ABSTRACT

Repeated serological and parasitological analyses of commercially raised swine have shown the Canadian swine herd to be free of *Trichinella* in recent years in all regions of the country except for sporadic cases from one community in Nova Scotia. Nevertheless, approximately 18 cases of human trichinellosis are reported each year in Canada. Cases are generally attributed to the consumption of infected meat from wildlife. Many surveys for *Trichinella* in wildlife have been conducted but their results are frequently limited to a few hosts or are limited in geographic range; nonetheless, they suggest that in some regions of Canada, trichinellosis appears to be common in some wildlife species. This literature review identifies two regions of Canada where sylvatic trichinellosis is prevalent and correlates with human cases. The occurrence of *Trichinella* in wildlife is significant from the point of view of public health as all known biotypes of the parasite can infect people.

ABRÉGÉ

Les résultats de nombreuses analyses sérologiques et parasitologiques effectuées sur des porcs commerciaux ont démontré que le cheptel porcin canadien est exempt de *Trichinella* partout au pays à l'exception de cas sporadiques identifiés dans une municipalité de Nouvelle- Écosse. Malgré tout, il y a environ une vingtaine de cas de trichinose humaine rapportés à chaque année au Canada. L'origine de la maladie est généralement attribuée à la consommation de gibier infecté. Plusieurs études de dépistage de *Trichinella* sur les animaux sauvages ont été conduites, mais celles-ci étaient généralement limitées à quelques espèces ou complétées dans quelques régions spécifiques seulement. Les résultats de ces études démontrent néanmoins que la trichinose serait commune chez un certain nombre d'espèces de la faune sauvage au pays. La revue de littérature faisant l'objet de la présente étude a permis d'identifier deux régions du Canada où la trichinose est présente chez les animaux sauvages et peut être corrélée à des cas de trichinose humaine. La présence de *Trichinella* en milieu naturel est significative du point de vue de la santé publique car tous les biotypes connus du parasite en cause peuvent infecter les êtres humains.

A Review of Trichinellosis in People and Wildlife in Canada

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Trichinellosis is a zoonotic parasitic disease caused by nematode parasites of the genus *Trichinella*. Larvae of *Trichinella spiralis* and *Trichinella pseudospiralis* larvae have been found around the world but other species have a more limited geographic distribution. *Trichinella nativa* has been found throughout northern temperate and arctic regions of Eurasia and North America.[1,2] Wild carnivores and omnivores are hosts for most *Trichinella* spp., and in North America commonly infected mammals include game animals such as bears, cougars and walrus.

Around the world, *T. spiralis* infect primarily rats and swine in synanthropic environments; this ecosystem has been termed the domestic cycle to differentiate it from sylvatic ecosystem cycles. The distinction is important for food safety, human health and control. On a farm, rodent control and avoiding contact between swine and wildlife are important strategies in preventing human trichinellosis.

Different species of *Trichinella* cannot be reliably distinguished by morphology. Classification of isolates has historically been made using criteria such as resistance to the lethal effects of freezing temperatures, isoenzyme patterns, and animal infectivity index. More recently DNA tests have been developed, some of which are capable of distinguishing among all biotypes.[3-6]

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Since many published reports on *Trichinella* in wildlife are limited by small sample size or limited geographic range, a review was initiated to consolidate previous findings and clarify trends in infection occurrence across Canada. The distribution of sylvatic *Trichinella* isolates and reported human trichinellosis cases (1970-1997) was compared to determine a better understanding of the risks to human health posed by this parasite.

Human trichinellosis in Canada

Typically there are three phases of illness which correspond to location or translocation of larvae within a person.[6] Invasion of the submucosa causes symptoms of the gastrointestinal phase including diarrhea, nausea, abdominal pain and vomiting, which may last up to 3 weeks. Migration of larvae through the blood stream and tissue invasion trigger fever, myalgia, muscle weakness and peri-orbital edema. Inflammatory responses to the presence of larvae include hypereosinophilia and leukocytosis peaking approximately 3 to 4 weeks post-ingestion. Mild cases may present as short duration diarrhea with little myalgia, however, complications of the central nervous, respiratory or cardiac systems occur in serious cases. Manifestations can include myocarditis, ischemia, respiratory failure and encephalopathy.[6]

A variation on the classic manifestation has been described in cases of trichinellosis in the Canadian Arctic. A clinical presentation which included a short period of myalgia, muscle weakness (4-5 days) and prolonged diarrhea (5-6 weeks) was described in patients after consumption of infected walrus meat.[7,8]

Surveys for *Trichinella* in human cadavers conducted at post-mortem in Vancouver,

TABLE I
Summary of 47 Years Worth of Trichinella Prevalence Studies in Canadian Wildlife
[% infected (number of animals tested)][23,25,26,31,37,42-62]

	BC	AB	SK	MB	ON	QC	NB	NS	PEI	NF	Territories
Polar Bear											83.3 (6)
Grizzly Bear	35.0 (20)	2.9 (35)									87.5 (24)
Cougar	9.8 (51)	51.6 (62)				0.0 (3)					
Wolverine	27.3 (11)	0.0 (2)									
Wolf	16.7 (6)	3.5 (343)		0.0 (1)	0.0 (1)	25.0 (8)				4.2 (48)	
Lynx	9.6 (52)	1.8 (57)			0.0 (12)	50.0 (2)		0.0 (29)		0.0 (1)	
Weasel	9.1 (33)										
Bobcat	17.6 (51)							0.0 (126)			
Martin	33.1 (148)	0.0 (24)		0.7 (139)	3.1 (2385)	1.8 (56)					
Otter	9.6 (52)					0.0 (6)					
Coyote	9.9 (335)	0.0 (210)	0.0 (75)	0.0 (8)	0.0 (23)	5.6 (36)	0.0 (4)				12.5 (8)
Mink	2.4 (42)				7.7 (13)	0.0 (13)					
Red Fox	0.0 (3)	3.4 (29)	0.0 (32)	0.0 (8)	0.0 (275)	9.6 (52)	0.0 (4)	0.0 (1)		0.0 (1)	10.5 (19)
Raccoon	7.1 (14)	0.0 (13)	0.0 (49)	0.0 (9)	0.3 (376)	7.7 (39)	0.0 (8)				
Fisher				1.2 (81)	4.6 (1821)	0.0 (1)					
Black Bear	11.9 (193)	0.0 (265)		0.0 (1)	2.7 (73)	0.8 (258)	0.4 (569)	0.0 (51)	0.0 (1)	0.6 (164)	
Arctic Fox										0.0 (1)	2.6 (1567)
Skunk	3.8 (26)	0.0 (98)		0.0 (2)	0.0 (222)	0.0 (3)					
Dog	0.0 (213)					1.9 (53)	0.0 (2)				50.0 (4)
Mouse	0.6 (2257)										
Ground Squirrel	0.4 (1645)										
Shrew	0.3 (330)										
Red Squirrel	0.4 (683)				0.0 (2)						
Badger	0.0 (3)	0.0 (3)	0.0 (2)		0.0 (1)						
Beaver	0.0 (33)		0.0 (1)		0.0 (2)	0.0 (5)					
Black Squirrel					0.0 (9)						
Brown Bat					0.0 (7)						
Cat	0.0 (632)					0.0 (4)	0.0 (1)				
Chipmunk				0.0 (6)							
Ermine					0.0 (4)						
Grey Squirrel				0.0 (2)							
Groundhog				0.0 (5)							
Marmot					0.0 (1)						
Muskrat				0.0 (50)	0.0 (18)						
Walrus											3.8 (441)
Whale Finback											0.0 (81)
Whale Humpback											0.0 (15)
Whale Piked											0.0 (2)
Whale Sei											0.0 (119)
Whale White											0.0 (14)
Whale Sperm											0.0 (1)
Seal Bearded											0.0 (29)
Seal Harp											0.0 (28)
Seal Jar											0.0 (244)
Arctic Hare											0.0 (25)
Lemming											0.0 (21)

Toronto and Montreal in the 1940s and early 1950s provided an historical prevalence rate of 1.5% to 7.3% (n=1,441).[9-12] In contrast, serological surveys conducted during the same time in northern Canada showed a much larger proportion of the population (22%, n=82; 25%, n=100; 46%, n=91; 30%, n=478) had been exposed to *Trichinella* antigens.[13-15] More recently, two serological studies conducted in northern Ontario and northern Quebec found a lower but still significant incidence of exposure among Cree and Ojibway populations near Sault-Saint Marie (2%, n=320) and in communities around Ungava Peninsula (5.5%, n=1,195).[16,17]

Trichinellosis was listed as a nationally reportable human disease by the Department of Health in 1971.[18] The mean number of human trichinellosis cases reported annually between 1970 and 1997 was 18.2 ± 13.2 annually (range 3 to 49, Figure 1).[19] Data from Health Canada and published reports, however, provide different estimates of the number of human cases prior to 1971. Ozere, in 1962, noted that the number of reported cases of human trichinellosis in the years 1930-1960 varied between 15 and 20 per annum and contradicted Health Canada's reports of 8.0 ± 8.4 cases per annum over the same years.[19,20] The mean number of cases reported increased between 1960 and 1970 to 40.7 ± 38.9 per annum. The reason for this increase is unclear.

Generally, only severe cases of trichinellosis are brought to the attention of medical personnel. The non-specific clinical signs of the disease make diagnosis difficult and it is likely that many human cases are unreported. Thus, an accurate count of the number of people infected with *Trichinella* each year is difficult to estimate. Since 1971, approximately 72% of reported human cases originated in the Northwest Territories and Quebec, where the infection rate has been 200 times the national rate. Until 1993, when there was an outbreak of trichinellosis in Ontario caused by *T. spiralis*-infected wild boar meat, the last reported pig-associated human trichinellosis case was in 1980.[21] Interestingly, the wild boar on the farm of origin were imported from the southern regions of North America. *Trichinella* is, however, occasionally identified at slaughter in swine from a small region of Nova Scotia.[22]

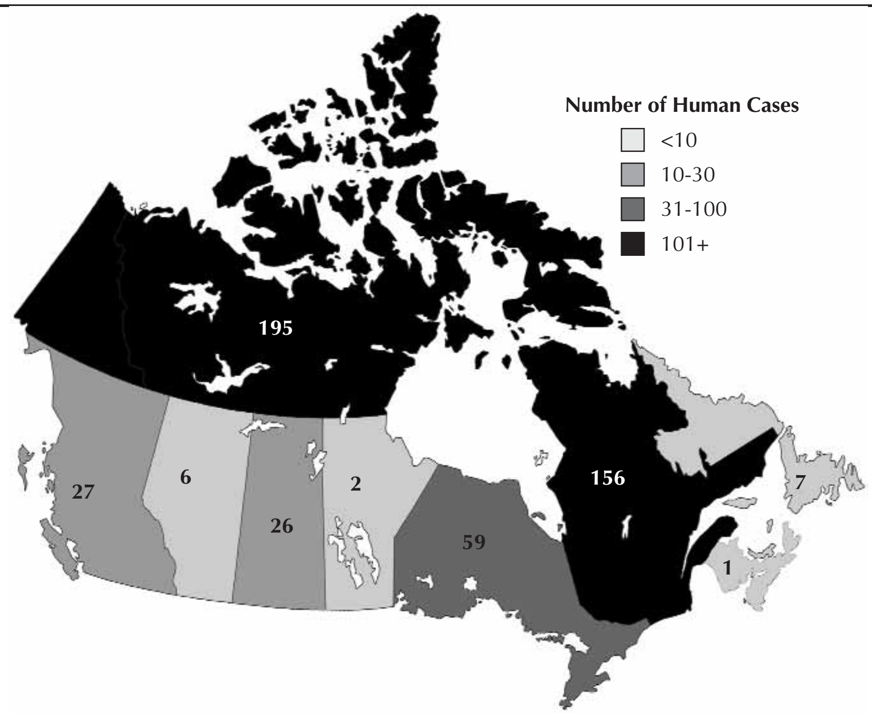

Figure 1. Summary of human trichinellosis cases reported by each province in Canada from 1970 to 1997.

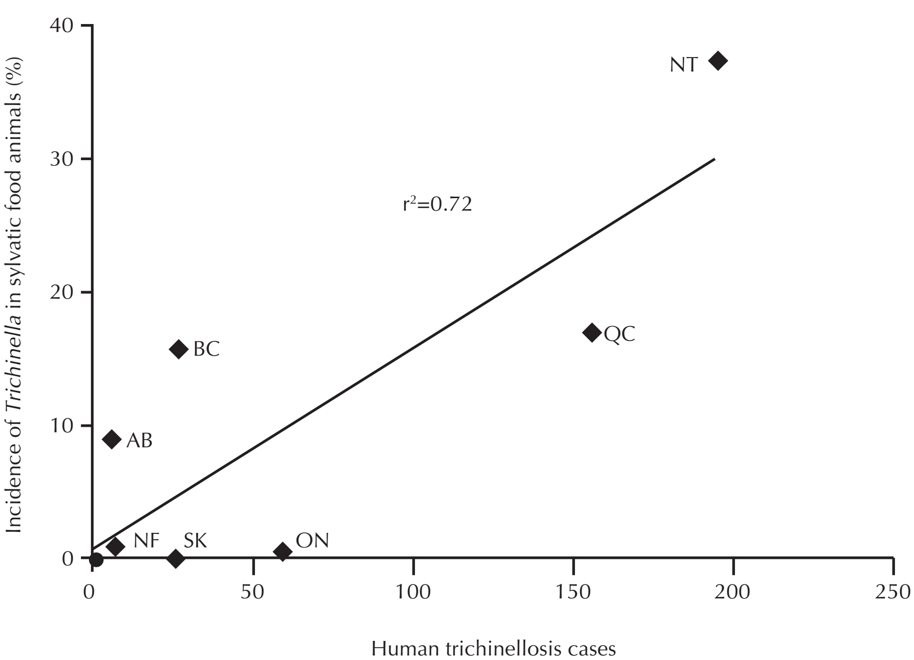

Figure 2. Linear relationship between reported human cases of trichinellosis and prevalence of *Trichinella* in game animals sorted by Canadian province.

Around the world, *T. spiralis* infections are generally associated with consumption of undercooked or raw pork.[6] In Canada, however, since most cases of human trichinellosis over the last 17 years have implicated meat other than pork, sylvatic species such as *T. nativa* are more likely responsible. Meat from wild animals such as polar bear, black bear, cougar, seal and walrus have been found infected with *Trichinella* sp. and sporadic outbreaks have occurred in communities where consumption of meat from selected species of wildlife is common.[23-27]

Sylvatic trichinellosis in Canada

In Canada, *Trichinella* have been found infecting more than 25 species of mammals. Little is known about the ecology or dynamics of sylvatic cycles except that host species with high prevalence of *Trichinella* infections have feeding behaviours which include scavenging or cannibalism. Of the eight described *Trichinella* biotypes, five have been found in North American wildlife[28] and all are capable of infecting people.

A fundamental hindrance to understanding sylvatic trichinellosis has been the low number of wild animals examined in most studies. To help alleviate this problem, a summary of the prevalence of *Trichinella* in mammalian species reported over the past 47 years in Canada is presented in Table I. While this summary may not provide an accurate reflection of current infection prevalence or population dynamics, certain trends are apparent.

From the pooled survey data, there appear to be two regions in Canada where sylvatic trichinellosis was and may still be common. In the eastern Arctic, the majority of polar bears and grizzly bears examined were infected, as were a significant proportion of foxes and coyotes. The second region was eastern British Columbia and western Alberta where a wide variety of mammals were infected including grizzly bears, black bears, cougars, wolverines, lynx, bobcats and martins. The identification of these two regions may have been due to regional biases in sampling a single species of *Trichinella* sp. found in different hosts with varied geographic distributions across northern Canada and cold high mountain altitudes.[23] Alternatively, the two regions may represent geographic ranges of two distinct *Trichinella* species. For example, the poorly characterized biotype T6 has been found in the Colorado area of the American Rocky Mountains and has been shown to be less resistant to freezing temperatures than *T. nativa*.[29]

Interestingly, the data indicate that the prevalence of *Trichinella* sp. infection in black bears is less than 1.5% across most of Canada with the exception of the Kootenay region of British Columbia where 12% of black bears (n=192) were found infected.[30] The generally low prevalence was surprising since black bears are opportunistic scavengers and some are frequent visitors to rural garbage dump sites. In contrast, 5-10% of black bears in Montana, USA, were shown to be infected with *Trichinella*.[30] The high prevalence of trichinellosis in Kootenay region may be because the parasite is more common in that area or because the strain of *Trichinella* found there has a greater infectivity for bears than strains found elsewhere in Canada. Comparative prevalence and biotyping studies are required to resolve this issue.

Small carnivores such as weasels, martins, fishers and mink showed varying infection prevalence across Canada with a national mean infection rate of 4.8%. Raccoons and skunks, which survive well in rural and urban landscapes, have a low infection prevalence (0.3%) and small herbivores such as squirrels, rabbits, beavers, groundhogs, muskrats and chipmunks in Canada, also have a low *Trichinella* prevalence, consistent with findings in the United States.[31] Schmitt et al. (1978) reported finding *Trichinella* larvae in a survey of ground squirrels (0.4%, n=1,639), mice (0.6%, n=2,244), and shrews (0.3%, n=329) in British Columbia.[32]

Data suggesting that some animal species have zero prevalence (Table I) may not be accurate if the sample numbers are less than 300 (CI 95%, for incidence rate of 1%).[33] The methods of larval detection used in these studies were variations on the acid-enzyme digestion or trichinoscope techniques.[34]

Relationships between sylvatic and human trichinellosis

Evidence from the literature suggests that *Trichinella* spp. are well established in wildlife across Canada, including commonly consumed game animals. Human (1970-1997) and wildlife *Trichinella* incidence data (1951-1997) are correlated by geographic region. Despite inadequate reporting and incomplete data sets, a positive correlation was found using linear regression between the number of human trichinellosis cases and the prevalence of sylvatic trichinellosis when grouped by provincial or territorial boundary (r^2 = 0.36). When only commonly consumed wild game animals are considered, the regional correlation with human trichinellosis cases increased (r^2 = 0.72) (Figure 2). This finding suggests that people living in the eastern Arctic, northern Quebec and the Rocky Mountain regions of British Columbia and Alberta are most at risk of being infected with *Trichinella* larvae.

Larvae of *T. spiralis* can be killed through adequate exposure to freezing temperatures.[35] Legislation governing meat inspection has used this strategy to ensure meat safety, and the common use of home freezers has been an important additional mechanism of preventing human trichinellosis. However, different isolates of *Trichinella* differ in resistance to freezing and *T. nativa* is well adapted to cold temperatures.[36] One isolate collected from a coyote in northern Alberta remained viable at -10°C for 18 months[37] and an isolate of *T. nativa* obtained from a wolf in New Brunswick was viable after being stored for over a year at -20°C at our laboratory. It should not be assumed, therefore, that freezing will kill larvae found in wild hosts in northern temperate regions. There is a need to biotype any *Trichinella* found in meat used or intended for human consumption. Identification of isolate biotype causing human trichinellosis cases can now be accomplished by DNA analysis on isolated larvae and every effort should be made to do so and report these findings.[38,39] Assistance in biotyping can be obtained from Canada's national Centre for Animal Parasitology where a database has been established for assembling findings of *Trichinella* and trichinellosis.

Game meats are commonly dry cured. The effectiveness of dry curing for sausages or jerky is dependent on the salt concentration, water content, time and temperature. Curing pork with less than 3.5% salt will not kill *T. spiralis* larvae.[40] Drying ground pork to below 9% water at a temperature of 49°C is sufficient to kill larvae, but at 39°C, dehydration below 5.8% water is required.[40] It should be noted that the conditions required to kill sylvatic isolates are not known. The Canadian Food Inspection Agency recommends that meat should be well cooked and heated to obtain a uniform internal temperature of at least 77°C prior to consumption.[41]

Farmers, as well as veterinarians, should be kept aware of the risks of raising swine in areas where contact with rats and other wildlife can occur. Hunters, game-meat processors and consumers of wild carnivores and omnivores should be made aware of the health risks in consuming raw or undercooked game meat and physicians should be aware that people infected with species of *Trichinella* other than *T. spiralis* may present with symptoms that differ from the classic case.

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