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Authors: Bridger, Kimberly E., Baggs, Eric M., and Finney-Crawley, Jean

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Endoparasites of the Coyote (*Canis latrans*), a Recent Migrant to Insular Newfoundland

Kimberly E. Bridger,[1,3] Eric M. Baggs,[2] and Jean Finney-Crawley[2] [1]Department of Natural Resources, Animal Health Division, PO Box 7400, St. John's, Newfoundland A1E 3Y5, Canada; [2]Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X9, Canada; [3]Corresponding author (email: kimbridger@gov.nl.ca)

ABSTRACT: This study provides the first data on the helminth fauna of the coyote (*Canis latrans*) in insular Newfoundland. Sixty-nine coyotes were collected between 2001 and 2003 and examined for helminths. A total of 10 helminth species were recorded: the cestodes *Taenia ovis krabbei* (9%), *Taenia hydatigena* (4%), *Taenia pisiformis* (1%), *and Mesocestoides* spp. (5%); and the nematodes *Toxocara canis* (19%), *Toxascaris leonina* (1%), *Crenosoma vulpis* (19%), *Physaloptera rara* (6%), *Uncinaria stenocephala* (3%), and *Angiostrongylus vasorum* (1%). No significant differences ($P \leq 0.05$) were detected between sexes. *Mesocestoides* spp., *T. canis*, and *C. vulpis* were more prevalent in juveniles than adults. *Angiostrongylus vasorum* is reported in coyotes for the second time in Newfoundland, Canada.

Key words: *Angiostrongylus vasorum*, *Canis latrans*, coyote, helminths, Newfoundland, opportunistic predator.

The island of Newfoundland, because of late glaciation and its offshore location, had a depauperate mammalian fauna consisting of 14 endemic and 11 nonnative species (Northcott, 1974). The coyote (*Canis latrans*) is one of the latest species to become established on the island after emigrating from mainland Canada in 1985 (McGrath, 2004). The introduction (natural or otherwise) of nonindigenous animals poses an inherent risk of bringing with it new parasites or diseases that could affect other species (Bennett et al., 2005). Coyotes may serve as the primary sylvatic host for helminths that are transmitted to wild and domestic animals. Although many of these helminths pose little or no consequence to their hosts, in any geographic region, some demonstrate a degree of pathogenicity (Custer and Pence, 1981). Coyote parasite surveys have been reported from several locations within the host's North American range, including the western and southwestern United States (Custer and Pence, 1981; Seesee et al., 1983) and the western Canadian provinces (Freeman et al., 1961; Holmes and Podesta, 1968; Samuel et al., 1978). Coyotes are capable of exploiting a variety of habitats, responding to prey abundance and diversity, this opportunistic feeding strategy can, in turn, dictate its helminth fauna (Dumond and Villard, 2000). The goals of the present work were to determine the species of helminths infecting coyotes in Newfoundland and to evaluate their helminth fauna in relation to their food habits.

Sixty-nine (50 adults, 19 juveniles) coyote carcasses were collected in the autumn and winter (October to February) of 2001–03 from trappers and hunters by staff of the Department of Tourism, Culture and Recreation, Government of Newfoundland and Labrador, from three regions of insular Newfoundland (Fig. 1). Data on individual coyotes were collected (trapping location, date, sex, and age). Sex (53 males and 16 females) was determined by gross examination, and age was determined by Matson's Laboratory, Milltown, Montana, USA, based on cementum layering of a lower canine tooth. Carcasses were refrigerated or frozen until necropsy. Thorough necropsies were performed on all 69 coyotes. Carcasses were opened, and organs were removed and examined macroscopically. Liver, stomach, and intestines were opened, and the contents

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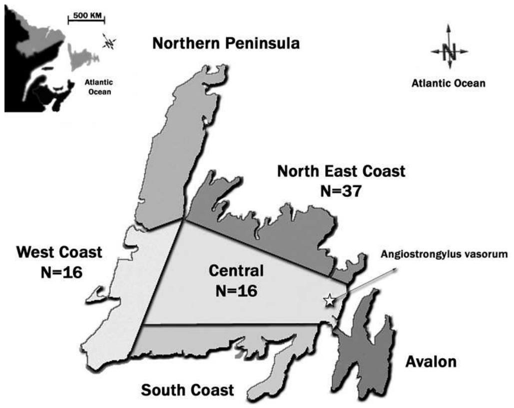

FIGURE 1. Insular Newfoundland, showing areas identified in the text and location of the coyote infected with *Angiostrongylus vasorum*.

TABLE 1. Results of the survey of the prevalence (%) and range of intensity of helminths in coyotes from insular Newfoundland.

Helminth species	Prevalence[a]	Range of intensity
Cestodes		
Taenia hydatigena	4 (3)	1–30
Taenia ovis krabbei	9 (6)	1–27
Taenia pisiformis	1 (1)	8
Mesocestoides spp.	4 (3)	1–35
Nematodes		
Toxocara canis	19 (13)	3–18
Toxascaris leonina	1 (1)	10
Crenosoma vulpis	19 (13)	6–98
Physaloptera rara	6 (4)	1–7
Uncinaria stenocephala	3 (2)	1–6
Angiostrongylus vasorum	1 (1)	6

[a] Percentage (number) of coyotes infected.

washed with physiologic saline solution into separate beakers. Each washing was allowed to settle, the fluid was decanted, and the procedure was repeated until the sediment became clean enough to detect and collect worms. Lungs, trachea, heart, and ureter were opened and washed with water into a tray. To examine for *Angiostrongylus vasorum*, the heart was separated from the lungs by transecting the major vessels as close as possible to the lungs, and all chambers, as well as the pulmonary arterial trunk, were opened and inspected visually for nematodes. The lung lobes were separated into left and right groups, and dissection consisted of opening all visible pulmonary vessels down to the narrowest point (about 0.5 mm diameter) and picking out any nematodes seen. Thereafter, bronchi were also dissected and then rinsed with water over a sieve with a 38-μm aperture, and the washings were examined under a dissecting microscope (Morgan et al., 2005). The gall bladder and urinary bladder were opened and examined, and the fluid was collected and examined as above. The kidneys were cut into 1- to 1.5-cm strips and examined macroscopically.

Cestodes were preserved in 70% ethanol, stained with Semichon's acetocarmine, and mounted in permount (Meyer and Olsen, 1988). Nematodes were preserved in 70% ethanol with 5% glycerine, then cleared and mounted in Canada balsam. The length of hooks on scolices was measured between the tips of the handle and the blade. To enable identification, proglottids of *Taenia* were cut off and cut into 300-μm sections and stained with Semichon's acetocarmine; identifications were made by the use the genital sacs (Bursey and Burt, 1970). Terminology for describing parasite infections (prevalence and intensity) follows Bush et al. (1997). Statistical analyses were performed using the SPSS 11.5 Statistical Software (SPSS Inc., Chicago, Illinois, USA). A comparison of parasite prevalence by age and sex was accomplished using χ^2 tests. Significance was set at $P \leq 0.05$.

Ten helminth species were recovered (Table 1): four cestodes, *Taenia ovis krabbei* (9%), *Taenia hydatigena*. (4%), *Taenia pisiformis* (1%), and *Mesocestoides* spp. (4%); and six nematodes, *Toxocara canis* (19%), *Toxascaris leonina* (1%), *Crenosoma vulpis* (19%), *Physaloptera rara* (6%), *Uncinaria stenocephala* (3%), and *Angiostrongylus vasorum* (1%). All observed species, except *A. vasorum*, have

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been previously reported from coyotes elsewhere in their range. Parasitism, involving one, two, or three parasite species per animal, was found in 20% (n=14), 12% (n=8), and 6% (n=4) of coyotes, respectively, whereas 62% (n=43) of the coyotes examined were not parasitized. Statistical differences in prevalence of infection were found only for *Mesocestoides* spp., *T. canis*, and *C. vulpis* ($P \leq 0.05$); all three were statistically more prevalent in juvenile than in adult animals (Table 1). Prevalence of *T. canis* and *C. vulpis* was significantly higher ($P \leq 0.05$) in animals from the northeast coast, whereas *P. rara* prevalence was significantly higher ($P \leq 0.05$) in animals on the west coast (Fig. 1). No significant differences occurred with respect to sex ($P \geq 0.05$).

The arrival of a new species, regardless of its ecologic position, carries with it the inherent risks of disruptions or interference with those species already established (Bennett et al., 2005). The establishment of the coyote on insular Newfoundland, following its arrival via sea ice in 1985 (McGrath, 2004), has raised much controversy because of its predation on woodland caribou (*Rangifer tarandus caribou*), but less well known is the effect that parasites carried by the coyote may have on resident species. The presence of helminths is primarily determined by the coyote's prey selection and, thereafter, by the ability of the respective parasite to become established. Helminth life cycles can play an important role in the ability of a species to colonize new habitats. Species with indirect life cycles have a lesser chance of following the invasion of their host than parasites with a direct life cycle (Morand, 1996). Therefore, the arrival to a new habitat is not enough for species with indirect life cycles because they also need to find an appropriate intermediate host. Several studies on the feeding habits of coyotes in eastern North America have shown that, in general, they are opportunists, capable of exploiting a wide range of habitats, and have a variable diet composition that coincides with prey availability (Dumond and Villard, 2000).

Concurrent with the study of helminth fauna, we examined the content of the coyotes' stomachs. This was collected and investigated, thus, creating a database not only on the feeding habits of each animal but also on the possibility of parasite transmission in the predator-prey relationship. So far, data on the feeding habits of coyotes in insular Newfoundland have revealed caribou (frequency of occurrence, 50.0%), snowshoe hare ([*Lepus americanus*] frequency of occurrence, 22.7%) and moose ([*Alces alces*] frequency of occurrence, 13.3%) (Bridger, 2006) as the coyotes' dominant prey. Two species of vole (*Microtus pennsylvanicus* and *Clethrionomys gapperi*) and spruce grouse (*Dendragapus canadensis*) were also identified in the stomach contents of coyotes. However, their occurrence was comparatively low at 14.7 and 6.7%, respectively (Bridger, 2006).

The larval stage of *T. o. krabbei*, the most prevalent cestode parasite (9%) in coyotes in our study, was reported in specimens of moose meat in 1987 in the areas adjacent to the west coast on which the coyotes first arrived (Ryan, 1995). At that time, seven moose management areas reported the parasite with hunting areas on the Island's west coast reporting the most cases. Although *T. o. krabbei* poses no human health risk, there is a license replacement policy for diseased animals killed by hunters, which can affect hunting quotas and could certainly affect outfitters who cater to tourist hunters. From 1987 to 1994, 294 replacement moose licenses were issued to hunters because of infestation of the meat with tapeworm cysts (Ryan, 1995). The larval stage of *T. hydatigena* has also been reported in caribou, although data on coyote food habits in Newfoundland clearly indicate that this ungulate is the most common prey item, *T. hydatigena* (4%) had a lower prevalence than *T. o. krabbei*. The reason

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for this may be that intermediate hosts can be infected with hundreds, if not thousands, of *T. o. krabbei* cysts throughout the body, whereas *T. hydatigena* cysticerci are found primarily in the liver of big game species. The authors are unaware of any reports of *T. o. krabbei* from caribou in Newfoundland, Canada.

The prevalence of *T. pisiformis* in coyotes in the present study (1%) is much lower than that reported from Minnesota, USA (39.0%; Erickson, 1944), Alberta, Canada (31.0%; Holmes and Podesta, 1968), or Manitoba, Canada (67%; Samuel et al., 1978), despite snowshoe hare being a dominant prey item in the coyote diet. Snowshoe hare occur in high densities throughout Newfoundland, Canada, and previous studies (Bennett et al., 2005) have revealed cysticerci in the viscera of hares from all three trapping areas in the present study. Previous studies have found this parasite to be ubiquitous (Custer and Pence, 1981).

Toxocara canis is considered to be one of the most frequent canine ascarids (Custer and Pence, 1981) and had a prevalence of infection (19%) in the present study, This is consistent with the results of other studies (Custer and Pence, 1981). Prevalence of this nematode was also significantly higher in juveniles (37%) rather than adult coyotes (12%). Because *T. canis* can be transmitted in utero or to newborn canids via milk, high prevalence rates are generally associated with younger animals. Adult canids can also acquire the intestinal infections following the ingestion of infected paratenic hosts. *Toxascaris leonina* was one of the least frequent parasites in the coyote. Such a low prevalence of 1% is surprising because this nematode has direct transmission via larvated eggs or via paratenic hosts such as rodents (Custer and Pence, 1981). In the present case, the dominant components of the coyotes' diet are ungulates, which would explain the low prevalence of *T. leonina* in the coyote. The hookworm, *U. stenocephala*, was found in only two individuals.

Two metastrongylid nematodes were recovered in this study: the fox (*Vulpes vulpes*) lungworm *C. vulpis* and the French heartworm, *A. vasorum* with prevalences of 19% and 1%, respectively. In Newfoundland, Canada, both parasitize dogs (*Canis familiaris*) and red foxes (Bihr and Conboy, 1999; Jeffery et al., 2004); *C. vulpis* is found in the bronchi, bronchioles, and trachea, whereas *A. vasorum* lodges in the right ventricle and pulmonary arteries (Bourque et al., 2005). *Crenosoma vulpis* has been reported previously from coyotes in the northeastern United States (Gompper et al., 2003). For *A. vasorum*, Bourque et al. (2005) first recorded it in a coyote from the Island's Avalon Peninsula. In the present study, *A. vasorum* was found in one coyote trapped on the north east coast of the island (Clarenville), highlighting the second time *A. vasorum* has been identified from coyotes in Newfoundland, Canada. Although coyotes may lack a significant role in the epidemiology of this parasite (as compared with foxes), they can, however, be used as an indicator host to reflect changes in the parasite's range. Given the long prepatent period of *A. vasorum*, this coyote could have been infected during the spring or summer. Coyotes are likely to include more gastropods in their diets at this time of year, providing greater opportunity for infection.

Although this study has likely identified the majority of helminths present in coyotes in Newfoundland, there are still some research issues to be considered. Additional seasons of study of the coyote population are needed to determine whether there are seasonal variations in helminth fauna. Seasonal variations in temperature and moisture influence the development of helminth eggs or larvae in the environment, and transmission of parasites in the intermediate hosts is, consequently, related to seasonal dietary shifts (Saeed et al., 2006). In addition, this study did not attempt to

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look for encysted muscle parasites, such as *Taenia spiralis* or *Sarcocystis* spp. However, *T. spiralis* larvae have not been detected in tongue and diaphragm samples from black bears (*Ursus americanus*) on the island of Newfoundland, but it was previously reported in one black bear from a Labrador sample (Butler and Khan, 1992). On the other hand, sporocysts of *Sarcocystis* spp. have been reported from red foxes, wolves (*Canis lupus*), caribou, and dogs in Labrador, Canada (Khan and Evans, 2006).

The findings of this study suggest that representatives of Taeniidae, *T. canis* and *C. vulpis*, are among the predominant helminths of coyotes in Newfoundland, Canada. Remarkably, however, numerous parasites commonly reported in coyotes were absent from this study (e.g., *D. renale*, *T. spiralis*, *Trichuris* spp., *Taenia crassiceps*, *Echinococcus* spp., and *Alaria* spp.; Freeman et al., 1961; Samuel et al., 1978; Seesee et al., 1983). Introduced populations generally result from relatively small subsets of native populations and are, more often than not, less parasitized (in terms of the percentages of infected animals) than are indigenous populations. There are several limitations associated with the establishment of introduced parasites, including that many parasites have complex life cycles that require more than one host, and if suitable hosts for all parasite life stages are absent, then the parasite will not become established. Thus, our data provide an important baseline for future studies.

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