

**PARASITE FAUNA OF MOUNTAIN GOATS (*OREAMNOS AMERICANUS*) IN  
THE NORTHWEST TERRITORIES, BRITISH COLUMBIA, AND IDAHO.**

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*Abstract:* For the first time, helminth and protozoan parasites are described from fecal samples of mountain goats (*Oreamnos americanus*) in the Northwest Territories (NT, Canada) (n=22; 62°18' N; 128°58' W), coastal British Columbia (BC, Canada) (n=18; 50°31' N; 124°39' W), and central BC (n=22; 56°30' N; 123°55' W). We also compared results with recent (1990-2003) and historical (1955) fecal-based surveys from mountain goats in Idaho (ID) (n=68 and 75, respectively). From fecal samples, we recovered eggs of the following gastrointestinal parasites: generic trichostrongyles (*Teladorsagia/Ostertagia* spp.); *Marshallagia* spp.; *Nematodirus* spp.; *Trichuris* sp.; *Moniezia* sp.; and the coccidians *Eimeria* spp. We also found protostrongylid larvae, including the lungworms *Protostrongylus rushi* and/or *P. stilesi*, and the muscleworm *Parelaphostrongylus odocoilei* (the last identified using molecular techniques). From carcasses of two mountain goats from coastal BC, we recovered adult specimens of *Teladorsagia circumcincta/T. boreoarcticus*, *Nematodirus maculosus*, and *P. rushi*, as well as larvae of *P. odocoilei*. From the carcass of an emaciated goat from central BC, we recovered a warble, *P. rushi*, larvae of *P. odocoilei* and high intensities of *Eimeria* spp., two species of *Marshallagia*, and *Teladorsagia circumcincta/T. boreoarcticus*.

Among the NT, central BC, coastal BC, and ID, the prevalence (percent of samples positive) and intensity (mean number of eggs or larvae per sample) of indirectly-transmitted parasites (protostrongylids and *Moniezia* sp.) were greatest in mountain goats from coastal BC. *Marshallagia* sp., common in mountain goats elsewhere, was rare in mountain goats from coastal BC. Our survey and a literature review support the hypothesis that, where range is shared, mountain goats and wild sheep may share some parasite species, but also have their own core parasite fauna (including a species of

*Marshallagia* that may be unique to mountain goats). In the NT and central BC, *Eimeria* spp. had greater abundance in fecal samples from mountain goats than season-matched samples from nearby thornhorn sheep populations. In combination with dental disease, chronic gastrointestinal parasitism may have contributed to emaciation and death of a goat from central BC.

Management recommendations include the recovery and identification of adult parasites from mountain goats, and/or combining more extensive fecal surveys with new methods for molecular identification of parasite eggs and larvae. These steps are crucial to understanding the parasite fauna and significance of parasitism in mountain goat populations, and the potential for parasite exchange with wild sheep.

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## INTRODUCTION

Knowledge of the parasite fauna of mountain goats (*Oreamnos americanus*) is currently limited to two fecal-based surveys (Brandborg, 1955; Pybus et al., 1984), and a few published reports, primarily from Alberta and South Dakota, based on adult parasites recovered from carcasses (Table 1; also see Hoberg et al., 2001). Such knowledge is necessary to assess the impact of parasitism on mountain goat populations, and to provide a sound basis for management decisions. Northern ungulates inhabit an environment threatened by habitat destruction and global climate change, and this could lead to shifts in the balance of host-parasite relationships (Hoberg et al., 2001). Such shifts, and their significance, cannot be detected or addressed without knowing the current parasite fauna of northern hosts, or established baselines for parasite shedding.

We examined parasites in fecal samples opportunistically collected from mountain goats in the Northwest Territories (NT), central British Columbia (BC), and coastal BC, from which parasites have not been described. As well, we compared our results with

both current (1990-2003) and historical (1955) surveys of fecal parasites of mountain goats in Idaho. Fecal surveys are the least invasive and logistically simplest approach to describing internal parasites of wildlife. They are limited, however, because definitive species identification cannot be accomplished based on the shape and size (morphology) of eggs and larvae shed in feces. Therefore, where possible, we obtained adult parasites from carcasses to confirm identification (coastal and central BC), or used DNA analysis of parasites in fecal samples to determine species (larvae of *Parelaphostrongylus odocoilei*). For the remaining parasites, we reviewed the literature to establish likely species identifications for eggs and larvae shed in feces of mountain goats.

In part, our interest in the parasite fauna of mountain goats stems from concurrent investigations of the health status and parasite fauna of thornhorn sheep (*Ovis dalli*) in NT and BC (Jenkins et al., 2000; Kutz, 2001; Kutz et al., 2001; Jenkins and Schwantje, 2004; Kutz et al., 2005). Transmission of parasites between mountain goats and wild sheep has implications for management (especially if animals are translocated),

and may have significance for the health of these populations. Mountain goats and thinhorn sheep likely share a similar parasite fauna: “Generally mountain goat and bighorn sheep (*Ovis canadensis*) have 1) similar numbers of helminth species, 2) many helminth species in common, and 3) are accidental hosts of a few others” (Samuel et al., 1977). To determine the potential for parasite exchange between mountain goats and wild sheep, we reviewed the available literature. As this suggested that many parasite species are shared, we compared prevalence and intensity of parasites shed in fecal samples from mountain goats and thinhorn sheep in two regions of range overlap (NT and central BC).

## METHODS

Primarily in 2001-2002, fecal samples were collected from the ground or from captured mountain goats at locations in the Northwest Territories (NT) (62°18' N; 128°58' W), coastal British Columbia (BC) (50°31' N; 124°39' W), and central BC (56°30' N; 123°55' W) (Table 2, Figure 1). Samples from Idaho were collected between 1990 and 2003 from various locations, including Hell's Canyon, 7 Devils, Mt. Baldy, Rainey Creek, Black Mt., Palisade, Dry Diggins, Mt. Baird, and Big Elk Creek, and processed at other laboratories. Therefore, methods may differ from the following protocol.

All samples were kept frozen until processing. Sub-samples (5 grams per test) from each fecal sample were processed using a fecal flotation technique to quantify eggs and oocysts of gastro-intestinal parasites (Cox and Todd, 1962), and a modified beaker Baermann technique to quantify larvae of protostrongylid parasites (Forrester

and Lankester, 1997). Dorsal-spined larvae and *Protostrongylus* spp. larvae were counted in 3 aliquots of 0.05 ml of the Baermann sediment on a slide under a compound microscope. If very few or no larvae were detected using the aliquot technique, the entire sediment was examined in a gridded Petri dish or on a slide, and all the larvae counted. The proportion of samples positive for each parasite (prevalence), and the average number of parasites shed per gram of feces (intensity), were calculated for each sampling location. Only prevalence was reported for the samples from Idaho.

Parasite larvae, eggs, and oocysts were identified as to type and, when possible, to genus or species. Nematodirine eggs from the Northwest Territories were cultured to third-stage larvae (Ministry of Agriculture, Fisheries, and Food, U.K., 1986). Dorsal-spined larvae were identified using molecular techniques (Jenkins et al., 2005). Adult parasites were recovered from the gastro-intestinal tracts and lungs of two adult female mountain goats from the Coastal Range of BC that died of causes unrelated to disease in November 2001 and September 2002. Adult parasites were identified using standard comparative morphology. As well, adult parasites were recovered and identified from an adult male mountain goat from the Ospika region (central BC) that died of emaciation, secondary to dental disease, in January 2004. Along with the rest of the samples from central BC, a fecal sample from this animal was collected and analyzed in March 2002 (at capture and collaring).

## RESULTS

Possible identifications for eggs and larvae shed in feces were based on the known parasite fauna of mountain goats (Table 3). Dorsal-spined larvae (DSL) of *Parelaphostrongylus odocoilei* were recovered from mountain goats in the NT, central BC, and coastal BC, and may have been present, but not recorded, in the samples from Idaho. Prevalence of eggs and larvae in feces of mountain goats at the four locations, as well as values reported in a previous survey in Idaho and Montana, are presented in Table 4. The intensities of parasites shed in feces were compared among the mountain goat populations in the NT, central, and coastal BC in Table 5.

Tail morphology of third-stage larvae (L3) of *Nematodirus* spp. from fecal samples of mountain goats in NT differed from those described for *Nematodirus* spp. from domestic animals, but were not identified further. Adult parasites from mountain goat carcasses from coastal BC were identified as *Teladorsagia circumcincta*/*T. boreoarcticus* from the abomasum and small intestine, *Nematodirus maculosus* from the small intestine, and *Protostrongylus rushi* from the lungs. Dorsal spined larvae from the lungs of these two goats were identified as *Parelaphostrongylus odocoilei* using molecular techniques. From the carcass of an emaciated goat from central BC, we recovered *P. rushi*, low numbers of dorsal-spined larvae that were assumed to be *P. odocoilei*, a warble larvae, and high intensities of *Eimeria* spp., *Teladorsagia circumcincta*/*T. boreoarcticus*, and two species of *Marshallagia* (including one that may be unique to mountain goats). On fecal examination in March 2002,

this goat had high intensities of eggs of *Marshallagia* spp. (10 eggs per gram of feces, EPG) and oocysts of *Eimeria* spp. (1200 oocysts per gram of feces, OPG) relative to the rest of the samples (means of 4 EPG and 330 OPG, respectively; see Table 5). On fecal examination in Jan. 2004 (at death), this animal still had high intensities of *Marshallagia* spp. (19 EPG) and *Eimeria* spp. (1200 OPG).

In samples from the NT, the prevalence and intensity of most parasites shed in feces were greater in Dall's sheep than mountain goats, except for eggs of generic trichostrongyles, which were present in 73% of samples from mountain goats, but absent in samples from Dall's sheep. As well, the intensity of *Eimeria* spp. was greater in fecal samples collected from mountain goats as compared to thinhorn sheep in the NT (3 X) and central BC (9 X). In samples collected in March 2002 from both mountain goats and Stone's sheep in central BC, no generic trichostrongyle eggs were observed, and DSL were present only in samples from mountain goats.

## DISCUSSION

Comparing mountain goat populations

Our findings in mountain goats in the Northwest Territories (NT), central and coastal British Columbia (BC), and Idaho (ID), were consistent with the parasite fauna of mountain goats reported elsewhere (Tables 1 and 3), bearing in mind the limitations of fecal surveys. For example, eggs of generic trichostrongyles (*Teladorsagia/Ostertagia* spp.) were not recovered from samples collected in March in central BC. This likely reflects seasonal inhibition of egg output, as

adult *Teladorsagia* spp. were present in the carcass of a goat from central BC examined in January. Season of collection strongly influences prevalence and intensity of parasite shedding in feces. Based on work in thinhorn sheep, shedding of eggs of trichostrongyles reaches a peak in late summer, when samples from mountain goats in the NT were collected. Conversely, prevalence and intensity of *Nematodirus* spp., *Marshallagia* spp., *Trichuris* sp., *Eimeria* spp., and the protostrongylids reach a peak in spring, when samples from mountain goats in BC were collected (Nielsen and Neiland, 1974; Jenkins and Schwantje, 2004). Prevalence results from Idaho cannot be interpreted in light of seasonal trends as the month of collection varied. The lower prevalence of some parasites in samples from mountain goats in Idaho in both the current and historical studies (Table 4) may reflect differences in season of collection, exposure to anthelmintics, or techniques among the different laboratories.

Observed differences in prevalence and intensity of parasites shed in feces must be interpreted carefully. Some may simply reflect small sample sizes combined with low prevalence of some parasites, for example, the tapeworm *Moniezia* sp. and the pinworm *Skrjabinema* sp. As well, there are limitations to identification of eggs and larvae in feces. For example, eggs of *Marshallagia* and *Nematodirus* spp. are somewhat similar in size and morphology, and may have been grouped together in the surveys in Idaho (Table 4). In addition, several protostrongylid species produce larvae similar in appearance; for example, both *Parelaphostrongylus odocoilei* and

*Muellerius capillaris* produce dorsal-spined larvae (DSL), and this has led to some confusion (Table 4). Larvae of *P. stilesi* and *P. rushi* are also thought to be indistinguishable; however, the tails of the larvae in samples from mountain goats in NT and BC, which likely represent *P. rushi*, were shorter than those of larvae observed in samples from sympatric thinhorn sheep, which are likely those of *P. stilesi*. Molecular techniques show great promise to resolve species identity of morphologically similar parasites. For example, recent molecular work suggests that there may be more species of *Teladorsagia* in wild caprines and cervids than previously suspected (Hoberg et al., 1999).

Despite the limitations of fecal surveys, differences in prevalence and intensity of parasite shedding among the four mountain goat populations (NT, ID, central and coastal BC) may reflect differences among climate, habitat, host density, and parasite sharing with sympatric ungulates. Both types of protostrongylid larvae (DSL and *Protostrongylus* spp.) and eggs of the tapeworm *Moniezia* sp. were present at higher prevalence and at least 10 times greater intensity in samples from coastal BC than any other location. While there may be a seasonal component to this difference, it is possible that climatic conditions of the coast are more favorable for the intermediate hosts required for transmission of these parasites (gastropods for protostrongylids and free-living oribatid mites for *Moniezia* sp).

Conversely, the warm, wet environment of coastal BC may not favor survival of free-living stages of *Marshallagia* spp.,

common in mountain goats elsewhere. Specimens of *Marshallagia* spp. were not recovered from mountain goat carcasses from coastal BC, and we recovered only one egg of *Marshallagia* spp. from feces of one mountain goat (of 18 examined) in coastal BC. This may reflect differences in climate or habitat; alternatively, as there is minimal range overlap between mountain goats and wild sheep in this region in coastal BC (Shackleton, 1999), perhaps *Marshallagia* spp. are maintained in mountain goat populations only when range is shared with wild sheep. *Marshallagia* spp. are the most prevalent gastrointestinal nematodes in wild sheep (Uhazy and Holmes 1971; Nielsen and Neiland 1974; Jenkins and Schwantje, 2004; Kutz et al., 2005).

Mountain goats may share range, and thereby some species of parasites, with sympatric ungulates. Eggs of *Strongyloides* sp., *Thysanosoma actinoides*, and *Thysaniezia giardii* (also known as *T. ovilla* according to Schmidt, 1986), were reported in 1 of 75 samples from mountain goats in Idaho and Montana (Brandborg, 1955), but were not found in samples from mountain goats at any location in the current study. It is possible that these parasites, which are more typically associated with domestic cattle and sheep, are present in goats from Idaho and Montana, some of which were translocated from other regions (Oldenburg, 1996). In addition, mountain goats in ID and MT may share range with bighorn sheep, which can harbor parasites of domestic sheep and cattle (Hoberg et al., 2001). Parasites of domestic animal origin may not be present in the mountain goat populations examined in NT and BC because the only sympatric ungulates are thinhorn

sheep, woodland caribou, moose, and, in BC, elk or mule deer (Shackleton, 1999; Veitch et al., 2002).

### Comparing mountain goats and thinhorn sheep

A literature search and our findings in mountain goats and thinhorn sheep in the NT and central BC were consistent with the hypothesis that many parasite species are common to both hosts (Table 3). For example, *Parelaphostrongylus odocoilei* was present in mountain goats as well as many populations of Dall's and Stone's sheep in the NT and BC (but not the Stone's sheep population at Williston Lake in central BC) (Jenkins et al., 2005). In Table 3, many species of gastrointestinal nematodes are common to both mountain goats and thinhorn sheep, including *Skrjabinema ovis*, *Nematodirus maculosus*, *N. davtiani*, *N. oiratianus interruptus*, *Marshallagia marshalli*, *Trichuris schumakovitschi*, as well as the protostrongylid lungworms *Protostrongylus stilesi* and *P. rushi*. For others, such as *Teladorsagia* spp. and *Moniezia* sp., specimens have not been identified to species level in one or both hosts, rendering comparisons impossible. In addition to shared parasite species, each host likely has its own core parasite fauna. For example, species of *Eimeria* appear to be relatively host specific (Table 3). As well, a species of *Marshallagia* that may be unique to mountain goats has been identified in Alberta, Alaska, Washington, Wyoming, and now, central British Columbia (Lichtenfels and Pilitt, 1989; Hoberg et al., 2001).

The relative significance and abundance of a parasite may differ between mountain goats and thinhorn sheep, even where range is shared. In the NT,

generic trichostrongyle eggs (*Teladorsagia* and *Ostertagia* spp.) were present in samples collected from mountain goats, but not Dall's sheep. Based on recovery of adult parasites and ongoing fecal surveys, the trichostrongyles *Teladorsagia* and *Ostertagia* spp. are apparently uncommon in Dall's sheep in the Mackenzie Mountains, NT, even in the summer months of peak shedding (Kutz, 2001; Kutz et al., 2005). Such a disparity between mountain goats and sheep in the same geographic area is not unusual; Samuel et al. (1977) found that *Teladorsagia circumcincta* was the most prevalent and abundant parasite in mountain goats of west-central Alberta, while *Marshallagia marshalli*/*M. occidentalis* predominated in bighorn sheep from the same area. *Teladorsagia* and *Ostertagia* spp. may dominate the abomasal niche in mountain goat populations, while *M. marshalli*/*M. occidentalis* fill this niche in wild sheep.

Differences in prevalence and intensity of parasites between mountain goats and wild sheep may reflect variation in host density and behavior (such as gregariousness), habitat selection, and/or susceptibility. To minimize variation due to seasonal effects on parasite shedding, we compared prevalence and intensity of parasites in samples from mountain goats and thinhorn sheep collected in the same month. In the NT, relative to Dall's sheep, prevalence and intensity of shedding of most parasites were lower in samples from mountain goats. Mountain goat populations in the NT are small and discontinuous (Veitch et al., 2002), and this could decrease parasite transmission and overall levels of infection. However, in the NT and central BC, *Eimeria* spp. had greater

abundance in fecal samples from mountain goats than those from thinhorn sheep. Coccidian parasites appear to be well-established in all mountain goat and thinhorn sheep populations that we examined, but further investigation is needed to determine the significance of these parasites.

### Significance

This is the first time that baseline data on parasites have been collected from mountain goats in the Northwest Territories (NT) and central and coastal British Columbia (BC). The parasite fauna of mountain goats in the NT, BC, and Idaho (ID) was generally consistent with that of mountain goats throughout their range (Table 1), although there were population-level differences (especially the coastal BC population). As well, mountain goats and thinhorn sheep shed similar types of parasite eggs and larvae, and the literature suggests that exchange of some parasite species between mountain goats and wild sheep is likely when range is shared (Table 3). When contemplating translocation of either mountain goats or wild sheep, the possibility of introduction of parasites and other important pathogens to naïve populations should be considered.

The effects of parasitism in mountain goats are largely undescribed, but may have implications for wildlife health and management. Both thinhorn sheep and mountain goats are hosts for the muscleworm *Parelaphostrongylus odocoilei*, which may have played a role in the death of one naturally-infected mountain goat in Washington (Pybus et al., 1984). It has also proven pathogenic in naturally and experimentally infected thinhorn sheep (Kutz et al., 2001; Jenkins, 2005). Disease-related die-

offs, such as those associated with the pneumonia complex in bighorn sheep, have not been reported in mountain goat or thornhorn sheep populations, despite the presence of several species of protostrongylid parasites known to cause lung damage.

The effects of gastrointestinal parasitism in wild ungulates range from subtle to severe, especially when combined with nutritional stress. In domestic livestock, high intensities of gastrointestinal parasitism can cause diarrhea, anorexia, weight loss, and even death. In wild sheep, high burdens of *Marshallagia* spp. have been linked to stomach ulceration and decreased body condition and fecundity (Uhazy and Holmes, 1971; Nielson and Neiland, 1974; Kutz, 2001). High intensities of *Marshallagia* spp., *Teladorsagia* spp., and *Eimeria* spp. in an emaciated mountain goat from central BC suggest that this animal had been compromised for some time (at least two years prior to death), and that parasitism may have contributed to, or been exacerbated by, the poor body condition.

This study represents a preliminary description and literature review of the internal parasite fauna of mountain goats. We did not include trematodes (flukes) or external parasites, although both have been recovered from mountain goats in Idaho (ticks in the recent study, trematode eggs in Brandborg, 1955). Definitive identification by recovery of adult parasites has yet to be accomplished in mountain goats in the NT and many other regions. If the opportunity arises, mountain goat carcasses should be examined in order to

definitively characterize the parasite fauna. Alternatively, molecular identification of eggs and larvae from fecal surveys may soon allow definitive species identification and accurate descriptions of the geographic distribution and relative proportions of shedding of previously indistinguishable parasite species (Hoberg et al., 2001; Jenkins et al., 2005; Kutz et al., 2005). We first need to know what parasites and diseases are present in wildlife such as mountain goats before we can assess their significance and management implications. Such baseline information is necessary to anticipate and mitigate the effects of habitat disturbance and global climate change on the impact of parasites on wildlife health.

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Table 1: Prevalence, expressed as number of positive animals/number of animals examined (percent), of adult parasites recovered and identified from mountain goats in seven studies from the literature.

	Pybus et al., 1984 AB and WA (n=2)	Samuel et al., 1977, AB (n=53) & BC (n=3)	Boddicker et al., 1971, S DK (n=28)	Boddicker & Huggins, 1969 S DK (n=1)	Kerr & Holmes, 1966 West-central AB (n=7 adults)	Brandborg, 1955 ID and MT (n=3)	Cowan, 1951 Banff and Jasper, AB (n=10)
<b>MUSCLE</b>							
<i>Parelaphostrongylus odocoilei</i>	2/2 (100)	NA	NA	NA	NA	NA	NA
<b>LUNG</b>							
<i>Protostrongylus stilesi</i>	1/2 (50)	26/41 (63) 0/3 (0)	26/26 (100)	1/1	1/7 (14)		2 (NA)
<i>P. rushi</i>	1/2 (50)	36/46 (78) 1/3 (33)	10/26 (38)				
<b>ABOMASUM</b>							
<i>Teladorsagia circumcincta</i> <sup>1</sup>	NA	29/30 (97) 2/3 (67)	24/25 (96)	1/1	7/7 (100)		10/10 (100)
<i>Teladorsagia trifurcata</i> <sup>1</sup>	NA	23/30 (77) 0/3 (0)	6/25 (24)		5/7 (71)		10/10 (100)
<i>Teladorsagia davtianai</i> <sup>1</sup>	NA	20/30 (67) 0/3 (0)			2/7 (29)		
<i>Marshallagia "O."</i> <sup>2</sup>	NA	24/30 (80) 3 (0)			5/7 (71)		10/10 (100)
<i>Marshallagia marshalli</i> <sup>2</sup>	NA	26/30 (87) 2/3 (67)			3/7 (43)		10/10 (100)
<i>Ostertagia ostertagi</i>	NA		11/25 (44)				
<i>Trichostrongylus axei</i>	NA		1/25 (4)				
<b>SM. INTESTINE</b>							
<i>T. colubriformis</i>	NA		1/25 (4)				
<i>Nematodirus davtianai</i>	NA	1/32 (3) 0/3 (0)					
<i>N. helveticus</i>	NA	1/32 (3) 0/3 (0)	2/26 (8)				
<i>N. maculosus</i> <sup>3</sup>	NA	27/33 (82) 3/3 (100)	11/26 (42)		6/7 (86)		

<i>Nematodirus</i> spp.	NA	28/33 (85) 2/3 (67)	1/1	1 (NA) <sup>4</sup>
<b>LG. INTESTINE</b>				
<i>Oesophagostomum venulosum</i>	NA	24/26 (92)		
<i>Trichuris</i> spp.	NA	0.3/28 (1) <i>sic</i> 0/3 (0)	1/7 (14)	2 (NA)
<i>T. oreamnos</i> <sup>5</sup>	NA	0/28 (0) 2/3 (67)		
<i>T. schumakovitschi</i>	NA	2/28 (7) 0/3 (0)		
<i>Skrjabinema ovis</i> <sup>6</sup>	NA	1/28 (4) 0/3 (0)	2/7 (29)	1/3 (33) <sup>7</sup> Present <sup>8</sup>
<b>CESTODES</b>				
<i>Avitellina</i> sp.	NA	6/31 (19) 0/3 (0)		
<i>Moniezia benedeni</i>	NA	6/31 (19) 0/3 (0)	1/26 (4)	1/6 (17)
Unidentified anoplocephalidae	NA	3/31 (10) 1/3 (33)		NA
<i>Thysanosoma actinooides</i>	NA	4/29 (14) 2/3 (67)	2/7 (29)	2 (NA) 2/3 (67) <sup>9</sup>
<i>Taenia hydatigena</i>	NA	5/39 (13) 0/3 (0)	1/7 (14)	10/10 (100) 2/3 (67) <sup>10</sup>

NA – not available, not reported, or not possible to conclude based on methods used by the investigators; <sup>1</sup> Some referred to as *Ostertagia* spp. in the original source, all now considered morphotypes of *Teladorsagia circumcincta* (Hoberg et al., 2001); <sup>2</sup> May represent species unique to mountain goat (Lichtenfels and Pflitt, 1989); <sup>3</sup> Species reported as *Nematodirus maculosus* may be a combination of *N. becklundii* (as described by Durette-Desset and Samuel, 1992, from goats in Alberta), and *N. maculosus*; <sup>4</sup> Identified as *Nematodirus filicollis*; <sup>5</sup> New species described by Knight, 1974; <sup>6</sup> *S. crami* and *S. oreamni* are synonyms for *S. ovis* (Schad, 1959); <sup>7</sup> Originally identified as *Skrjabinema crami*; <sup>8</sup> Originally identified as *Skrjabinema oreamni*; <sup>9</sup> May have been reported as “*Thysanosoma wyominia*” in one case; <sup>10</sup> Cysticerci, probably *T. hydatigena*

Table 2: Collection data for fecal samples from mountain goats in the current study, and thinhorn sheep from a concurrent study used for comparison. Numbers in the Map column correspond to Fig. 1.

Map	Location	Species	Date collected	n
1	Katherine Creek, Mackenzie Mts, Northwest Territories (NT)	Dall's sheep	August 2001	37
2	Ramhead Outfitting Zone, Mackenzie Mts, NT	Mountain goat	August 2001	22
3	Ospika R., Central British Columbia (BC)	Mountain goat	March 2002	22
4	Williston Lake, Central BC	Stone's sheep	March 2002	14
5	Coastal Mts, BC	Mountain goat	March 1995 (5) Nov. 2001 (13)	18
6	Idaho, various locations	Mountain goat	1990-2003	68

Table 3: Labels used in tables and possible species identifications for eggs and larvae recovered from fecal samples, based on: Shah and Levine, 1964; Todd and Ogara, 1968; Uhazy et al., 1971; Clark and Colwell, 1974; Nielsen and Neiland, 1974; Hoberg et al., 2001; Kutz, 2001; and Kutz et al., 2005.

Label	Species in mountain goat	Species in thinhorn sheep
SKRJAB	<i>Skrjabinema ovis</i> <sup>1</sup>	<i>Skrjabinema ovis</i> <sup>1</sup>
TRICHO	Generic trichostrongyle eggs: <i>Teladorsagia</i> spp. <sup>2</sup> , <i>Ostertagia</i> spp. <sup>3</sup> , <i>Trichostrongylus</i> sp.	Generic trichostrongyle eggs: <i>Teladorsagia</i> spp. <sup>2</sup> , <i>Ostertagia</i> <i>gruehneri</i> / <i>O. arctica</i> , <i>Ostertagia</i> <i>ostertagi</i> <sup>3</sup>
NEM	<i>Nematodirus maculosus</i> , <i>N. becklundi</i> , <i>N. davtiani</i> , <i>N. filicollis</i> , <i>N. helveticus</i> , <i>N. odocoilei</i> , <i>N. oiratianus interruptus</i>	<i>Nematodirus maculosus</i> , <i>N. davtiani</i> , <i>N. oiratianus</i> , <i>N. oiratianus interruptus</i> , <i>N. spathiger</i> , <i>N. archari</i> , <i>N. andersoni</i>
MARSH	<i>Marshallagia marshalli</i> / <i>M. occidentalis</i> , <i>Marshallagia</i> sp. <sup>4</sup>	<i>Marshallagia marshalli</i> / <i>M. occidentalis</i>
TRICHU	<i>Trichuris oreamnos</i> , <i>T. schumakovitschi</i>	<i>T. schumakovitschi</i>
MON	<i>Moniezia benedeni</i> , <i>M. expansa</i>	<i>Moniezia</i> sp.
PROTO	<i>Protostrongylus stilesi</i> , <i>P. rushi</i>	<i>Protostrongylus stilesi</i> , <i>P. rushi</i>
DSL	dorsal-spined larvae: <i>Parelaphostrongylus odocoilei</i>	dorsal-spined larvae: <i>Parelaphostrongylus odocoilei</i>
EIM	<i>Eimeria oreamni</i> , <i>E. montanaensis</i> , <i>E. ernesti</i>	<i>Eimeria dalli</i> , <i>E. crandallis</i> , <i>E. ahsata</i> , <i>E. parva</i> , and <i>E. ninakohlyakimovae</i>

<sup>1</sup> synonyms include *S. crami* and *S. oreamni* (Schad, 1959)

<sup>2</sup> *Teladorsagia* probably represents a group of cryptic species (Hoberg et al., 1999)

<sup>3</sup> *O. ostertagi* in Dall's sheep in Alaska is thought to originate from bison. May occur in mountain goats that have shared range with domestic animals or bighorn sheep.

<sup>4</sup> An undescribed species of *Marshallagia* possibly unique to mountain goats (Lichtenfels and Pilitt, 1989).



Table 4: Prevalence, expressed as number of positive samples/number of samples examined (percent), of parasites in fecal samples from mountain goats in the Northwest Territories (NT), central British Columbia (BC), coastal BC, and current and historical fecal surveys in Idaho (ID) and Montana (MT).

	Mackenzie Mts, NT August 2001	Ospika, Central BC March 2002	Coastal BC Mar 1995 (5) & Nov 2001 (13)	Idaho 1990-2003	ID and MT Brandborg, 1955 <sup>2</sup>
<b>NEMATODE LARVAE</b>					
Dorsal-spined	9/22 (41) <sup>1</sup>	14/22 (64) <sup>1</sup>	16/18 (89) <sup>1</sup>	NA*	5/75 (7) <sup>3</sup>
<i>Protostrongylus</i> sp.	11/22 (50)	12/22 (55)	14/18 (78)	7/68 (10)*	10/75 (13)
<b>NEMATODE EGGS</b>					
<i>Marshallagia</i> sp.	10/22 (45)	20/22 (91)	1/18 (6)	NA*	11/75 (15)
<i>Nematodirus</i> sp.	7/22 (32)	19/22 (86)	15/18 (83)	16/68 (24)*	0/75
Generic trichostrongyle	16/22 (73)	0	5/18 (28)	11/68 (16)*	1/75 (1) <sup>4</sup>
<i>Trichuris</i> sp.	2/22 (9)	6/22 (27)	2/18 (11)	12/68 (18)*	7/75 (9)
<i>Skrjabinema</i> sp.	0	0	1/18 (6)	NA*	0
<b>TAPEWORM EGGS</b>					
( <i>Moniezia</i> sp.)	1/22 (5)	0	8/18 (44)	4/68 (6)*	2/75 (3)
<b>COCCIDIAN OOCYSTS</b>					
( <i>Eimeria</i> sp.)	22/22 (100)	22/22 (100)	14/18 (78)	50/68 (74)*	NA

NA = not reported

\* identified in other laboratories. Dorsal-spined larvae may not been distinguished from *Protostrongylus* sp. larvae, and *Marshallagia* sp. eggs may have been grouped with those of *Nematodirus* sp. (or the reverse in Brandborg, 1955). As well, tapeworm eggs were not identified as to genus and were assumed to be *Moniezia*-type (versus *Thysanosoma*, for example)

<sup>1</sup> *Parelaphostrongylus odocoilei*, based on molecular identification (Jenkins et al., 2005)

<sup>2</sup> Identified parasites to species level; however, species generally cannot be determined from egg or larval morphology alone.

<sup>3</sup> Thought to be *Muellerius* sp., but may be *P. odocoilei*

<sup>4</sup> Thought to be larvae of *Trichostrongylus* sp.

Table 5: Mean and range of intensities (number of eggs, larvae, or oocysts per gram of feces) in fecal samples from mountain goats in NT, central, and coastal BC.

Parasite	Mackenzie Mts, NT	Ospika, Central BC	Coastal BC
	August 2001	March 2002	Mar 1995 & Nov 2001
SKRJAB	0	0	0.9
TRICHO	2.8 (0.2-10.4)	0	1.2 (0.2-3.3)
NEM	0.4 (0.2-0.6)	3.2 (0.2-20)	3 (0.2-11.8)
MARSH	0.5 (0.2-1.4)	4 (0.2-20)	0.59
TRICHU	0.2	1.2 (0.2-3.8)	0.4
MON	6.4	0	79.2 (0.5-215.9)
PROTO	1.5 (0.2-5.2)	0.9 (0.2-2.61)	25.6 (0.3-129)
DSL	1.6 (0.2-3.2)	6 (0.2-29)	54.4 (0.59-504.4)
EIM	145 (1.8-800)	330 (2.4-3000)	200 (30.8-937.5)

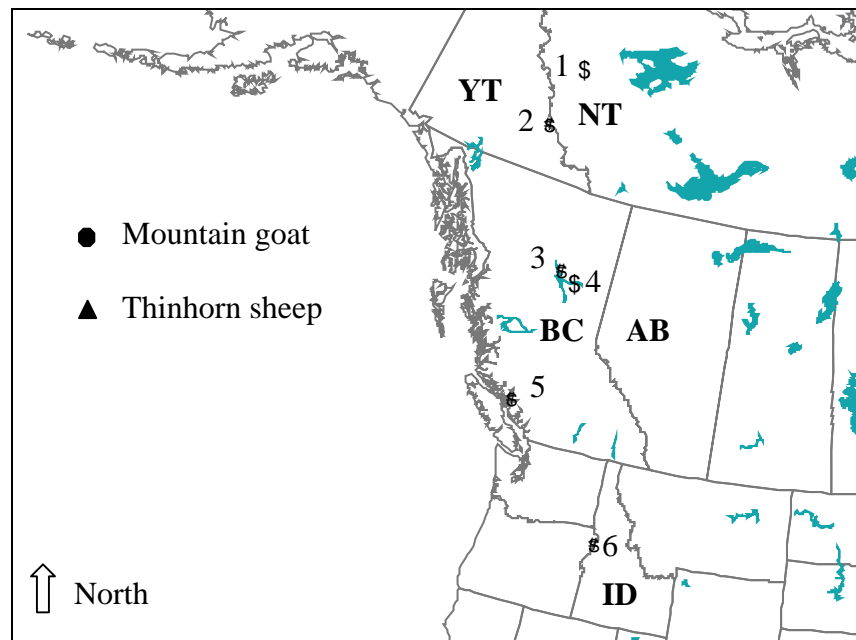


Figure 1: Locations where fecal samples were collected from mountain goats (2, 3, 5, and 6) and thinhorn sheep (1 and 4); numbers correspond to Map column in Table 2. Two carcasses of mountain goats were collected at site 5, and one at site 3. YT = Yukon Territory, NT = Northwest Territories, BC = British Columbia, AB = Alberta, ID = Idaho