. The eggs are released from the segments and develop in mites. Ruminants are infected by accidentally ingesting the mites while grazing.

Eimeria are microscopic, protozoan parasites that live and multiply in intestinal mucosa (cells lining the inside of the intestine). The oocysts are shed in the feces where they sporulate and can then infect another host. Oocysts are quite resistant to environmental extremes.

Significance of gastrointestinal parasites

The abomasal trichostrongyles are considered the most pathogenic of the strongyles in ruminants, decreasing growth, fecundity, and survival (Myers and Taylor 1989). Both the adult parasites and the larval stages can cause disease (Type I and Type II Ostertagiasis). In cattle, heavy infections are associated with anemia, emaciation, and diarrhea. Their effects in wild species are much more difficult to determine, however, subclinical effects including depression of food intake and decreased weight gain have been reported in reindeer (Arneberg et al., 1996). Current research on abomasal nematodes in muskoxen has demonstrated severe lesions associated with larvae in the mucosa of the abomasum and preliminary data suggest negative correlations between abomasal parasite intensities and body condition as well as pregnancy rates (J. Nagy, S. Kutz, B. Elkin [DRWED, Yellowknife], unpublished data).

Nematodirines are typically found in the small intestine. There is little evidence to suggest that they (with the exception of *N. battus*) have significant pathological effects on adult hosts.

Moniezia are primarily found in young animals, older animals tend to develop an immunity to them. They appear to be of little consequence to the definitive hosts.

There are numerous species of *Eimeria* with varying pathogenicity reported in domestic and wild ruminants. Generally, *Eimeria* is a problem in young animals, as they age they develop and immunity. Clinical signs associated with infection can include diarrhea, with or with out blood or mucous, dehydration, decreased appetite, and in heavy infection a rapid loss of condition. *Eimeria* can cause mortality in young or compromised animals. The number of oocysts in the feces is not always a good indicator of degree of infection: the most pathogenic stage can occur before oocysts are passed in the feces. Clinical disease is usually associated with crowding and poor husbandry, and is not common in free-ranging ruminants.

Appendix II - Parasites in North American *Rangifer* spp.

The following gastrointestinal parasites have been recovered as adults from free-ranging *Rangifer* spp. in North America (from Fruetel and Lankester 1989; Hoberg et al. 2000; Hoberg et al. 2001*a*). Asterix (*) indicates parasites that have been recorded in caribou in the Northwest Territories.

Abomasum

- *Marshallagia marshalli**
- *Ostertagia* spp.
- *O. gruehneri/O. arctica* *
- *O. mossi*
- *Teladorsagia circumcincta* *
- *T. boreoarcticus**
- *Trichostrongylus axei*

Small Intestine

- *Nematodirus* spp.
- *N. alcidis**
- *N. odocoilei*
- *N. tarandi**
- *N. skrjabini*
- *N. filicollis*
- *Nematodirella longissimespiculata**

Large Intestine

- *Skrjabinema* sp.*

Peritoneal cavity

- *Setaria* sp.

The following eggs/oocysts have also been recovered from wild *Rangifer* in North America

- *Trichuris* sp.
- *Capillaria* sp
- *Moniezia* sp.*
- *Eimeria**