A COMPARATIVE STUDY OF THE DIETARY HABITS AND HELMINTH FAUNA OF CANADA LYNX (*Lynx canadensis*), RED FOX (*Vulpes vulpes*) AND EASTERN COYOTE (*Canis latrans*) ON INSULAR NEWFOUNDLAND

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A comparative study of the dietary habits and helminth fauna of Canada lynx (*Lynx canadensis*), Red fox (*Vulpes vulpes*) and Eastern coyote (*Canis latrans*) on insular Newfoundland

by

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Abstract

The morphology, diet and helminth fauna of 366 Canada lynx (*Lynx canadensis*), 112 Red fox (*Vulpes vulpes*) and 75 Eastern coyote (*Canis latrans*) were examined from insular Newfoundland. Morphometric data of each species was similar to that reported elsewhere. Lynx diet was less diverse than that of either canid and dietary overlap was highest between Red fox and coyote. Snowshoe hare (*Lepus americanus*) was the most important food item to lynx while Red fox depended more on other prey items including Meadow voles (*Microtus pennsylvanicus*). Woodland caribou (*Rangifer tarandus*) was more prominent in coyote diets. Examinations for parasites were carried out on the heart, lungs, urigenital system and digestive tracts only. Twelve, seven and ten helminth species were recovered from lynx, Red fox and coyote respectively. *Taenia macrocystis* and *T. laticollis* were only recovered from lynx. *Taenia pisiformis* and *Toxascaris leonina* were recovered in lynx and coyote, with higher prevalences in lynx. *Crenosoma vulpis* was most prevalent in Red fox and coyote, while *T. ovis krabbei* and *Toxocara canis* were more prevalent in coyotes. Seventy-three percent of lynx, 10.3% of Red fox and 16.0% of coyotes were parasitized by two or more co-occurring parasite species. Multiple parasite infections were significantly higher in juvenile Red fox and coyotes. The geographic areas studied in this report did not contain all of the species under consideration. Some areas were more heavily represented by some species (i.e. Red fox) which were collected during the Rabies Eradication Program carried out in northern and western Newfoundland during 2002-2004 whereas there was one specimen from central Newfoundland and none from the other locations. There were significant differences in parasite prevalence patterns and parasite species diversity with respect to intrinsic and extrinsic factors associated with each host and geographic location where specimen numbers permitted. Of the areas with sufficient sample sizes three main areas of parasite infection were identified; Northern Peninsula, West Coast and North East Coast. Higher prevalences were recorded from West to East. This study represents the first record of *Physaloptera rara* from Red fox and coyotes in insular Newfoundland. *Angiostrongylus vasorum* was recovered from one coyote on the North East Coast. *Taenia ovis krabbei* was recovered from coyotes on the North East Coast and Central Newfoundland but was previously only known from Arctic fox in northern Newfoundland. Diversity of parasite species in insular Newfoundland may be increasing as a result of the establishment of Eastern coyote populations.

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1. Introduction.

Research regarding the helminth fauna of furbearers in insular Newfoundland has been limited, with most work directed towards the parasite parameters of a single species. No studies have examined the helminth fauna of animals that co-occur, occupy similar niches, and utilize similar prey species. Different species using the same habitat often provides a situation whereby parasites have a greater opportunity to spread from one host to another. This situation is further exacerbated when the prey base for the furbearers is limited to very few species.

Lynx canadensis (Canada lynx), *Vulpes vulpes* (Red fox) and *Canis latrans* (Eastern coyote) are important predators throughout Eastern Canada. Several studies have examined the parasites of these hosts elsewhere in North America and have related the parasites found to the dietary habits of each host (Freeman *et al.* 1961; Van Zyll de Jong, 1966 a; Holmes and Podesta, 1968; Baron, 1970; Pence *et al.* 1978). There have only been a few sporadic reports on the helminth fauna of these hosts in Newfoundland (Threlfall, 1969; Bursey and Burt, 1970; Smith and Threlfall, 1973; Forsey, 1992; Jefferey, 2002; Levandier, 2003) (see Appendix for a detailed list).

The Canada lynx has a Holarctic distribution and is one of the most common felids of the boreal forests of North America and is most likely to be found in dense coniferous forests interspersed with bogs, swamps and thickets (Saunders, 1961; McCord and Cardoza, 1983). Its prime habitat is composed of a mosaic of both mature and young forests (Parker *et al.* 1983). Early successional forests provide food and cover for their principal prey, Snowshoe hare (*Lepus americanus*), while mature coniferous stands are important to Red squirrel (*Tamiasciurus hudsonicus*) which is an important alternative prey species (Ray, 2000). Newfoundland represents one of two areas in Eastern Canada, the other being Cape Breton Island, Nova Scotia, where the lynx is completely isolated from the remaining continental range of the species (Parker *et al.* 1983).

The Canada lynx is a medium sized, reddish to grey-brown felid, with a flared facial ruff, black ear tufts and long hind limbs that create a stooped posture. The belly, legs, and feet are typically a greyish white or buff white. Their paws are broad and produce a snowshoe–like effect that enables them to traverse deep snow quite easily (Banfield, 1974). Lynx are shy, solitary animals and except for females with kittens, do not hunt together.

Sexual dimorphism occurs within this species with ranges of standard measurements being greater in males than females (Quinn and Parker, 1987; Tumilson, 1987). Weights of adult lynx often vary according to sex, subspecies, and geographic location. In Canada, weights of adult male and females range from 8.6 to 10.6 kg and lengths from 71.0 to 87.6 cm (McCord and Cardoza, 1983). Weights and lengths of Newfoundland lynx (*Lynx canadensis subsolanus* Bangs) have been reported as being higher than elsewhere in North America. Saunders (1964) reported an average range of weights and lengths of females and males as 5.0 to 11.8 kg, and 73.7 to 106.7 cm respectively. Mating occurs between March and April and peaks around the third week in March, gestation lasts 63 to 70 days and litter sizes range from 1 to 5 kittens (Saunders, 1961).

Among felid predator-prey relationships, there are none as closely tied as that between the lynx and the Snowshoe hare (Van Zyll de Jong, 1966 a; Nellis *et al.* 1972; Brand and Keith, 1979; Ward and Krebs, 1985). The lynx is a dietary specialist, meaning that it preys primarily on one type of prey, i.e. the Snowshoe hare. Few studies have documented the feeding habits of lynx in Newfoundland (Saunders, 1963 a; Levandier, 2003), although there are others that have been carried out in other regions of Canada (Van Zyll de Jong, 1966 a; More, 1976). All studies of food habits of lynx have shown that the Snowshoe hare is the dominant prey item (Brand and Keith, 1979; Van Zyll de Jong, 1966 b), particularly when hares are abundant. Hares normally constitute approximately 60 % of the winter diet and 40 % of the summer diet.

The near total dependency of lynx on the Snowshoe hare for food has locked lynx populations into the Snowshoe hare cycle, thereby establishing a cycle of approximately 10 years that is relatively synchronous over vast areas of North America (Smith *et al.* 1986). However, lynx are prey switchers, and often do so when hare populations decline (Brand *et al.* 1976). During summer months and times of hare scarcity, lynx will utilize alternative prey items that are at higher densities than the hare. Such alternative or "buffer" prey species may include mice (*Peromyscus* spp.), voles (*Clethrionomys* spp. and *Microtus* spp.), Red squirrel, Ruffed grouse (*Bonasa umbellus)* and ptarmigan (*Lagopus* spp.). Lynx may also consume vegetation (Saunders, 1963 a) and grass has often been found in the stomachs of trapped lynx (Saunders, 1963 a; Stewart, 1973). The presence of grass in lynx stomachs is usually interpreted as an example of aberrant feeding behaviour after capture. Predation on large mammals is uncommon; however, lynx may occasionally prey on Woodland caribou (*Rangifer tarandus*) and moose (*Alces alces*) calves (Saunders, 1963 a), and in rare cases adult animals. Caribou or moose hair found in lynx scats has often been associated with their scavenging on carrion.

Little is known of the parasitology of lynx. Van Zyll de Jong (1966 a) reported helminths from lynx in Alberta and the adjacent Northwest Territories of which *Taenia rileyi* was the most prevalent cestode and *Toxascaris leonina* the most common nematode. Other helminths recovered included *Taenia pisiformis, Taenia multiceps, Troglostrongylus wilsoni, Toxocara cati,* and *Physaloptera praeputialis*. Smith *et al.* (1986) recovered six helminths from Canada lynx in northern Ontario: *Troglostrongylus wilsoni, Cylicospirura felineus, Toxascaris leonina, Toxocara cati, Taenia laticollis,* and *T. rileyi*. *Aelurostrongylus* spp. and *Oslerus* spp. have been recovered from the respiratory systems of lynx (Bowman, 2000) and *Oncicola canis* from the small intestine (Scmidt, 1968). There have been several studies on the parasites of Canada lynx in Eastern Canada (Threlfall, 1969; Bursey and Burt, 1970; Levandier, 2003). Threlfall (1969) reported the parasites *Taenia laticollis* and *Toxascaris leonina* from two lynx found near Gander, Newfoundland. Bursey and Burt (1970) examined lynx from New Brunswick, Nova Scotia and Newfoundland for the presence of adult *Taenia macrocystis*. Fourteen lynx were examined and all were infected with this parasite. Levandier (2003) examined 48 lynx in Newfoundland and recovered the cestode *T. macrocystis*, and the nematodes *T. wilsoni* and *T. leonina*.

The Red fox, *Vulpes vulpes,* has the largest geographic range of any living carnivore and is widely distributed in North America, Europe, Asia, Northern Africa and

Australia (Forsyth, 2000). This animal is found in an enormous variety of habitats such as forests, mixed woodlands, meadows, plains, and mountainous regions.

The Red fox has many color phases with the red, silver and cross (Storm *et al.* 1976) phases being most common. This species of fox has black tipped ears, black cheek patches, a white throat, and black "leg stockings". The Red fox is the largest member of the ten species in the genus *Vulpes* and varies in size throughout its range with males typically larger and heavier than females. Total body lengths of Red fox populations in mainland Canada range from 82.7 to 109.7 cm with a tail length of 29.1 to 45.5 cm, and weights range from 3 to 7 kg (Storm *et al.* 1976). Red foxes are monogamous and breed once a year between December and March, depending on the latitude (the further north, the later the breeding season). Litter size ranges from 1 – 5 pups (Storm *et al.* 1976).

The Red fox is a non-specific predator, one that forages on a variety of prey. It is also a proficient scavenger, insectivore, and frugivore. Season, habitat, and availability of food all influence their dietary patterns. Their small size and agility make them particularly well suited for killing small prey. Dietary studies of the Red fox in North America indicated that they feed on a variety of prey and plant material including voles (*Microtus* spp.), shrews (*Sorex* spp.) and lagomorphs (*Lepus* spp.), birds, fish, carrion and berries (Johnson, 1970; Hockman and Chapman, 1983; Jones and Theberge, 1983; Voigt, 1987). To date there have been two studies on the food habits of this animal in insular Newfoundland, by Dodds (1955) and Tucker (2003) both of whom reported mammals such as Snowshoe hare, mice (*Peromyscus* spp.), and voles (*Clethrionomys* spp. and

Microtus spp.) as prominent food items recovered, followed by vegetation. The limited mammalian fauna of Newfoundland restricts Red fox diet to only a few prey species.

Several surveys of the helminth parasites of Red foxes have been conducted throughout North America. Samuel *et al.* (1978) examined Red foxes from south-western Manitoba and recovered five helminths from them of which *Toxascaris leonina, Echinococcus granulosus* and *Alaria americanae* were most prevalent. Dibble *et al.* (1983) found *Taenia pisiformis* and *T. leonina* to be the most prevalent parasites in Red foxes in central Wisconsin. In South Carolina, several helminths were recovered from Red foxes including *Trichinella spiralis*, *Trichuris* spp., and *Ancylostoma caninum* (Davidson *et al.* 1992). In Minnesota, Erickson (1944) reported the kidney worm, *Dioctophyme renale* in Red foxes. In Newfoundland, Threlfall (1969) examined one Red fox infected with *Uncinaria stenocephala* and *Crenosoma vulpis,* while Smith and Threlfall (1973), who examined three Red foxes from the Avalon Peninsula, recorded the presence of *Angiostrongylus vasorum* for the first time in two foxes, and one with *C. vulpis.* Forsey (1992) examined the viscera of 74 Red foxes from the western and northern regions of Newfoundland and recovered nine helminths; *Taenia* spp., *Mesocestoides* spp., *Diphyllobothrium* spp., *U. stenocephala, C. vulpis*, *T. leonina*, *T. canis*, an unidentified spirurid species and several ascarid species. Jefferey (2002) necropsied the lungs and hearts of 366 Red foxes from six regions of Newfoundland and reported a prevalence of 87% and 56% for *C. vulpis* and *A. vasorum* respectively.

Coyotes moved eastward on a northern front out of Minnesota, Wisconsin and Manitoba and into Ontario during the early 1900's (Parker, 1995), and have recently become established in Newfoundland. The first observation of the Eastern coyote in insular Newfoundland occurred on March 29, 1985 when three animals were sighted on pack ice near the shore of the island's West coast (M. McGrath, pers comm., 2003). Coyotes occupy a wide range of habitats from grasslands, agricultural areas, and dense boreal forest (Nowak, 1978), but tend to be more abundant in open habitats (Ray, 2000).

Coyotes physically resemble wolves to such a degree that they are sometimes mistaken for them. However, coyotes are smaller, with a slender build, and have proportionately larger ears and slender legs. Size varies regionally and between sexes, with males being larger and heavier than females. Body lengths of Eastern coyotes range from 100 to140 cm with tail lengths of 30 to 40 cm while weights range from 7 to 23 kg (Banfield, 1974; Gier, 1975; Bekoff, 1977; Parker, 1995; Dumond and Villard, 2000). The size of Eastern coyotes is often overestimated in the field due to their long pelage (Bekoff, 1977; Voigt and Berg, 1987) which ranges from cream to dark rufous (Gier, 1968; Andrews and Boggess, 1978), with throat and belly areas that are light grey or white, and a shoulder saddle or mane of black tipped hairs (Voigt, 1987). The larger body size of the Eastern coyote may be attributed to past hybridization with red or grey wolves (*Canis rufus* or *Canis lupus* respectively) (Parker, 1995) and/or domestic dogs (*Canis lupus familiaris*) (Gompper, 2002).

Coyotes are monesterous canids that form monogamous pair bonds that may last for more than one breeding season. Mating generally occurs in late – mid February, and pups are born after a gestation period of 60 to 63 days (Parker, 1995). Litter size varies with prey availability, and ranges from 4.8-5.1 during times of low prey density to 5.8-6.2 during times of prey abundance (Gier *et al.* 1978).

The coyote has been studied extensively throughout most of its North American range (Bekoff, 1978) and remains one of the most controversial predators (Parker and Maxwell, 1989). This is especially so along the northeastern limits of its range, where the coyote has only recently become established, and its relationship with potential prey species, and other predators, remains virtually unknown. The impact of this new and important predator upon Newfoundland species, both predators and prey, remains uncertain. In most areas of its range the coyote is referred to as an opportunistic and generalist predator and scavenger, living mainly on a diet of rodents and lagomorphs, while scavenging the remains of larger mammals, often domestic (Gier, 1975; Bekoff, 1977).

The food habits of the coyote have been studied in many parts of its range (Knowlton, 1964; Hamilton, 1974; Hilton, 1976; Neibauer and Rongstad, 1977; Todd *et al.* 1981; Todd, 1985). Diets of Eastern coyotes in Atlantic Canada were described by Moore and Millar (1984, 1986) and Patterson (1994) in Nova Scotia, and Parker (1986) in New Brunswick. No previous studies have been conducted on Eastern coyote food habits in Newfoundland.

It has been known that coyote diets vary markedly within and between habitats (Gier, 1975; Bekoff, 1977). The coyote's body size, bioenergetics, and flexible social behaviour enable them to prey on animals of all sizes (Andrews and Boggess, 1978).

Rabbits (*Sylvilagus* spp.) and hares (*Lepus* spp.) are common in winter diets and may be the major food item by both percent occurrence and biomass. Small mammals such as voles (*Cleithrionomys* spp. and *Microtus* spp.) and mice (*Peromyscus* spp.) and fruits such as blueberries (*Vaccinium angustifolium*) and raspberries (*Rubus* spp.) are important during the summer and fall. In addition, coyotes prey on larger animals such as White-tailed deer (*Odocoileus virginiansus*) (Richens and Hugie, 1974; Todd and Keith, 1983; Moore and Millar, 1986). In Newfoundland, there is evidence that they have expanded their diet to include juvenile and adult moose and caribou (E. Baggs, pers comm., 2004).

Cyclic fluctuations of northern coyote populations have been documented from fur returns since the early 1900's (Keith, 1963) and reflect the 10-year cycle of the Snowshoe hare. However, there have been few long-term field studies of functional and numerical responses of coyotes to changing hare abundance (Todd *et al.* 1981; Murray *et al.* 1994; O' Donoghue *et al.* 1998).

The wide geographic range, behavioural characteristics, social organization, and varied food habits of coyotes potentially bring them into close contact with a diversity of helminth parasites. While many of these helminths are of little consequence to their hosts, there are usually several in any geographic region which demonstrate some degree of pathogenicity. Furthermore, coyotes harbour several helminth parasites in common with domestic dogs (Holmes and Podesta, 1968; Samuel *et al.* 1978; Pence and Menzier, 1979). Wild coyote populations may therefore serve as reservoirs for parasites of domestic dogs, and vice versa especially in geographic areas where coyote densities are high.

Coyotes are known to harbour 53 identified helminths: 18 cestodes, 24 nematodes, nine trematodes and two acanthocephalans (Custer and Pence, 1981). Freeman *et al.* (1961) examined 339 coyotes from Ontario and recovered four cestodes: *T. pisiformis*, *T. hydatigena*, *T. crassiceps*, and *Mesocestoides* spp., with *T. pisiformis* being most prevalent. Samuel *et al.* (1978) examined 43 coyotes, from south-western Manitoba and recovered 11 helminths of which *T. pisiformis, T. leonina*, *T. hydatigena, Echinococcus granulosus, E. multilocularis* and *U. stenocephala* were most prevalent. Foreyt and Foreyt (1982) examined 122 coyotes from Washington State and Idaho for helminths and *T. leonina* was the most common parasite recovered. Holmes and Podesta (1968) examined 73 coyotes from the forested regions of Alberta. Eighteen helminths were recovered, of which *T. leonina, T. pisiformis, U. stenocephala, Filaroides olseri, D. renale,* and *Alaria americanae* were the most prevalent. *Trichinella spiralis*, *Trichuris* spp., and *O. canis* have also been reported from coyotes (Gier and Ameel, 1959; Seesee et al. 1983). No studies have thoroughly examined the parasites of the Eastern coyote in Newfoundland.

The recent expansion of the Eastern coyote in insular Newfoundland could result in the establishment of exotic parasite species that might negatively affect Canada lynx, Red fox and other native species. Also of concern is the potential spread of the tapeworm *Taenia ovis krabbei* which is normally associated with the predator–prey relationship between wolves and moose elsewhere in Canada (Samuel *et al.* 1978). With no wolves on the Island of Newfoundland, the Eastern coyote may serve as the definitive host for this parasite which could have detrimental affects on the moose population, as well as cause increased infections of this parasite in other hosts such as the Canada lynx, Red fox and Black bear (*Ursus americanus*).

The purpose of this study is to examine the dietary habits and enteric parasites of three mammalian predators in Newfoundland: Canada lynx, Red fox and Eastern coyote and determine any relationships between their diets and parasite burdens. The composition of the helminth fauna of each species will be described and the epizootiology of the helminths in relation to intrinsic (age and sex) and extrinsic (geographic regions) factors of each host discussed. The extent to which helminths are shared by all three species and the identity of any previously unrecorded helminths will also be identified.

2. Materials and Methods.

2.1 Site descriptions.

Newfoundland is located between 40° and 50° N and between 50° and 60° W in the Northwest Atlantic Ocean. Its vegetation is the most easterly extension of North America's boreal forest (South, 1983). Newfoundland has a temperate maritime climate; winters are usually mild with an average temperature of 0°C. Six geographic regions (Meades and Moores, 1994) were chosen for sample collections and are referred to according to their geographical locations (West Coast, Central Newfoundland, North East Coast, Northern Peninsula, Avalon Peninsula, and South Coast) (Figure 1).

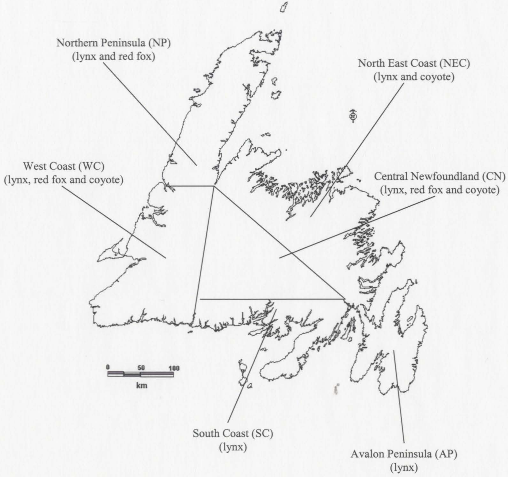

Figure 1: Map of insular Newfoundland indicating the geographic locations where Canada lynx (*Lynx canadensis*), Red fox (*Vulpes vulpes*) and Eastern coyote (*Canis latrans*) were collected during the 1999-2003 trapping years.

2.1.1 West Coast (WC).

This region is characterized by a humid climate with a relatively longer frost - free period than most other regions of Newfoundland. The *Dryopteris – Hylocomium* Balsam Fir forest type is the zonal forest of this region. Balsam Fir is the dominant forest cover, with Yellow Birch being common.

2.1.2 Central Newfoundland (CN).

This region has the most continental climate of any other part of insular Newfoundland, with the highest temperatures in the summer and lowest in the winter. The *Hylocomium* Balsam Fir forest is the dominant forest of this region, with extensive Aspen growth. Yellow Birch is absent from this region; alders are common.

2.1.3 North East Coast (NEC).

This region represents a narrow coastal zone 20-25 km extending from Bonavista Bay to the Baie Verte Peninsula. Black Spruce and Balsam Fir predominate. White Spruce is more common than in Central Newfoundland. *Alnus crispa* is the dominant Alder type.

2.1.4 Northern Peninsula (NP).

This region has a relatively shorter growing season of 110-150 days compared to other regions. Precipitation is low. Balsam Fir is the dominant forest cover, except at high elevations on the eastern portion of the peninsula where Black Spruce is dominant.

2.1.5 Avalon Peninsula (AP).

The forests of this region consist primarily of Balsam Fir with a mixture of White Birch and Yellow Birch. Black Spruce is abundant in wet areas.

2.1.6 South Coast (SC).

This region has the coldest summers but relatively mild winters that cause intermittent snow cover. The landscape consists of Balsam Fir, with Yellow Birch present in valley regions.

2.2 Collection and necropsy of carcasses.

Lynx, Red fox and Eastern coyote carcasses were obtained from licensed trappers by staff of the Science Division – Wildlife and Protected Areas of the Department of Tourism, Culture and Recreation of the Government of Newfoundland as part of the furbearer management program. Most of the Red foxes were obtained from the Animal Health Division of the Department of Natural Resources. In 1988, a rabies outbreak in Labrador spread to the Northern Peninsula of Newfoundland. Rabies was again found on insular Newfoundland, with the majority of cases reported from the Northern Peninsula and West Coast. The majority of Red foxes used in this study were acquired from the Rabies Eradication Program that took place during 2002-2004 (H. Whitney, pers comm., 2003). Carcasses were immediately frozen upon receipt by the respective government agencies and were maintained in that state until examination. Lynx were chosen from trapping years 1999-2000 through to 2002-2003, and Red fox and coyotes from 2000-2001 through to 2002 – 2003. Date and location of capture were recorded for each animal.

Research has shown that cementum annuli occur in the teeth of many North American carnivores and has been used as a reliable indicator of age (Crowe, 1972). The lower left canine tooth was removed from most animals to estimate age by counting cementum annuli (Matson's Laboratory, Milltown, Montana, USA). This process requires the assumption that the first cementum layer is deposited during the animal's second winter and that subsequent annuli represent incremental growth over a one-year period (Crowe, 1972). Kits or young-of-the-year (YOY) (6-9 months) were identified by incomplete closure of the basal foramen in the roots of the canine tooth. Older animals were grouped as juveniles (1.5 – 2.5 years) and adults (3.5 years and older) on the basis of closure of this foramen (Crowe, 1972). Saunders (1961) found that the basal foramen in Canada lynx closed at between 13 and 18 months of age, while other studies indicate closure at about 20-23 months in Red foxes and coyotes.

Carcasses were thawed until pliable to allow for collection of morphometric parameters including: total length, tail length, shoulder height, right hind foot, heart girth, neck and head circumferences. Sex was determined through gross observation. Total length was measured from the tip of the nose to the last caudal vertebra; shoulder height, distance from the tip of the toe along the radial surface of the extended foreleg to the dorsal tip of the spinous process of the thoracic vertebra. All measurements were made to the nearest centimeter. Total weights (un-skinned and skinned) were measured to the nearest kilogram. If the animals had not previously been skinned a total un-skinned weight was taken. Skinned weights were recorded following pelt removal. A longitudinal incision was made at the anus along the mid-ventral rafe between the rectus abdomini muscles to the sternum. The sternum was cut along its length and the incision extended to the apex of the chin (Deblase and Martin, 1981).

A visual inspection of all specimens was conducted to determine if there were any parasites within the coelomic cavity or visceral mesenteries. Prior to the removal of the partially frozen internal organs, the esophagus, stomach, small and large intestines were isolated from each other using ligatures which were placed at the start of the esophagus, the cardiac sphincter, the pyloric sphincter, the iliocoelic sphincter and the terminus of the rectum. The diaphragm was cut from the thoracic wall and the viscera were removed, placed in a labeled plastic bag and returned to the freezer until parasitological examination.

2.3 Extraction of dietary elements and parasites.

Following thawing, the alimentary tract was opened longitudinally to remove its contents. The mucosa of the digestive tracts was examined under a 4x magnifier for the presence of parasites. Particular attention was paid to the removal of cestode scolices from the intestine which was achieved by gently scraping along the inner length using the smooth edge of a scalpel blade. The contents of the digestive tract were then washed through progressively smaller screens (400 mm - 0.42 mm) and parasites and food particles were isolated. Fleshy food items were preserved in 10% formalin, while fur, bones, feathers, etc., were placed in petri dishes and air-dried prior to examination and identification. Cuticular scale patterns of hairs were identified using a stereomicroscope and compared to a hair guide (Adorjan and Kolenosky, 1969). Stomach contents were separated by gross identification according to category: mammal, bird, insect, plant and miscellaneous. Lynx, Red fox and coyote fur were commonly found as part of the stomach contents, but were not considered to be food unless they were accompanied by large chunks of flesh believed to belong to that species. Stomach analysis data were used to relate the parasites recovered from each animal to their dietary habits as well as to determine if any animals were infected with the same parasite species. Parasites were placed in glass vials containing 5% glycerine in 95% ethanol and retained for further analysis.

The remaining viscera were handled in the following manner: the heart and lungs were opened separately, the latter along the bronchi and bronchioles and washed with water into a tray. To examine for *C. vulpis*, each lobe of the lung was separated from the heart by severing the main pulmonary artery and vein. Lungs were divided into seven lobes (Evans and DeLahunta, 1971; Jefferey, 2002), a cranial, middle, and caudal (diaphragmatic) lobe on the left side, and cranial, middle, caudal and accessory lobes on the right side. Each lobe was opened in a shallow tray of water and contents were examined at 4x magnification. To examine for *A. vasorum* the pulmonary arteries were opened along their length with fine-tipped scissors and the heart was bissected transversely through both ventricle walls. The liver and kidneys were sliced into 1 cm thick pieces and examined macroscopically (4x) for the presence of trematodes (e.g. *Alaria* spp.) and kidney worm (*D. renale*) respectively. The gall and urinary bladders were opened, washed with 5% glycerine in 95% ethanol and the mucosa was examined for parasites.

Cestodes were stained with Trichrome or Semichon's acetic carmine, dehydrated in an alcohol series (70 – 100%), cleared in xylene and mounted in permount (Meyer and Olsen, 1988). Nematodes were processed in a similar manner, and mounted in glycerol.

To facilitate examination of rostellar hooks, the rostellum when present, was cut off the scolex of some cestodes, mounted with the anterior end uppermost in glycerol and squashed with a cover slip (Bursey and Burt, 1970). Cestodes and nematodes were identified using the keys of Hall (1919), Yorke and Maplestone (1969), Khalil *et al.* (1994) and Samuel *et al.* (2001). When helminths were in poor condition (i.e. desiccated) identifications were only made to the level of genus as in the case of *Mesocestoides* spp. and *Nematodirus* spp. Following identification the parasites were counted for statistical analysis.

2.4 Data analysis.

2.4.1 Morphometric analysis.

Data were analyzed using the SPSS 11.5 statistical program (SPSS Inc., Chicago, Illinois, USA). The normality of data was tested with the Kolmogorov-Smirnov test for goodness of fit (Sokal and Rohlf, 1995). When data were not normally distributed ($p<0.05$), they were normalized by log transformation (Zar, 1999). Morphometric data for each group of animals was compared using one-way ANOVA's. In some instances sample sizes used for morphometric analysis were smaller than the actual number of animals collected for each trapping year as some animals were in poor condition or body parts were missing.

2.4.2 Dietary analysis.

Percent occurrence of prey items was calculated as the proportion of food items recovered from those gastrointestinal tracts that contained food and was compared among lynx (N=262), Red fox (N=91) and coyote (N=66) using contingency table analyses and chi-square tests.

Dietary diversity of each host was compared using the Shannon-Weiner diversity index (Brower and Zar, 1984). The formula for computing dietary diversity was:

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i)$$

where p_i is the proportional occurrence of item i in the sample. A one-way ANOVA was used to determine whether diversity indices differed between species (Hutchenson, 1970).

To compare diets between species, items were grouped into the following categories: mammal, bird, vegetation, invertebrates, fish and miscellaneous (e.g. rocks, plastics, clothing material). Calculations for percent occurrence of food items were done on an item-by-item basis as any one gastrointestinal tract may have contained more than one item. The occurrence of lynx, Red fox and coyote fur was not taken into account based on the fact that much of this material was not considered to be taken in as food but is based on the accidental ingestion of hair, due to grooming.

Horn's similarity index, also known as the Morista-Horn index (C_{mh}) (Horn, 1966) was used to determine the extent of dietary overlap between lynx, Red fox and coyote. The formula for computing dietary similarity was:

$$C_{mh} = \frac{2\sum_{i=1}^{S}(an_i \times bn_i)}{(da + bd)(aN \times bN)}$$

- S = total number of species at both sites (species A and B)
- aN = the total number of individuals of all species collected at site A
- bN = the total number of individuals of all species collected at site B
- an_i = the number of individuals of the i^{th} species collected at site A
- bn_i = the number of individuals of the i^{th} species collected at site B
- and, in the denominator, there are two terms summed that are defined as:

$$da = \frac{\sum_{i=1}^{S} an_i^2}{aN^2} \qquad db = \frac{\sum_{i=1}^{S} bn_i^2}{bN^2}$$

Horn's similarity index can range from 0 (no dietary similarity) to 1 (identical diets). When computing dietary overlap, the occurrence of miscellaneous items, vegetation found in lynx, and lynx, Red fox and coyote fur were omitted because such items were not considered dietary or food items that contributed to each species' diet.

2.4.3 Parasite analysis.

Parasite parameters (prevalence, intensity, mean intensity, abundance and dispersion) were determined according to Margolis *et al.* (1982). The prevalence of infection by parasites for sex, age, region and trapping year were compared using chi-square tests.

3. Results.

There were differences in the number of specimens of any given host and some of the parameters under consideration. Samples obtained were subject to trapping regulations set forth by the Provincial Government. The data presented show considerable variability as a result of trapping efforts or the skinning process prior to receipt of animals. For example, age was determined for those animals that had intact jawbones, and a complete set of morphometric measurements were taken on those animals having all body parts. The actual numbers used in all statistical analyses are shown in the respective tables.

3.1 Age structure.

The age structure of lynx, Red fox and coyote is shown in Figure 2a. The total number of lynx (N=330) and Red fox (N=107) for which age was determined was less than the total number of lynx (N=366) and red fox (N=112) collected. Age was determined for all coyotes (N=75) collected.

3.2 Sex ratio and morphometrics.

3.2.1 Lynx.

The sex ratio for all lynx collected (Figure 2b), males to females was 1.01:1.00 (166:164).The morphometric data for four trapping years was compared by sex for each year and age category. The statistical analysis for morphological parameters showed that significant differences for any one parameter varied by age, sex and trapping year.

3.2.1.1 1999-2000 trapping year (Table 1).

Adult lynx differed significantly by sex with respect to total length, heart girth, and head circumference, with males having larger measurements than females. Juvenile

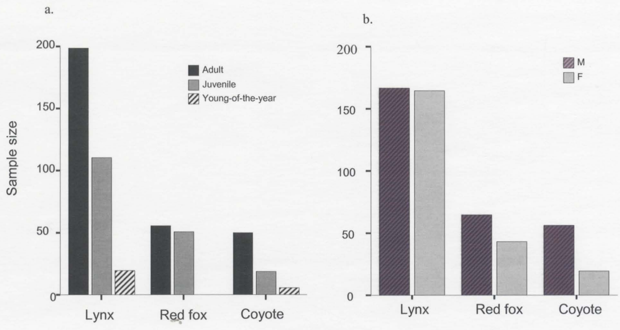

Figure 2: (a) Age structure and (b) sex of lynx, Red fox and coyote in insular Newfoundland from 1999-2000 through to 2002-2003.

Table 1: Summary of the morphometric data (mean +/- SE) for Canada lynx (*Lynx canadensis*) collected during the 1999-2000 trapping year.

Age Class	Measurements	Males (N=6)	Females (N=12)	(P)
Adults	Weight (kg)	8.79 +/- 0.56	7.89 +/- 0.15	0.110
	Shoulder Height (cm)	56.50 +/- 1.44	54.31 +/- 0.65	0.110
	Total Length (cm)	95.04 +/- 1.35	90.47 +/- 1.13	0.020
	Tail Length (cm)	10.34 +/- 0.39	10.18 +/- 0.35	0.762
	Neck Circumference (cm)	20.27 +/- 0.57	19.37 +/- 0.34	0.170
	Heart Girth (cm)	36.54 +/-1.15	32.97 +/- 0.76	0.016
	Head Circumference (cm)	28.21 +/- 0.39	26.88 +/- 0.22	0.006
	Right Hind Foot (cm)	22.36 +/- 0.56	22.18 +/- 0.91	0.888
		Males (N=30)	**Females (N=20)**	**(P)**
Juveniles	Weight (kg)	8.58 +/- 0.21	6.82 +/- 0.25	0.0001
	Shoulder Height (cm)	54.04 +/- 1.23	52.53 +/- 0.78	0.430
	Total Length (cm)	95.13 +/- 0.76	91.13 +/- 0.99	0.002
	Tail Length (cm)	10.42 +/- 0.26	9.56 +/- 0.21	0.013
	Neck Circumference (cm)	20.24 +/- 0.39	18.23 +/-0.36	0.001
	Heart Girth (cm)	36.06 +/- 1.12	32.67 +/- 0.89	0.0001
	Head Circumference (cm)	28.38 +/- 0.18	26.41 +/- 0.39	0.0001
	Right Hind Foot (cm)	22.62 +/- 0.25	21.34 +/- 0.28	0.002

Note: Differences in sample sizes (N) between those collected and those specified here are due to missing body parts of some specimens.

Note: The sex ratio of lynx examined from the 1999-2000 trapping year, males to females was 1.10:1.00.

lynx differed significantly with respect to all measurements with males being larger than females with respect to these measurements.

3.2.1.2 2000-2001 trapping year (Table 2).

Adult lynx differed significantly by sex for all variables except tail length, with males being larger than females with respect to these measurements. Juvenile lynx differed significantly with respect to weight, total length, and head circumference with males being larger than females. Young-of-the-year lynx differed significantly with respect to tail length and neck circumference with males being larger than females with respect to both measurements.

3.2.1.3 2001-2002 trapping year (Table 3).

Adult lynx differed by sex with respect to total length and right hind foot measurements, with males being larger than females with respect to both measurements.

3.2.1.4 2002-2003 trapping year (Table 4).

Adult lynx differed significantly by sex for all criteria except total length. There were no significant morphometric differences by sex for juvenile or young-of-the-year lynx.

Table 2: Summary of the morphometric data (mean +/- SE) for Canada lynx (*Lynx canadensis*) collected during the 2000-2001 trapping year.

Age Class	Measurements			
		Males (N=27)	**Females (N=17)**	**(P)**
Adults	Weight (kg)	9.68 +/- 0.21	7.99 +/- 0.24	0.0001
	Shoulder Height (cm)	57.43 +/- 0.46	55.91 +/- 0.60	0.047
	Total Length (cm)	96.30 +/- 0.75	92.22 +/- 0.65	0.0001
	Tail Length (cm)	9.88 +/- 0.26	9.61 +/- 0.15	0.370
	Neck Circumference (cm)	21.90 +/- 0.42	19.56 +/- 0.47	0.001
	Heart Girth (cm)	37.74 +/- 0.52	33.84 +/- 0.96	0.0001
	Head Circumference (cm)	28.92 +/- 0.25	26.61 +/- 0.49	0.0001
	Right Hind Foot (cm)	23.38 +/- 0.14	22.28 +/- 0.25	0.0001
		Males (N=21)	**Females (N=26)**	**(P)**
Juveniles	Weight (kg)	7.74 +/- 0.43	6.79 +/- 0.24	0.040
	Shoulder Height (cm)	55.76 +/- 0.83	54.39 +/- 0.59	0.190
	Total Length (cm)	93.12 +/- 1.22	90.04 +/- 0.62	0.020
	Tail Length (cm)	9.60 +/- 0.19	9.44 +/- 0.13	0.478
	Neck Circumference (cm)	20.02 +/- 0.53	19.04 +/- 0.29	0.110
	Heart Girth (cm)	34.18 +/- 0.94	33.08 +/- 0.49	0.300
	Head Circumference (cm)	27.64 +/- 0.35	26.22 +/- 0.16	0.001
	Right Hind Foot (cm)	22.29 +/- 0.26	22.00 +/- 0.23	0.401
		Males (N=3)	**Females (N=7)**	**(P)**
Young-of-the-year	Weight (kg)	3.73 +/- 0.87	3.43 +/- 0.23	0.645
	Shoulder Height (cm)	45.67 +/- 2.19	43.17 +/- 1.58	0.388
	Total Length (cm)	77.17 +/- 1.17	70.50 +/- 2.03	0.077
	Tail Length (cm)	9.00 +/- 0.89	6.91 +/- 0.51	0.020
	Neck Circumference (cm)	15.17 +/- 1.17	14.50 +/- 0.31	0.456
	Heart Girth (cm)	25.50 +/- 2.75	25.36 +/- 0.92	0.950
	Head Circumference (cm)	24.00 +/- 0.58	22.92 +/- 0.34	0.129
	Right Hind Foot (cm)	20.50 +/- 1.26	19.00 +/- 0.57	0.236

Note: Differences in sample sizes (N) between those collected and those specified here are due to missing body parts of some specimens.

Note: The sex ratio of lynx examined from the 2000-2001 trapping year, male to females was 1.00:1.00.

Table 3: Summary of the morphometric data (mean +/- SE) for adult Canada lynx (*Lynx canadensis*) collected during the 2001-2002 trapping year.

Measurements	**Males (N=13)**	**Females (N=19)**	**(P)**
Weight (kg)	8.22 +/- 0.32	7.97 +/- 0.24	0.550
Shoulder Height (cm)	44.09 +/- 1.22	45.67 +/- 5.61	0.650
Total Length (cm)	95.66 +/- 0.71	92.50 +/- 1.11	0.018
Tail Length (cm)	11.17 +/- 0.48	10.33 +/- 0.33	0.240
Neck Circumference (cm)	18.83 +/- 0.79	19.33 +/- 1.20	0.732
Heart Girth (cm)	34.17 +/- 1.40	34.67 +/- 2.40	0.852
Head Circumference (cm)	25.60 +/- 0.68	26.67 +/- 0.88	0.374
Right Hind Foot (cm)	22.71 +/- 0.39	21.22 +/- 0.71	0.030

Note: Differences in sample sizes (N) between those collected and those specified here are due to missing body parts of some specimens.

Note: The sex ratio of lynx examined from the 2001-2002 trapping year, males to females was 0.68:1.00.

Table 4: Summary of the morphometric data (mean +/- SE) for Canada lynx (*Lynx canadensis*) collected during the 2002-2003 trapping year.

Age Class	**Measurements**			
		Males (N=57)	**Females (N=48)**	**(P)**
Adults	Weight (kg)	8.07 +/- 0.15	7.11 +/- 0.17	0.0001
	Shoulder Height (cm)	49.02+/- 0.67	45.94 +/- 0.82	0.015
	Total Length (cm)	90.77 +/- 1.06	88.50 +/- 0.91	0.180
	Tail Length (cm)	11.85 +/- 0.22	10.91 +/- 0.25	0.016
	Neck Circumference (cm)	19.61 +/- 0.18	18.55 +/- 0.27	0.002
	Heart Girth (cm)	33.76 +/- 0.34	32.50 +/- 0.31	0.050
	Head Circumference (cm)	27.32 +/- 0.17	26.32 +/- 0.22	0.001
	Right Hind Foot (cm)	22.47 +/- 0.19	21.38 +/- 0.36	0.030
		Males (N=7)	**Females (N=7)**	**(P)**
Juveniles	Weight (kg)	5.17 +/- 0.25	5.27 +/- 0.17	0.722
	Shoulder Height (cm)	44.33 +/- 1.89	44.13 +/- 1.77	0.937
	Total Length (cm)	84.67 +/- 4.22	82.00 +/- 2.31	0.554
	Tail Length (cm)	11.00 +/- 0.63	10.80 +/- 0.20	0.700
	Neck Circumference (cm)	17.11 +/- 0.51	16.27 +/- 0.24	0.130
	Heart Girth (cm)	28.78 +/- 0.59	28.55 +/- 0.64	0.797
	Head Circumference (cm)	25.78 +/- 0.66	25.18 +/- 0.48	0.467
	Right Hind Foot (cm)	20.78 +/- 0.74	20.33 +/- 0.53	0.632
		Males (N=2)	**Females (N=8)**	**(P)**
Young-of-the-year	Weight (kg)	3.25 +/- 0.25	3.00 +/- 0.15	0.407
	Shoulder Height (cm)	38.75 +/- 1.75	37.33 +/- 1.11	0.498
	Total Length (cm)	63.00 +/- 3.14	67.13 +/- 2.68	0.350
	Tail Length (cm)	9.50 +/- 0.29	9.00 +/- 0.41	0.420
	Neck Circumference (cm)	14.25 +/- 0.25	13.73 +/- 0.47	0.500
	Heart Girth (cm)	25.25 +/- 0.63	23.81 +/- 0.40	0.084
	Head Circumference (cm)	23.25 +/- 0.48	22.56 +/- 0.60	0.470
	Right Hind Foot (cm)	18.50 +/- 0.29	18.27 +/- 0.54	0.810

Note: Differences in sample sizes (N) between those collected and those specified here are due to missing body parts of some specimens.

Note: The sex ratio of lynx examined from the 2002-2003 trapping year, males to females was 1.04:1.00.

3.2.2 Red fox.

3.2.2.1 2002-2003 trapping year (Table 5).

The overall sex ratio for all Red fox examined, males to females, was 1.5:1.0. The morphometric data for the 2002-2003 trapping year was compared by sex for each age category. The statistical analysis for morphological parameters showed that significant differences for any one parameter varied by sex and age category.

Adult Red fox differed significantly by sex with respect to weight, total length, and tail measurements with males being larger than females. Juvenile Red fox differed significantly with respect to total length and heart girth measurements with males being larger than females.

3.2.3 Coyote.

The sex ratio for all coyotes examined, males to females, was 2.90:1.00. Six young-of-the-year coyotes collected during the 2000-2001 trapping year were excluded from morphological analysis as sample size was too small. The morphometric data for the 2001-2003 trapping years was compared by sex for each year and age category (Table 7 and 8). The statistical analysis for morphological parameters showed that significant differences for any one parameter varied by age, sex and trapping year.

3.2.3.1 2001-2002 trapping year (Table 6).

Adult coyotes differed significantly with respect to weight, total length, heart girth, head circumference, and right hind foot measurements, with males being larger

Table 5: Summary of the morphometric data (mean +/- SE) for Red fox (*Vulpes vulpes*) collected during the 2002-2003 trapping year.

Age Class	Measurements	Males (N=40)	Females (N=16)	(P)
Adults	Weight (kg)	4.46 +/- 0.091	4.02 +/- 0.15	0.021
	Shoulder Height (cm)	35.79 +/- 0.55	34.60 +/- 0.78	0.270
	Total Length (cm)	107.6 +/- 0.99	102.3 +/- 1.87	0.010
	Tail Length (cm)	40.05 +/- 0.55	37.23 +/- 0.88	0.011
	Neck Circumference (cm)	17.97 +/- 0.24	17.62 +/- 0.51	0.487
	Heart Girth (cm)	32.87 +/- 0.46	31.77 +/- 0.97	0.264
	Head Circumference (cm)	24.82 +/- 0.26	24.0 +/- 0.47	0.130
	Right Hind Foot (cm)	16.74 +/- 0.18	16.1 +/- 0.23	0.086
		Males (N=24)	**Females (N=27)**	**(P)**
Juveniles	Weight (kg)	3.22 +/- 0.064	3.052 +/- 0.063	0.063
	Shoulder Height (cm)	34.89 +/- 1.07	34.05 +/- 0.59	0.460
	Total Length (cm)	100.38 +/- 1.12	97.05 +/- 0.99	0.033
	Tail Length (cm)	36.71 +/- 0.48	36.1 +/- 0.55	0.423
	Neck Circumference (cm)	16.89 +/- 0.32	16.200 +/- 0.29	0.121
	Heart Girth (cm)	30.75 +/- 0.74	28.87 +/- 0.59	0.050
	Head Circumference (cm)	23.21 +/- 0.54	22.43 +/- 0.24	0.177
	Right Hind Foot (cm)	15.91 +/- 0.14	15.9 +/- 0.18	0.983

Note: The sex ratio of Red fox examined from the 2002-2003 trapping year, males to females was 1.50:1.00.

Table 6: Summary of the morphometric data (mean +/- SE) for Eastern coyote (*Canis latrans*) collected during the 2001-2002 trapping year.

Age Class	Measurements			
		Males (N=10)	**Females (N=3)**	**(P)**
Adults	Weight (kg)	11.71 +/- 0.60	8.67 +/- 0.17	0.021
	Shoulder Height (cm)	60.11 +/- 3.07	51.67 +/- 4.84	0.180
	Total Length (cm)	124.0 +/- 3.99	99.67 +/- 7.45	0.014
	Tail Length (cm)	31.63 +/- 1.73	26.0 +/- 0.46	0.290
	Neck Circumference (cm)	27.90 +/- 0.57	27.33 +/- 1.20	0.200
	Heart Girth (cm)	48.55 +/- 1.35	42.00 +/- 1.15	0.028
	Head Circumference (cm)	35.10 +/- 0.69	32.33 +/- 0.33	0.050
	Right Hind Foot (cm)	19.80 +/- 0.49	17.00 +/- 0.35	0.034
		Males (N=4)	**Females (N=4)**	**(P)**
Juveniles	Weight (kg)	6.55 +/- 0.36	6.68 +/- 0.38	0.814
	Shoulder Height (cm)	48.33 +/- 2.96	47.60 +/- 3.70	0.896
	Total Length (cm)	110.7 +/- 3.71	104.8 +/- 2.08	0.183
	Tail Length (cm)	30.50 +/- 1.85	27.60 +/- 0.51	0.136
	Neck Circumference (cm)	22.0 +/- 1.22	22.20 +/- 1.46	0.922
	Heart Girth (cm)	40.80 +/- 2.40	36.50 +/- 3.71	0.344
	Head Circumference (cm)	31.40 +/- 1.36	27.0 +/- 2.04	0.105
	Right Hind Foot (cm)	18.0 +/- 0.32	16.5 +/- 0.29	0.011

Note: The sex ratio of coyotes examined from the 2001-2002 trapping year, males to females was 2.00:1.00.

than females. Juvenile coyotes differed significantly with respect to right hind foot measurements with males having larger right hind feet than females.

3.2.3.2 2002-2003 trapping year (Table 7).

Adult coyotes differed significantly with respect to right hind foot measurements with males having larger right hind feet than females. There were no significant morphometric differences between male and female juvenile coyotes.

3.3 Diet.

Dietary analysis of each host species was based on the stomachs that contained food items and was compared between species and trapping year. No attempt was made to compare diet between age and sex.

3.3.1 Lynx.

Of the 366 lynx gastrointestinal tracts examined, 28% (n=104) were empty. A total of eight different food items (Table 8) were identified. Snowshoe hare was utilized most heavily by lynx during this study and accounted for the highest percent occurrence (68.7%) of mammals over the four years (Table 9).

Table 7: Summary of the morphometric data (mean +/- SE) for Eastern coyote (*Canis latrans*) collected during the 2002-2003 trapping year.

Age Class	**Measurements**			
		Males (N=30)	**Females (N=7)**	**(P)**
Adults	Weight (kg)	13.09 +/- 2.61	10.17 +/- 0.53	0.450
	Shoulder Height (cm)	49.10 +/- 1.20	47.50 +/- 0.93	0.400
	Total Length (cm)	117.7 +/- 2.66	112.10 +/- 1.95	0.184
	Tail Length (cm)	32.24 +/- 0.81	30.90 +/- 0.82	0.315
	Neck Circumference (cm)	25.50 +/- 0.64	25.91 +/- 1.23	0.747
	Heart Girth (cm)	45.82 +/- 1.03	43.73 +/- 1.09	0.233
	Head Circumference (cm)	31.30 +/- 0.64	30.27 +/- 0.93	0.377
	Right Hind Foot (cm)	19.78 +/- 0.31	18.46 +/- 0.37	0.016
		Males (N=9)	**Females (N=2)**	**(P)**
Juveniles	Weight (kg)	5.71 +/- 0.42	5.50 +/- 0.39	0.850
	Shoulder Height (cm)	45.56 +/- 1.41	42.0 +/- 0.95	0.450
	Total Length (cm)	107.2 +/- 2.77	103.0 +/- 1.02	0.642
	Tail Length (cm)	29.56 +/- 0.85	28.0 +/- 0.81	0.579
	Neck Circumference (cm)	22.0 +/- 0.82	20.0 +/- 0.77	0.461
	Heart Girth (cm)	37.0 +/- 1.56	35.0 +/- 1.48	0.696
	Head Circumference (cm)	28.44 +/- 1.06	26.0 +/- 0.98	0.485
	Right Hind Foot (cm)	18.22 +/- 0.43	19.0 +/- 0.45	0.586

Note: The sex ratio of coyotes examined from the 2002-2003 trapping year, males to females was 4.30:1.00

Table 8: Number of occurrences and diversity of food items in the diet of Canada lynx (*Lynx canadensis*) in insular Newfoundland collected during the 1999-2003 trapping years as determined from gastrointestinal contents.

Food Items	**1999-2000 (n=72)**	**2000-2001 (n=107)**	**2001-2002 (n=39)**	**2002-2003 (n=148)**	**Total (n=366)**
Snowshoe hare	30	61	20	69	180
Red squirrel	1	5	3	12	21
Voles	1	0	0	4	5
Shrews	0	0	0	0	0
Caribou	0	1	4	2	7
Moose	0	0	0	1	1
Birds	2	5	1	9	17
Free-living invertebrates	0	0	0	1	1
Miscellaneous*	2	0	0	2	4
Vegetation**	33	47	14	60	154
Lynx*	13	39	3	9	64
Fish	0	0	0	1	1
Empty	21	32	2	49	104
Total Food Items	**34**	**72**	**28**	**99**	**233**
Dietary Diversity Index (H')	**0.48**	**0.57**	**0.88**	**1.07**	

*Not considered a food item

** Not normally a food item

Table 9: Percent occurrence (%) of food items recovered from 262 Canada lynx (*Lynx canadensis*) gastrointestinal tracts that contained food items over four trapping years.

Food Items	**1999-2000 (n=51)**	**2000-2001 (n=75)**	**2001-2002 (n=37)**	**2002-2003 (n=99)**	**Overall (n=262)**
Snowshoe hare	58.8	81.3	54.1	69.7	68.7
Red squirrel	1.9	6.7	8.1	12.1	8.1
Voles	1.9	----	----	4.0	1.9
Caribou	----	1.3	10.8	2.0	2.7
Moose	----	----	----	1.0	0.38
Birds	3.9	6.7	2.7	9.1	6.5
Free-living invertebrates	----	----	----	1.0	0.38
Fish	----	----	----	1.0	0.38
Vegetation*	64.7	62.7	37.8	60.6	58.8

Note: The calculations of percent occurrence (%) for food were done on an item by item basis as any one gastrointestinal tract may have contained more than one item. The total percent occurrence may exceed 100%.

* Not normally a food item

Percent occurrence of Snowshoe hare in lynx diets varied from a high of 81.3% during the 2000-2001 trapping year to a low of 54.1% during the 2001-2002 trapping year (Figure 3). There was no significant difference in the occurrence of Snowshoe hare with respect to year (P=0.087).

Red squirrels (*T. hudsonicus*) constituted 8.0% of the total food occurrences during the four years, with the highest occurrence in the 2002-2003 year (12.1%). Percent occurrence of Meadow voles (*M. pennsylvanicus*) overall was 1.9%. Birds such as Ruffed and Spruce grouse (*B. umbellus* and *Falcipennis canadensis* respectively) and Black duck (*Anas rubripes*) constituted 6.5% of the lynx diet, with the highest percent occurrence during the 2002-2003 trapping year (9.1%). Moose and caribou (most likely in the form of carrion) constituted 0.38% and 2.7% of the total occurrences respectively. Vegetation (mostly grasses) had a percent occurrence of 58.8% over four trapping years.

3.3.2 Red fox.

Of the 112 Red fox gastrointestinal tracts examined, 18.7% (n=21) were empty. A total of 11 different food items (Table 10) were identified. Snowshoe hare (31.8%) and Meadow voles (25.3%) were the most abundant mammalian species recovered followed by caribou (17.6%), Masked shrews (*Sorex cinereus*) (3.3%), Red squirrel (2.2%) and moose (2.2%). Birds such as Canada warbler (*Wilsonia canadensis*), American robins (*Turdus migratorius*) and Gray jays (*Perisoreus canadensis*) accounted for 17.6% of the total food items recovered. Fish and free-living invertebrates constituted 6.6% and 4.4% of the total occurrences respectively. Lynx (carrion) had a percent occurrence of 10.9%.

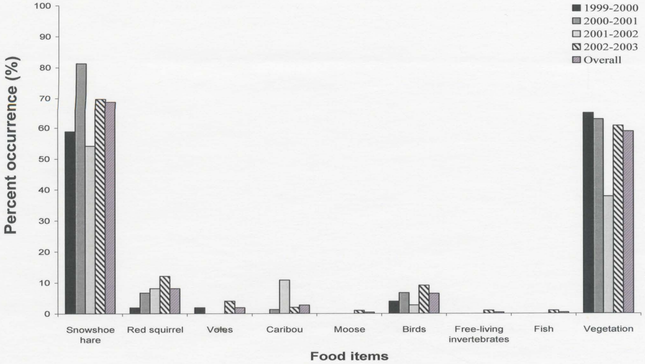

Figure 3: Percent occurrence (%) of food items recovered from 262 Canada lynx (*Lynx canadensis*) gastrointestinal tracts that contained food items over four trapping years.

Note: The calculations of percent occurrence (%) for food were done on an item by item basis as any one gastrointestinal tract may have contained more than one item. The total percent occurrence may exceed 100%.

Table 10: Number of occurrences and diversity of food items in the diet of Red fox (*Vulpes vulpes*) in insular Newfoundland collected during the 2001-2003 trapping years as determined from gastrointestinal contents.

Food Items	**2001-2002 (n=5)**	**2002-2003 (n=107)**	**Total (n=112)**
Snowshoe hare	0	29	29
Red squirrel	2	0	2
Voles	2	21	23
Shrews	2	1	3
Caribou	1	15	16
Moose	0	2	2
Birds	0	16	16
Free-living invertebrates	2	2	4
Miscellaneous*	0	4	4
Vegetation	5	48	53
Lynx	2	8	10
Fish	0	6	6
Empty	1	20	21
Red fox*	0	2	2
Total Food Items	**14**	**148**	**164**
Dietary Diversity Index (H')	**1.57**	**1.87**	

*Not considered a food item

Table 11: Percent occurrence (%) of food items recovered from 91 Red fox (*Vulpes vulpes*) gastrointestinal tracts that contained food items over two trapping years.

Food Items	**2001-2002 (n=4)**	**2002-2003 (n=87)**	**Overall (n=91)**
Snowshoe hare	----	33.3	31.8
Red squirrel	50.0	----	2.2
Voles	50.0	24.1	25.3
Shrews	50.0	1.1	3.3
Caribou	25.0	17.2	17.6
Moose	----	2.3	2.2
Birds	----	18.4	17.6
Free-living invertebrates	50.0	2.3	4.4
Fish	----	6.9	6.6
Lynx	50.0	9.2	10.9
Vegetation	100.0	55.2	57.1

Note: The calculations of percent occurrence (%) for food were done on an item by item basis as any one gastrointestinal tract may have contained more than one item. The total percent occurrence may exceed 100%.

Vegetation, mostly blueberries (*Vaccinium angustifolium*) and partridgeberries (*Vaccinium vitis-idaea*) had a percent occurrence of 57.1% over two trapping years (Table 11 and Figure 4).

3.3.3 Coyote.

Of the 75 coyote gastrointestinal tracts examined, 12.0% (n=9) were empty. A total of nine different food items (Table 12) were identified. Mammals, primarily caribou and Snowshoe hare accounted for the greatest percent occurrence over the three trapping years. Percent occurrence of caribou varied from a high of 66.6% during the 2000-2001 trapping year to a low of 38.1% during the 2001-2002 trapping year (Table 13). There was a significant difference in the occurrence of caribou with respect to year ($P = 0.019$). Snowshoe hare had an overall percent occurrence of 25.8%, followed by Meadow voles (16.7%), moose (15.2%), and Red squirrel (1.5%). Birds and fish had percent occurrences of 7.6% and 9.1% respectively. Percent occurrence of free-living invertebrates (e.g. fly larvae and grasshoppers) was 3.0%. Vegetation, mostly blueberries and partridgeberries had a percent occurrence of 86.4% (Table 13 and Figure 5).

Frequency of occurrence of food items differed significantly between coyote and lynx samples ($P = 0.0001$), and lynx and Red fox samples ($P = 0.0001$). The frequency of occurrence of food items did not differ significantly between the two canid species ($P = 0.126$).

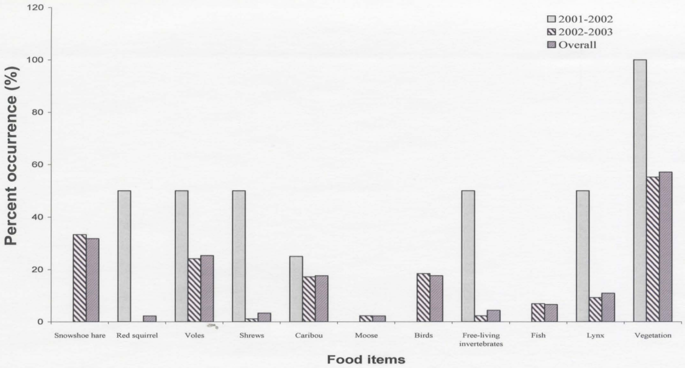

Figure 4: Percent occurrence (%) of food items recovered from 91 Red fox (*Vulpes vulpes*) gastrointestinal tracts that contained food items over two trapping years.

Note: The calculations of percent occurrence (%) for food were done on an item by item basis as any one gastrointestinal tract may have contained more than one item. The total percent occurrence may exceed 100%.

Table 12: Number of occurrences and diversity of food items in the diet of Eastern coyotes (*Canis latrans*) in insular Newfoundland collected during the 2000-2003 trapping years as determined from gastrointestinal contents.

Food Items	**2000-2001 (n=3)**	**2001-2002 (n=24)**	**2002-2003 (n=48)**	**Total (n=75)**
Snowshoe hare	1	9	7	17
Red squirrel	0	0	1	1
Voles	0	2	9	11
Shrews	0	0	0	0
Caribou	2	8	23	33
Moose	1	1	8	10
Birds	0	4	1	5
Free-living invertebrates	0	0	2	2
Miscellaneous*	0	1	2	3
Vegetation	1	19	37	57
Lynx	0	0	0	0
Fish	0	0	6	6
Empty	0	3	6	9
Coyote*	2	2	2	6
Total Food Items	**5**	**43**	**94**	**142**
Dietary Diversity Index (H')	**1.33**	**1.46**	**1.68**	

*Not considered a food item

Table 13: Percent occurrence (%) of food items recovered from 66 Eastern coyote (*Canis latrans*) gastrointestinal tracts that contained food items over three trapping years.

Food Items	**2000-2001 (n=3)**	**2001-2002 (n=21)**	**2002-2003 (n=42)**	**Overall (n=66)**
Snowshoe hare	33.3	42.9	16.7	25.8
Red squirrel	----	----	2.4	1.5
Voles	----	9.5	21.4	16.7
Caribou	66.6	38.1	54.8	50.0
Moose	33.3	4.8	19.0	15.2
Birds	----	19.0	2.4	7.6
Free-living invertebrates	----	----	4.8	3.0
Fish	----	----	14.3	9.1
Vegetation	33.3	90.5	88.1	86.4

Note: The calculations of percent occurrence (%) for food were done on an item by item basis as any one gastrointestinal tract may have contained more than one item. The total percent occurrence may exceed 100%.

Dietary diversities were examined with respect to trapping year and species. For lynx samples, dietary diversity indices ranged from 0.48 in 1999-2000, to 1.07 in 2002-2003 (Table 8). Red fox dietary diversity indices were much higher, ranging from 1.57 in 2001-2002, to 1.87 in 2002-2003 (Table 10). Coyote dietary diversity indices ranged from 1.33 in 2000-2001, to 1.69 in 2002-2003 (Table 12).

Dietary diversity indices differed significantly between coyote and lynx diets (P=0.010), and lynx and Red fox diets (P=0.010). Dietary diversities did not differ significantly between coyote and Red fox diets (P=0.202). Lynx dietary diversity indices differed significantly over the four year trapping period (P = 0.019). Coyote dietary diversity indices were not significantly different for the three year period (P = 0.127). Red fox dietary diversities were not analyzed for significance with respect to trapping year due to the fact that only two dietary diversities were computed.

Horn's dietary overlap index was generally high, but varied greatly between species. The similarity index (C_{mh}) was 0.38 between lynx and Red fox diets, 0.90 among coyote and Red fox diets and 0.25 between lynx and coyote diets.

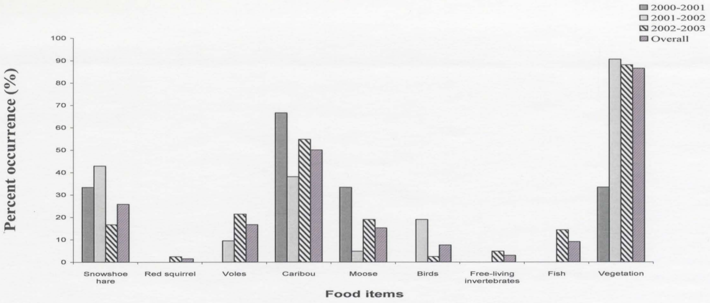

Figure 5: Percent occurrence (%) of food items recovered from 66 Eastern coyote (*Canis latrans*) gastrointestinal tracts that contained food items over three trapping years.

Note: The calculations of percent occurrence (%) for food were done on an item by item basis as any one gastrointestinal tract may have contained more than one item. The total percent occurrence may exceed 100%.

3.4 Parasite prevalence.

3.4.1 Lynx.

The number of lynx (N=330) that were examined for enteric parasites was less than the total number of lynx (N=366) as age, sex and trapping area of some animals was unknown. Lynx were recovered from all regions (Figure 6). The actual numbers used in statistical analyses are shown in the respective tables.

Twelve helminths were recovered from lynx, the cestodes *Taenia pisiformis*, *T. macrocystis*, *T. laticollis*, *T. hydatigena* and *T. krabbei*, and the nematodes *Toxascaris leonina*, *Troglostrongylus wilsoni*, *Toxocara canis*, *T. cati*, *Nematodirus* spp. *Uncinaria stenocephala*, and *Crenosoma vulpis*. Of these only *T. pisiformis*, *T. macrocystis*, *T. laticollis*, *T. leonina* and *T. wilsoni* were found in young-of-the-year lynx (Table 14).

3.4.1.1 Cestodes.

Taenia pisiformis was found in lynx of all age classes. Prevalence of *T. pisiformis* did not differ significantly with respect to age (P = 0.772) or sex (P = 1.000) (Tables 14-17). Between regions, prevalence was lowest in Central Newfoundland (18.7%), but was not significantly different (P = 0.262) than other regions examined (Table 18 and Figure 7). Prevalence of *T. pisiformis* differed significantly with respect to trapping year (P = 0.026) with the highest prevalence (43.8%) in 2001-2002 (Table 19).

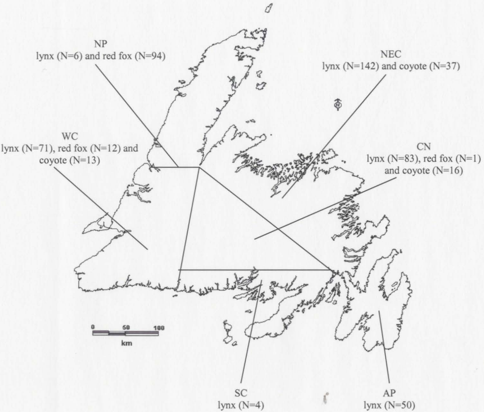

Figure 6: Map of insular Newfoundland indicating sample sizes and known regions where Canada lynx (*Lynx canadensis*), Red fox (*Vulpes vulpes*) and Eastern coyote (*Canis latrans*) were trapped during the 1999-2003 trapping years.

Table 14: Parasite parameters of helminths recovered in young-of-the-year Canada lynx (*Lynx canadensis*) from insular Newfoundland during the 2000-2003 trapping years.

Trapping year	Sex	Parasite Parameters	Cestodes			Nematodes	
			Taenia pisiformis	*Taenia macrocystis*	*Taenia laticollis*	*Toxascaris leonina*	*Troglostrongylus wilsoni*
2000-2001	Males (N=3)	P	----	33.3	----	66.7	----
		I	----	0-35	----	0-6	----
		MI	----	11.7	----	2.17	----
		A	----	3.89	----	1.45	----
		D	----	34.9	----	4.69	----
	Females (N=7)	P	28.6	28.6	28.6	85.7	14.3
		I	0-16	0-35	0-40	0-34	0-59
		MI	3.79	2.93	1.43	2.69	8.43
		A	1.08	0.84	0.41	2.31	1.21
		D	30.1	29.0	12.5	15.2	58.9
2002-2003	Males (N=2)	P	50.0	----	----	100.0	50.0
		I	0-15	----	----	0-66	0-240
		MI	7.50	----	----	16.8	120.0
		A	3.75	----	----	16.8	60.0
		D	15.0	----	----	63.2	240.0
	Females (N=8)	P	25.0	12.5	12.5	37.5	37.5
		I	0-50	0-5	0-10	0-20	0-56
		MI	3.63	0.63	1.25	1.38	2.63
		A	0.91	0.08	0.16	0.52	0.99
		D	42.2	5.00	10.0	12.9	48.4

Note: P (Prevalence - %), I (Intensity), MI (Mean Intensity), A (Abundance) and D (Dispersion).

Table 15: A comparison of the overall prevalence (%) of helminths with respect to age and sex, in 330 Canada lynx (*Lynx canadensis*) collected during the 1999-2003 trapping years.

Helminths	**Age**				**Sex**		
	Young-of-the-year (N=20)	Juveniles (N=111)	Adults (N=199)	(P)	Males (N=166)	Females (N=164)	(P)
Cestodes							
Taenia pisiformis	25.0	26.1	29.6	0.519	28.6	28.2	1.00
Taenia macrocystis	20.0	33.3	37.7	0.058	33.5	38.9	0.633
Taenia laticollis	15.0	2.7	5.5	0.008	4.9	4.7	0.763
Taenia hydatigena	----	----	2.0	N/A	1.2	1.3	1.00
Taenia ovis krabbei	----	0.9	----	N/A	0.6	----	N/A
Nematodes							
Toxascaris leonina	65.0	72.9	81.4	0.416	76.4	80.5	0.811
Troglostrongylus wilsoni	25.0	18.0	28.1	0.329	26.7	22.1	0.572
Toxocara canis	----	4.5	5.0	0.144	4.9	4.7	0.739
Toxocara cati	----	2.7	5.5	0.317	4.3	4.7	1.00
Nematodirus spp.	----	0.9	1.0	1.00	1.2	0.67	1.00
Uncinaria stenocephala	----	0.9	----	N/A	----	0.67	N/A
Crenosoma vulpis	----	0.9	----	N/A	----	0.67	N/A

N/A - not applicable

Table 16: Parasite parameters of cestodes recovered in juvenile Canada lynx (*Lynx canadensis*) from insular Newfoundland during the 1999-2003 trapping years.

Trapping year	Sex	Parasite Parameters	*Taenia pisiformis*	*Taenia macrocystis*	*Taenia laticollis*	*Taenia ovis krabbei*
1999-2000	Males (N=30)	P	26.7	26.7	----	3.3
		I	0-39	0-56	----	0-3
		MI	0.52	0.64	----	0.10
		A	0.14	0.17	----	0.003
		D	30.5	28.9	----	3.00
	Females (N=20)	P	25.0	25.0	5.0	----
		I	0-29	0-44	0-9	----
		MI	1.27	1.05	0.45	----
		A	0.32	0.26	0.02	----
		D	30.5	28.6	8.99	----
2000-2001	Males (N=21)	P	23.8	38.1	----	----
		I	0-49	0-47	----	----
		MI	1.19	0.91	----	----
		A	0.05	0.34	----	----
		D	29.9	22.4	----	----
	Females (N=26)	P	23.1	38.5	7.7	----
		I	0-11	0-53	0-10	----
		MI	0.17	0.63	0.21	----
		A	0.04	0.24	0.02	----
		D	6.8	26.4	9.11	----
2002-2003	Males (N=7)	P	28.6	42.9	----	----
		I	0-60	0-146	----	----
		MI	5.65	10.9	----	----
		A	1.62	4.71	----	----
		D	45.3	90.9	----	----
	Females (N=7)	P	42.9	42.9	----	----
		I	0-84	0-130	----	----
		MI	7.37	10.4	----	----
		A	3.16	4.45	----	----
		D	64.3	75.6	----	----

Note: P (Prevalence - %), I (Intensity), MI (Mean Intensity), A (Abundance) and D (Dispersion).

Table 17: Parasite parameters of cestodes recovered in adult Canada lynx (*Lynx canadensis*) from insular Newfoundland during the 1999-2003 trapping years.

Trapping year	Sex	Parasite Parameters	*Taenia pisiformis*	*Taenia macrocystis*	*Taenia laticollis*	*Taenia hydatigena*
1999-2000	Males (N=6)	P	16.7	16.7	16.7	----
		I	0-27	0-13	0-5	----
		MI	4.50	2.17	0.83	----
		A	0.75	0.36	0.14	----
		D	26.9	12.9	5.00	----
	Females (N=12)	P	33.3	25.0	8.3	----
		I	0-55	0-6	0-34	----
		MI	4.12	3.46	1.73	----
		A	1.37	0.87	0.14	----
		D	35.8	24.3	5.99	----
2000-2001	Males (N=27)	P	22.2	44.4	7.4	----
		I	0-51	0-130	0-26	----
		MI	1.30	1.28	1.00	----
		A	0.29	0.57	0.07	----
		D	37.1	53.5	19.1	----
	Females (N=17)	P	23.5	41.2	5.9	----
		I	0-76	0-44	0-11	----
		MI	2.35	2.14	0.65	----
		A	0.55	0.88	0.04	----
		D	45.6	39.2	11.00	----
2001-2002	Males (N=13)	P	46.1	7.7	----	7.7
		I	0-40	0-10	----	0-5
		MI	1.22	0.77	----	0.39
		A	0.56	0.06	----	0.03
		D	19.9	10.00	----	4.99
	Females (N=19)	P	31.6	36.8	----	10.5
		I	0-66	0-51	----	0-14
		MI	1.52	1.38	----	0.63
		A	0.48	0.51	----	0.07
		D	44.3	26.9	----	11.7
2002-2003	Males (N=57)	P	31.6	36.8	8.8	1.8
		I	0-103	0-71	0-43	0-4
		MI	0.59	0.49	0.38	0.07
		A	0.19	0.18	0.03	0.001
		D	50.8	33.5	31.0	3.99
	Females (N=48)	P	29.2	47.9	4.2	----
		I	0-58	0-55	0-21	----
		MI	0-34	0-35	0.23	----
		A	0.09	0.17	0.009	----
		D	38.3	19.6	20.1	----

Note: P (Prevalence - %), I (Intensity), MI (Mean Intensity), A (Abundance) and D (Dispersion).

Taenia macrocystis was found in lynx of all age classes and prevalence differed with respect to age (P = 0.058) with adults having the highest prevalence (37.7%) (Tables 14-17). Prevalence did not differ with respect to sex (P = 0.633) (Table 15). Between regions, prevalence was significantly lower on the Avalon Peninsula (24.0%) (P = 0.012) than other regions examined (Table 18 and Figure 7). Prevalence of *T. macrocystis* did not differ significantly with respect to trapping year (P = 0.295) (Table 19).

Prevalence of *Taenia laticollis* was significantly different with respect to age (P = 0.008), with young-of-the-year lynx having the highest prevalence (15.0%) (Tables 14-17). Prevalence did not differ significantly with respect to sex (P = 0.763) but males had a higher prevalence (4.9%) (Table 15). Between regions, prevalence was lowest on the West Coast (5.6%), but was not significantly lower than other regions examined (P = 0.903) (Table 18 and Figure 7). Prevalence of *T. laticollis* did not differ significantly with respect to trapping year (P = 0.506) (Table 19).

Taenia hydatigena was recovered from adult lynx only, and prevalence did not differ significantly between males and females (P = 1.000) (Tables 15 and 16). It was only recovered from lynx on the North East Coast and had a prevalence of 2.8% (Table 18 and Figure 7). Prevalence did not differ significantly with respect to trapping year (P = 0.808) (Table 19).

Taenia ovis krabbei occurred in one juvenile male lynx from the North East Coast (Table 18 and Figure 6) during the 1999-2000 trapping year with a prevalence of 0.7%.

Table 18: Parasite parameters of cestodes recovered in Canada lynx (*Lynx canadensis*) from six regions of insular Newfoundland during the 1999-2003 trapping years.

Species	Parasite Parameters	CN (N=83)	AP (N=50)	NEC (N=142)	WC (N=71)	NP* (N=6)	SC* (N=4)
Taenia pisiformis	Prevalence (%)	18.7	24.0	31.7	30.1	16.7	100.0
	Intensity	0-66	0-55	0-100	0-84	0-22	0-49
	Mean Intensity	0.215	0.451	0.214	0.326	3.67	5.83
	Abundance	0.040	0.101	0.071	0.097	0.613	5.83
	Dispersion	37.10	31.00	39.09	59.03	21.97	29.44
Taenia macrocystis	Prevalence (%)	28.9	24.0	46.5	25.4	66.7	25.0
	Intensity	0-130	0-44	0-89	0-146	0-25	0-14
	Mean Intensity	0.539	0.278	0.140	0.649	1.29	3.50
	Abundance	0.162	0.068	0.067	0.167	0.86	0.88
	Dispersion	50.61	25.56	29.19	46.72	18.76	14.00
Taenia laticollis	Prevalence (%)	8.4	8.0	6.3	5.6	----	----
	Intensity	0-34	0-11	0-21	0-43	----	----
	Mean Intensity	0.114	0.135	0.079	0.488	----	----
	Abundance	0.010	0.011	0.0042	0.022	----	----
	Dispersion	22.99	9.16	16.28	29.07	----	----
Taenia hydatigena	Prevalence (%)	----	----	2.8	----	----	----
	Intensity	----	----	0-14	----	----	----
	Mean Intensity	----	----	0.062	----	----	----
	Abundance	----	----	0.0019	----	----	----
	Dispersion	----	----	10.04	----	----	----
Taenia ovis krabbei	Prevalence (%)	----	----	0.7	----	----	----
	Intensity	----	----	0-3	----	----	----
	Mean Intensity	----	----	0.0226	----	----	----
	Abundance	----	----	1.7×10^{-3}	----	----	----
	Dispersion	----	----	2.99	----	----	----

* - Excluded from regional statistical analyses

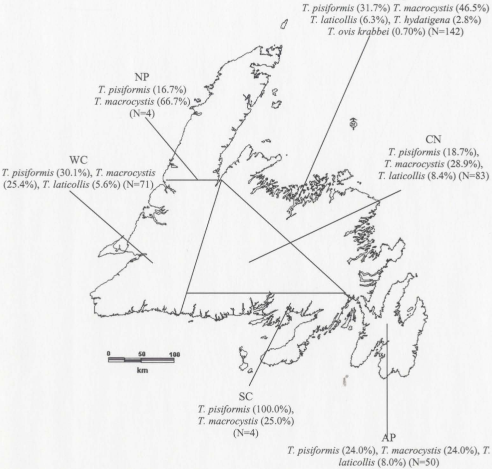

Figure 7: Distribution and prevalence of cestodes recovered in Canada lynx (*Lynx canadensis*) from six regions of insular Newfoundland during the 1999-2003 trapping years.

Note: Data includes prevalence (%) and the number of animals (N) examined from each region.

Table 19: Comparison of the overall prevalence (%) of helminths recovered in 330 Canada lynx (*Lynx canadensis*) during the 1999-2003 trapping years.

Helminths	**Trapping Year** 1999-2000 (N=68)	2000-2001 (N=101)	2001-2002 (N=32)	2002-2003 (N=129)	Overall (N=330)	(P)
Cestodes						
Taenia pisiformis	26.5	20.8	43.8	31.0	28.2	0.026
Taenia macrocystis	25.0	36.6	34.4	39.5	35.2	0.295
Taenia laticollis	4.4	4.9	6.3	9.3	6.7	0.506
Taenia hydatigena	----	----	9.4	7.8	12.1	0.808
Taenia ovis krabbei	1.5	----	----	----	0.3	N/A
Nematodes						
Toxascaris leonina	67.6	68.3	87.5	82.2	77.6	0.000
Troglostrongylus wilsoni	19.1	7.9	28.1	38.8	24.5	0.000
Toxocara canis	4.4	7.9	----	3.1	4.5	0.247
Toxocara cati	5.9	1.0	6.3	5.4	4.2	0.286
Nematodirus spp.	----	1.0	----	1.6	0.9	0.564
Uncinaria stenocephala	----	1.0	----	----	0.3	N/A
Crenosoma vulpis	----	----	----	0.7	0.3	N/A

N/A – not applicable

3.4.1.2 Nematodes.

Toxascaris leonina was found in lynx of all age classes. Prevalence of *T. leonina* did not differ significantly with respect to age (P = 0.416) or sex (P = 0.811) (Tables 15, 20 and 21). Prevalence was lowest on the Avalon Peninsula (68.0%) (Table 22 and Figure 8) although not significantly different than the other regions examined (P = 0.702). Prevalence of *T. leonina* differed significantly with respect to trapping year (P = 0.000) (Table 19).

Troglostrongylus wilsoni was found in lynx of all age classes. Prevalence of *T. wilsoni* did not differ significantly with respect to age (P = 0.329) or sex (P = 0.572) (Tables 15, 20 and 21). Between regions, prevalence was lowest on the Avalon Peninsula (16.0%) (Table 22 and Figure 8) but was not significantly different than the other regions examined (P = 0.120). Prevalence of *T. wilsoni* differed significantly with respect to trapping year (P = 0.000) with the highest prevalence (38.8%) in 2002-2003 (Table 19).

Prevalence of *Toxocara canis* did not differ significantly with respect to age (P = 1.000) or between males and females (P = 0.739) (Tables 15, 20 and 21). Prevalence differed significantly with respect to region (P = 0.041) with the lowest prevalence occurring on the North East Coast (3.5%) (Table 22 and Figure 8). Prevalence of *T. canis* did not differ significantly with respect to trapping year (P = 0.247) (Table 19).

Prevalence of *Toxocara cati* did not differ significantly with respect to age (P= 0.317) or sex (P = 1.000) (Tables 15, 20 and 21). Between regions, prevalence was lowest on the West Coast (1.4%) but did not differ significantly from other regions examined.

Table 20: Parasite parameters of nematodes recovered in juvenile Canada lynx (*Lynx canadensis*) from insular Newfoundland during the 1999-2003 trapping years.

Trapping year	Sex	Parasite Parameters	*Toxascaris leonina*	*Troglostrongylus wilsoni*	*Toxocara canis*	*Toxocara cati*	*Nematodirus* spp.	*Uncinaria stenocephala*	*Crenosoma vulpis*
1999-2000	Males (N=30)	P	63.3	23.3	6.7	----	----	----	----
		I	0-39	0-37	0-4	----	----	----	----
		MI	0.53	0.66	0.28	----	----	----	----
		A	0.34	0.15	4.24	----	----	----	----
		D	16.8	20.8	9.21	----	----	----	----
	Females (N=20)	P	65.0	5.0	----	10.0	----	----	----
		I	0-20	0-20	----	0-8	----	----	----
		MI	0.70	1.00	----	0.33	----	----	----
		A	0.46	5.00	----	0.03	----	----	----
		D	8.61	19.9	----	6.52	----	----	----
2000-2001	Males (N=21)	P	76.2	14.3	----	----	----	----	----
		I	0.34	0-16	----	----	----	----	----
		MI	0.68	0.56	----	----	----	----	----
		A	0.52	0.08	----	----	----	----	----
		D	10.8	11.5	----	----	----	----	----
	Females (N=26)	P	80.8	7.7	7.7	3.8	----	3.8	----
		I	0-48	0-37	0-6	0-14	----	0-3	----
		MI	0.58	1.35	0.15	0.54	----	0.12	----
		A	0.47	0.10	0.01	0.02	----	4.37×10^{-3}	----
		D	13.8	33.8	4.87	14.0	----	3.01	----
2002-2003	Males (N=7)	P	85.7	71.4	14.3	----	----	----	----
		I	0-23	0-220	0-19	----	----	----	----
		MI	1.24	13.22	2.71	----	----	----	----
		A	1.06	9.45	0.39	----	----	----	----
		D	8.92	171.9	19.0	----	----	----	----
	Females (N=7)	P	85.7	28.6	----	----	14.3	----	14.3
		I	0-54	0-43	----	----	0-5	----	0-2
		MI	2.69	5.50	----	----	0.71	----	0.29
		A	2.31	1.57	----	----	0.10	----	0.04
		D	20.2	32.7	----	----	5.00	----	1.99

Note: P (Prevalence - %), I (Intensity), MI (Mean Intensity), A (Abundance) and D (Dispersion

Table 21: Parasite parameters of nematodes recovered from adult Canada lynx (*Lynx canadensis*) from insular Newfoundland during the 1999-2003 trapping years.

Trapping year	Sex	Parasite Parameters	*Toxascaris leonina*	*Troglostrongylus wilsoni*	*Toxocara canis*	*Toxocara cati*	*Nematodirus* spp.
1999-2000	Males (N=6)	P	83.3	16.7	----	6.7	----
		I	0-50	0-10	----	0-50	----
		MI	2.93	1.67	----	8.33	----
		A	2.44	0.28	----	1.39	----
		D	23.2	9.96	----	50.0	----
	Females (N=12)	P	75.0	33.3	8.3	8.3	----
		I	0-105	0-25	0-5	0-2	----
		MI	2.79	1.48	0.42	0.17	----
		A	2.09	0.49	0.34	0.01	----
		D	32.9	14.5	4.99	1.99	----
2000-2001	Males (N=27)	P	70.4	11.1	14.8	----	3.7
		I	0-39	0-20	0-5	----	0-6
		MI	1.79	0.49	0.10	----	0.22
		A	1.25	0.06	1.45	----	0.01
		D	12.0	14.8	3.26	----	6.00
	Females (N=17)	P	76.5	----	11.8	----	----
		I	0-43	----	0-2	----	----
		MI	1.72	----	0.24	----	----
		A	1.34	----	0.03	----	----
		D	35.8	----	1.87	----	----
2001-2002	Males (N=13)	P	76.9	38.5	----	7.7	----
		I	0-26	0-109	----	0-9	----
		MI	0.86	2.95	----	0.69	----
		A	0.66	1.14	----	0.05	----
		D	8.40	64.7	----	9.00	----
	Females (N=19)	P	94.7	21.1	----	5.3	----
		I	0-28	0-39	----	0-8	----
		MI	0.68	1.17	----	0.42	----
		A	0.65	0.25	----	0.02	----
		D	6.16	24.1	----	7.99	----
2002-2003	Males (N=57)	P	84.2	33.3	1.8	8.8	1.8
		I	0-62	0-57	0-5	0-15	0-5
		MI	0.28	0.54	0.09	0.15	0.09
		A	0.24	0.18	0.002	0.01	0.002
		D	15.8	43.0	5.00	10.2	5.00
	Females (N=48)	P	85.4	41.7	4.2	4.2	----
		I	0-54	0-227	0-6	0-19	----
		MI	0.28	1.35	0.12	0.28	----
		A	0.24	0.56	0.005	0.01	----
		D	15.6	99.2	5.43	15.5	----

Note: P (Prevalence - %), I (Intensity), MI (Mean Intensity), A (Abundance) and D (Dispersion)

Table 22: Parasite parameters of nematodes recovered in Canada lynx (*Lynx canadensis*) from six regions of insular Newfoundland during the 1999-2003 trapping years.

Species	Parasite Parameters	Region					
		CN (N=83)	AP (N=50)	NEC (N=142)	WC (N=71)	NP* (N=6)	SC* (N=4)
Toxascaris leonina	Prevalence (%)	76.7	68.0	82.4	73.0	83.3	75.0
	Intensity	0-46	0-105	0-66	0-66	0-54	0-13
	Mean Intensity	0.198	0.535	0.113	0.202	3.11	4.63
	Abundance	0.139	0.360	0.094	0.149	2.58	3.47
	Dispersion	11.80	29.28	14.64	18.88	18.13	11.30
Troglostrongylus wilsoni	Prevalence (%)	21.2	16.0	24.6	32.4	----	25.0
	Intensity	0-220	0-134	0-109	0-77	----	0-5
	Mean Intensity	0.729	0.708	0.335	0.636	----	1.00
	Abundance	0.164	0.115	0.083	0.193	----	0.250
	Dispersion	132.2	71.03	75.52	124.7	----	4.00
Toxocara canis	Prevalence (%)	6.0	6.0	3.5	4.2	----	----
	Intensity	0-12	0-12	0-19	0-4	----	----
	Mean Intensity	0.077	0.10	0.05	0.059	----	----
	Abundance	0.0048	0.0061	0.0034	0.0027	----	----
	Dispersion	3.66	9.83	13.29	3.88	----	----
Toxocara cati	Prevalence (%)	3.6	4.0	2.1	1.4	----	25.0
	Intensity	0-14	0-8	0-9	0-10	----	0-6
	Mean Intensity	0.109	0.130	0.055	0.746	----	1.50
	Abundance	0.0042	0.0053	0.0013	0.011	----	0.375
	Dispersion	10.05	7.63	6.72	7.69	----	6.00
Nematodirus spp.	Prevalence (%)	----	----	0.7	1.4	----	25.0
	Intensity	----	----	0-3	0-5	----	0-6
	Mean Intensity	----	----	0.022	0.149	----	1.50
	Abundance	----	----	1.6×10^{-3}	0.0022	----	0.375
	Dispersion	----	----	5.63	6.70	----	6.00
Uncinaria stenocephala	Prevalence (%)	----	----	0.7	----	----	----
	Intensity	----	----	0-6	----	----	----
	Mean Intensity	----	----	0.023	----	----	----
	Abundance	----	----	0.0017	----	----	----
	Dispersion	----	----	2.99	----	----	----
Crenosoma vulpis	Prevalence (%)	----	----	1.4	----	----	----
	Intensity	----	----	0-2	----	----	----
	Mean Intensity	----	----	0.0299	----	----	----
	Abundance	----	----	4.5×10^{-3}	----	----	----
	Dispersion	----	----	1.99	----	----	----

* - Excluded from regional statistical analyses

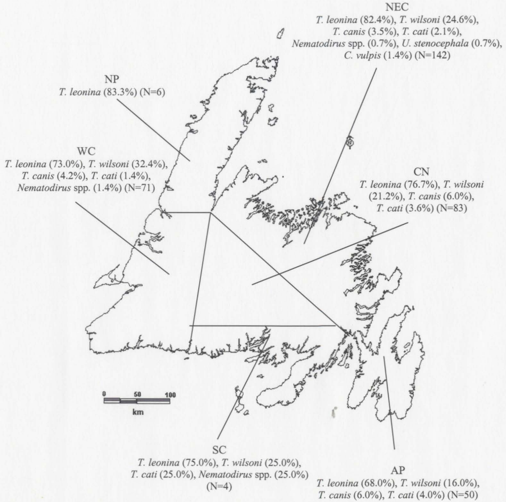

Figure 8: Distribution and prevalence of nematodes recovered in Canada lynx (*Lynx canadensis*) from six regions of insular Newfoundland during the 1999-2003 trapping years.

Note: Data includes prevalence (%) and number of animals (N) examined from each region.

(P= 0.484) (Table 22and Figure 8). Prevalence did not differ significantly with respect to trapping year (P = 0.286).

Prevalence of *Nematodirus* spp. did not differ significantly with respect to age (P = 1.000) or sex (P = 1.000) (Tables 15, 20 and 21). Between regions, prevalence was lowest on the North East Coast (0.70%) but was not significantly lower than the West Coast (1.4%) (P = 0.564) (Table 22 and Figure 8). Prevalence did not differ with respect to trapping year (P = 0.564) (Table 19).

Uncinaria stenocephala was recovered from one juvenile female on the North East Coast (Figure 8) with a prevalence of 0.7%.

Crenosoma vulpis was recovered from one juvenile female from the West Coast (Figure 8) with a prevalence of 1.4%.

3.4.2 Red fox.

The number of Red fox (N=107) that were examined for enteric parasites was less than the total number of Red fox (N=112) as age, sex and/or region of five Red fox trapped during the 2001-2002 trapping year were unknown. Statistical analyses are based on data from the 2002-2003 trapping year. Red fox were obtained from three regions (Figure 6). The actual numbers used in statistical analyses are shown in the respective tables.

Seven helminths were recovered from Red fox, the cestodes *Mesocestoides* spp. and *Diphyllobothrium latum* and the nematodes *Troglostrongylus wilsoni*, *Toxocara canis*, *Uncinaria stenocephala*, *Crenosoma vulpis* and *Physaloptera rara*.

3.4.2.1 Cestodes.

Mesocestoides spp. was only recovered from juvenile female Red fox (Table 23). Prevalence differed significantly among regions (P = 0.000) with Red fox from the West Coast having a higher prevalence (18.2%) than those on the Northern Peninsula (2.1%) (Figure 9).

Prevalence of *Diphyllobothrium latum* did not differ significantly with respect to age (P = 0.564) or sex (P = 0.763) (Table 23 and 25). *Diphyllobothrium latum* was only recovered from Red fox on the Northern Peninsula with a prevalence of 7.5% (Figure 9).

3.4.2.2 Nematodes.

Troglostrongylus wilsoni was recovered from one juvenile female on the Northern Peninsula with a prevalence of 1.0% (Table 24 and Figure 10).

Prevalence of *Toxocara canis* differed significantly with respect to age (P =0.003) with prevalence being higher in juveniles (13.7%). It did not differ significantly between males and females (P =0.796) (Table 24 and 25). Prevalence of *T. canis* on the Northern Peninsula (10.4%) was significantly lower than that of the West Coast (25.0%) (P = 0.005) (Figure 10).

Prevalence of *Uncinaria stenocephala* did not differ significantly with respect to age (P = 0.157) or sex (P = 0.157) (Table 24 and 25). *Uncinaria stenocephala* was only recovered from Red fox on the Northern Peninsula and had a prevalence of 5.2% (Figure 10).

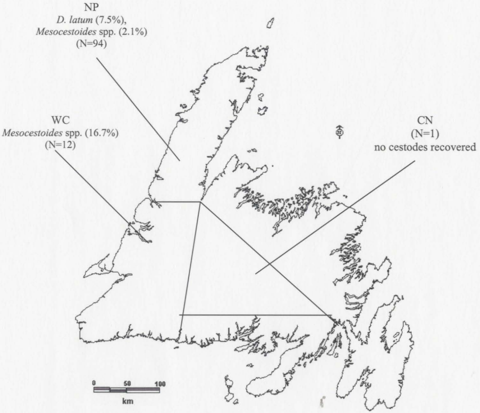

Figure 9: Distribution and prevalence of cestodes recovered in Red fox (*Vulpes vulpes*) from two regions of insular Newfoundland during the 2002-2003 trapping year.

Note: Data includes prevalence (%) and the number of animals (N) examined from each region.

Table 23: Parasite parameters of cestodes recovered in adult and juvenile Red fox (*Vulpes vulpes*) from insular Newfoundland during the 2002-2003 trapping year.

Trapping year	Sex	Parasite Parameters	*Mesocestoides* spp.	*Diphyllobothrium latum*
Adults	Males (N=40)	P	----	7.5
		I	----	0-6
		MI	----	0.07
		A	----	0.005
		D	----	4.67
	Females (N=16)	P	----	----
		I	----	----
		MI	----	----
		A	----	----
		D	----	----
Juveniles	Males (N=24)	P	----	4.2
		I	----	0-5
		MI	----	0.21
		A	----	0.009
		D	----	5.01
	Females (N=27)	P	14.8	7.4
		I	0-8	0-10
		MI	0.21	0.26
		A	0.03	0.02
		D	6.56	8.06

Note: P (Prevalence - %), I (Intensity), MI (Mean Intensity), A (Abundance) and D (Dispersion).

Table 24: Parasite parameters of nematodes recovered in adult and juvenile Red fox (*Vulpes vulpes*) from insular Newfoundland during the 2002-2003 trapping year.

Trapping year	Sex	Parasite Parameters	*Troglostrongylus wilsoni*	*Toxocara canis*	*Uncinaria stenocephala*	*Crenosoma vulpis*	*Physaloptera rara*
Adults	Males (N=40)	P	----	2.5	7.5	55.0	----
		I	----	0-15	0-6	0-170	----
		MI	----	0.38	0.07	0.71	----
		A	----	0.009	0.005	0.39	----
		D	----	15.0	4.67	69.5	----
	Females (N=16)	P	----	----	----	62.5	----
		I	----	----	----	0-72	----
		MI	----	----	----	1.02	----
		A	----	----	----	0.64	----
		D	----	----	----	30.8	----
Juveniles	Males (N=24)	P	----	16.7	4.2	29.2	4.2
		I	----	0-46	0-1	0-50	0-2
		MI	----	0.69	0.04	0.84	0.08
		A	----	0.12	0.002	0.25	0.004
		D	----	33.2	0.99	25.7	2.00
	Females (N=27)	P	3.7	11.1	3.7	25.9	----
		I	0-3	0-44	0-1	0-205	----
		MI	0.11	0.84	0.04	1.76	----
		A	0.004	0.09	0.001	0.46	----
		D	2.99	31.4	1.00	138.9	----

Note: P (Prevalence - %), I (Intensity), MI (Mean Intensity), A (Abundance) and D (Dispersion).

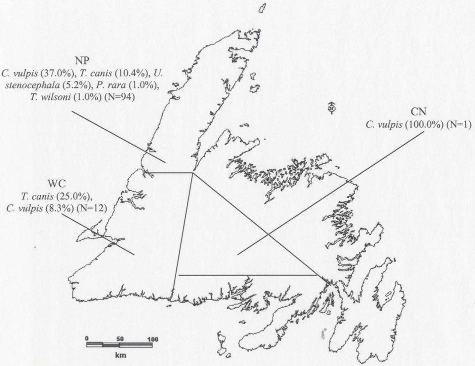

Figure 10: Distribution and prevalence of nematodes recovered in Red fox (*Vulpes vulpes*) from three regions of insular Newfoundland during the 2002-2003 trapping year.

Table 25: A comparison of the overall prevalence (%) of helminths with respect to age and sex, in 107 Red fox (*Vulpes vulpes*) collected during the 2002-2003 trapping year.

Helminths	Age Class			Sex		
	Adults (N=56)	Juveniles (N=51)	(P)	Males (N=64)	Females (N=43)	(P)
Cestodes						
Mesocestoides spp.	---	7.8	N/A	---	9.3	N/A
Diphyllobothrium latum	5.4	5.9	0.564	6.3	4.7	0.763
Nematodes						
Troglostrongylus wilsoni	---	1.9	N/A	---	2.3	N/A
Toxocara canis	1.8	13.7	0.003	7.8	6.9	0.796
Uncinaria stenocephala	5.4	3.9	0.157	6.3	2.3	0.157
Crenosoma vulpis	83.9	27.5	0.00	45.3	74.4	0.008
Physaloptera rara	---	1.9	N/A	1.6	---	N/A

Note: Total sample size (N=107) for this table is smaller than the overall sample of Red fox examined due to the fact that age and sex were unknown for Red fox (N=5) collected during the 2001-2002 trapping year and were therefore excluded from statistical analyses.

N/A – not applicable

Prevalence of *Crenosoma vulpis* differed significantly with respect to age (P = 0.000) and sex (P =0.008) with the prevalence being highest in adults (83.9%) and females (74.4%) (Tables 24 and 25). Between regions, prevalence on the Northern Peninsula (37%) and the West Coast (8.3%) differed significantly (P = 0.000) (Figure 9). One Red fox from Central Newfoundland was infected with four *C. vulpis* but was not used in statistical analysis as the sample size (N=1) was too small.

Physaloptera rara was recovered from one Red fox on the Northern Peninsula with a prevalence of 1.0% (Figure 10).

3.4.3 Coyote.

Seventy-five coyotes were examined for enteric parasites. Six young-of-the-year coyotes were infected with *C. vulpis* but were excluded from statistical analyses as sample size was too small. Coyotes were obtained from three regions (Figure 6). The number of coyotes used in regional analyses (N=66) is smaller than the total sample (N=75) as area of capture for some animals was unknown.

Ten helminths were recovered from coyotes, the cestodes *Taenia ovis krabbei, T. pisiformis, T. hydatigena* and *Mesocestoides* spp. and the nematodes *Toxascaris leonina, Toxocara canis, Uncinaria stenocephala, Physaloptera rara, Crenosoma vulpis*, and *Angiostrongylus vasorum.*

3.4.3.1 Cestodes.

Prevalence of *Taenia ovis krabbei* did not differ significantly with respect to age (P = 0.637). *Taenia ovis krabbei* was only recovered from males (Table 26 and 28).

Table 26: Parasite parameters of cestodes recovered in juvenile Eastern coyote (*Canis latrans*) from insular Newfoundland during the 2001-2003 trapping years.

Trapping year	Sex	Parasite Parameters	*Taenia ovis krabbei*	*Taenia hydatigena*	*Mesocestoides* spp.
2001-2002	Males (N=4)	P	----	----	25.0
		I	----	----	0-1
		MI	----	----	0.25
		A	----	----	0.06
		D	----	----	1.00
	Females (N=4)	P	----	----	----
		I	----	----	----
		MI	----	----	----
		A	----	----	----
		D	----	----	----
2002-2003	Males (N=9)	P	22.2	11.1	11.1
		I	0-1	0-1	0-35
		MI	0.11	0.11	3.88
		A	0.03	0.01	0.43
		D	0.87	1.00	34.9
	Females (N=2)	P	----	----	----
		I	----	----	----
		MI	----	----	----
		A	----	----	----
		D	----	----	----

Note: P (Prevalence - %), I (Intensity), MI (Mean Intensity), A (Abundance) and D (Dispersion).

Table 27: Parasite parameters of cestodes recovered in adult Eastern coyote (*Canis latrans*) from insular Newfoundland during the 2001-2003 trapping years.

Trapping year	Sex	Parasite Parameters	*Taenia ovis krabbei*	*Taenia pisiformis*	*Taenia hydatigena*	*Mesocestoides* spp.
2001-2002	Males (N=10)	P	10.0	----	10.0	----
		I	0-20	----	0-8	----
		MI	2.00	----	0.80	----
		A	0.20	----	0.08	----
		D	20.0	----	8.00	----
	Females (N=3)	P	----	----	33.3	33.3
		I	----	----	0-30	0-30
		MI	----	----	10.0	10.0
		A	----	----	3.33	3.33
		D	----	----	30.0	30.0
2002-2003	Males (N=30)	P	10.0	3.3	----	----
		I	0-27	0-8	----	----
		MI	0.39	0.27	----	----
		A	0.04	0.01	----	----
		D	21.3	7.99	----	----
	Females (N=7)	P	----	----	----	----
		I	----	----	----	----
		MI	----	----	----	----
		A	----	----	----	----
		D	----	----	----	----

Note: P (Prevalence - %), I (Intensity), MI (Mean Intensity), A (Abundance) and D (Dispersion).

Table 28: A comparison of the overall prevalence (%) of helminths with respect to age and sex, in 69 Eastern coyote (*Canis latrans*) collected during the 2001-2003 trapping years.

Helminths	**Age Class**			**Sex**		
	Adults (N=50)	Juveniles (N=19)	(P)	Males (N=53)	Females (N=16)	(P)
Cestodes						
Taenia ovis krabbei	8.0	10.5	0.637	9.1	----	N/A
Taenia pisiformis	2.0	----	N/A	1.8	----	N/A
Taenia hydatigena	4.0	5.3	0.739	3.6	6.3	0.527
Mesocestoides spp.	2.0	10.5	0.013	3.6	6.3	0.527
Nematodes						
Toxascaris leonina	---	5.3	N/A	1.9	---	N/A
Toxocara canis	12.0	36.8	0.010	20.8	12.5	0.170
Uncinaria stenocephala	2.0	5.3	0.257	3.7	----	N/A
Crenosoma vulpis	12.0	36.8	0.00	20.8	12.5	0.170
Physaloptera rara	6.0	5.3	0.763	5.7	6.3	1.00
Angiostrongylus vasorum	2.0	---	N/A	1.9	---	N/A

Note: Total sample size (N=69) for this table is smaller than the overall sample of coyote examined because young-of-the-year (N=6) were not included in the overall analyses.

N/A – not applicable

Prevalence of *T. ovis krabbei* on the North East Coast (13.5%) was not significantly different (P = 0.074) than in Central Newfoundland (6.3%) (Figure 11). Prevalence did not differ significantly with respect to trapping year (P = 0.197) (Table 29).

Taenia pisiformis was recovered from one adult male coyote from the North East Coast during the 2002-2003 trapping year with a prevalence of 2.7% (Figure 11).

Prevalence of *Taenia hydatigena* did not differ significantly with respect to sex (P = 0.527) or age (P = 0.739) (Tables 26-28). Between regions, prevalence was significantly higher (P = 0.004) in Central Newfoundland than (18.9%) the North East Coast (5.4%) (Figure 11). Prevalence did not differ with respect to trapping year (P = 0.109) (Table 29).

Prevalence of *Mesocestoides* spp. differed significantly with respect to age (P = 0.013) with juveniles having the highest prevalence (10.5%). It did not differ with respect to sex (P = 0.527) (Table 25-28). Between regions, prevalence did not differ significantly (P = 0.763) (Figure 10). Prevalence differed significantly with respect to trapping year (P = 0.021) with the highest prevalence in 2001-2002 (9.5%) (Table 29).

3.4.3.2 Nematodes.

Ten *Toxascaris leonina* were recovered from one juvenile male coyote from the North East Coast with a prevalence of 2.7%. Based on the total sample examined prevalence with respect to age and sex was 5.3% and 1.9% respectively (Figure 12).

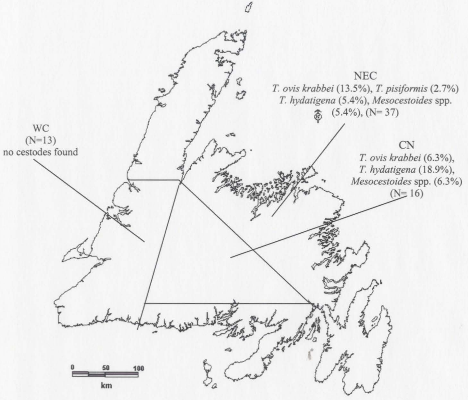

Figure 11: Distribution and prevalence of cestodes recovered in Eastern coyotes (*Canis latrans*) from two regions of insular Newfoundland during the 2000-2003 trapping years

Note: Data includes the prevalence (%) and the number of animals (N) examined from each region.

Table 29: Overall prevalence (%) of helminths recovered in 69 Eastern coyote (*Canis latrans*) from insular Newfoundland during the 2001-2003 trapping years.

Helminths	Trapping Year			
	2001-2002 (n=21)	2002-2003 (n=48)	Overall (n=69)	(P)
Cestodes				
Taenia ovis krabbei	4.8	10.4	8.6	0.197
Taenia pisiformis	----	2.1	1.4	N/A
Taenia hydatigena	9.5	4.2	7.2	0.109
Mesocestoides spp.	9.5	2.1	4.3	0.021
Nematodes				
Toxascaris leonina	----	2.1	1.5	N/A
Toxocara canis	19.0	18.9	18.8	1.00
Uncinaria stenocephala	----	4.2	2.9	N/A
Crenosoma vulpis	9.5	16.7	14.5	0.178
Physaloptera rara	4.8	6.3	5.8	0.763
Angiostrongylus vasorum	----	2.1	1.5	N/A

N/A – not applicable

Prevalence of *Toxocara canis* differed significantly with respect to age ($P = 0.010$) with juveniles having the highest prevalence (36.8%). It did not differ significantly with respect to sex ($P = 0.170$) (Table 28). Between regions, prevalence on the North East Coast (27.0%) was significantly higher than in either Central Newfoundland (15.4%) or the West Coast (12.5%) ($P = 0.004$) (Figure 12). Prevalence did not differ significantly with respect to trapping year ($P = 1.000$) (Table 29).

Prevalence did not differ significantly with respect to age ($P = 0.257$) (Table 28). *Uncinaria stenocephala* was only recovered from coyotes on the North East Coast and had a prevalence of 5.4% (Figure 12). Prevalence during 2002-2003 was 4.2% (Table 29). This nematode was not recovered from female coyotes.

Prevalence of *Crenosoma vulpis* differed significantly with respect to age ($P = 0.000$) with juveniles having the highest prevalence (36.8%). Prevalence was not significantly different with respect to sex ($P = 0.170$) (Table 27). Between regions, prevalence on the North East Coast (27.0%) was significantly higher than in Central Newfoundland (12.5%) and the West Coast (15.4%) ($P = 0.044$) (Figure 12). Prevalence did not differ significantly with respect to trapping year ($P = 0.178$) (Table 29).

Prevalence of *Physaloptera rara* did not differ significantly by age ($P = 0.763$) or sex ($P = 1.000$) (Table 28). Prevalence differed significantly with respect to region with prevalence being lower on the North East Coast (5.4%) than the West Coast (15.4%) ($P = 0.025$) (Figure 12). Prevalence did not differ significantly with respect to trapping year ($P = 0.763$) (Table 29).

Table 30: Parasite parameters of nematodes recovered in juvenile Eastern coyote (*Canis latrans*) from insular Newfoundland during the 2001-2003 trapping years.

Trapping year	**Sex**	**Parasite Parameters**	*Toxascaris leonina*	*Toxocara canis*	*Uncinaria stenocephala*	*Crenosoma vulpis*	*Physaloptera rara*
2001-2002	Males (N=4)	P	----	75.0	----	75.0	25.0
		I	----	0-7	----	0-42	0-1
		MI	----	0.92	----	4.92	0.25
		A	----	0.39	----	3.69	0.06
		D	----	3.49	----	23.6	1.00
	Females (N=4)	P	----	----	----	25.0	----
		I	----	----	----	0-21	----
		MI	----	----	----	5.25	----
		A	----	----	----	1.31	----
		D	----	----	----	21.0	----
2002-2003	Males (N=9)	P	11.1	33.3	11.1	33.3	----
		I	0-10	0-12	0-1	0-98	----
		MI	1.11	0.78	0.11	0.47	----
		A	0.12	0.26	0.012	0.16	----
		D	9.99	7.29	0.99	75.8	----
	Females (N=2)	P	----	50.0	----	----	----
		I	----	0-3	----	----	----
		MI	----	1.50	----	----	----
		A	----	0.75	----	----	----
		D	----	2.99	----	----	----

Note: P (Prevalence - %), I (Intensity), MI (Mean Intensity), A (Abundance) and D (Dispersion).

Table 31: Parasite parameters of nematodes recovered in adult Eastern coyote (*Canis latrans*) from insular Newfoundland during the 2001-2003 trapping years.

Trapping year	Sex	Parasite Parameters	*Toxocara canis*	*Uncinaria stenocephala*	*Crenosoma vulpis*	*Physaloptera rara*	*Angiostrongylus vasorum*
2001-2002	Males (N=10)	P	----	----	----	----	----
		I	----	----	----	----	----
		MI	----	----	----	----	----
		A	----	----	----	----	----
		D	----	----	----	----	----
	Females (N=3)	P	33.3	----	33.3	----	----
		I	0-4	----	0-6	----	----
		MI	1.33	----	2.00	----	----
		A	0.44	----	0.67	----	----
		D	4.01	----	5.99	----	----
2002-2003	Males (N=30)	P	13.3	3.3	16.7	6.7	3.3
		I	0-18	0-6	0-52	0-6	0-6
		MI	0.34	0.20	0.78	0.12	0.20
		A	0.05	0.007	0.13	0.008	0.007
		D	15.4	5.9	42.7	5.23	5.99
	Females (N=7)	P	14.3	----	----	14.3	----
		I	0-9	----	----	0-7	----
		MI	1.29	----	----	1.00	----
		A	0.18	----	----	0.14	----
		D	8.96	----	----	7.02	----

Note: P (Prevalence - %), I (Intensity), MI (Mean Intensity), A (Abundance) and D (Dispersion).

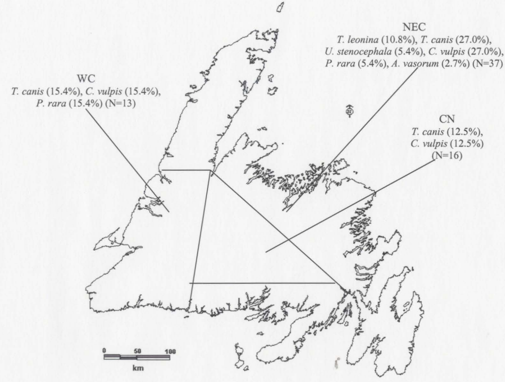

Figure 12: Distribution and prevalence of nematodes recovered in Eastern coyote (*Canis latrans*) from three regions of insular Newfoundland during the 2000-2003 trapping years.

Note: Data includes prevalence (%) and the number of animals (N) examined from each region.

Six *Angiostrongylus vasorum* occurred in one adult male coyote trapped on the North East Coast with a prevalence of 2.7% (Figure 12).

3.5 Multiple parasitism.

A comparison of multiple parasite infections in lynx by sex and age class (Table 32) shows that most lynx (N=237) had between one and three co-occurring parasites species. Fifty-three percent contained two parasite species. There were no significant differences in multiple parasite infections with respect to age (P = 0.455) or sex (P =0.622).

10.3% (N=11) of all Red fox were parasitized by more than two parasite species (Table 33). Most of the sample (N=48) was not parasitized. Adult females were not infected with two or more parasite species. Significant differences with respect to multiple infections occurred between adults and juveniles with more juveniles being infected with more parasite species than adults (P =0.003).

Sixteen percent of coyotes examined (N=12) contained two or more co-occurring parasite species (Table 34), with no young-of-the-year or female coyote being infected with multiple species. Most of the sample (N=46) was not parasitized. Significant differences with respect to multiple infections occurred with respect to age with juveniles being infected with more parasite species than adults (P=0.000).

Table 32: A comparison of multiple parasite infections with respect to age and sex, in 330 Canada lynx (*Lynx canadensis*) in insular Newfoundland during the 1999-2003 trapping years.

Age Class	Number of Parasite Species (%)					
	Sex (N)	**0**	**1**	**2**	**3**	**4**
Adults	Male (103)	7 (3.5)	19 (9.5)	52 (26.1)	24 (12.1)	1 (0.50)
	Female (96)	6 (3.0)	12 (6.0)	53 (26.6)	22 (11.0)	3 (1.5)
	Total (199)	13 (6.5)	31(15.6)	105(52.7)	46 (23.1)	4 (2.0)
Juveniles	Male (58)	8 (7.2)	12 (10.8)	29 (26.1)	9 (8.1)	----
	Female (53)	7 (6.3)	8 (7.2)	32 (28.8)	4 (3.6)	1 (0.90)
	Total (111)	15 (13.5)	20 (18.0)	61(54.9)	13 (11.7)	1 (0.90)
Young-of-the-year	Male (5)	1 (5.0)	2 (10.0)	1 (5.0)	1 (5.0)	----
	Female (15)	2 (10.0)	3 (15.0)	9 (45.0)	1 (5.0)	----
	Total (20)	3 (15.0)	5 (25.0)	10 (50.0)	2 (10.0)	----
Total Population		31	56	176	61	5
Total Population (%)		9.4	16.9	53.3	18.5	1.5

Note: Differences in sample sizes are due to the presence of specimens for which age and sex were unknown (N=36).

Table 33: A comparison of multiple parasite infections with respect to age and sex, in 107 Red fox (*Vulpes vulpes*) in insular Newfoundland during the 2002-2003 trapping year.

Age Class	Sex (N)	Number of Parasite Species (%) 0	1	2	3	4
Adults	Male (40)	13 (23.2)	25 (44.6)	2 (3.6)	----	----
	Female (16)	6 (10.7)	10 (17.9)	----	----	----
	Total (56)	19 (33.9)	35 (62.5)	2 (3.6)	----	----
Juveniles	Male (24)	15 (29.4)	5 (9.8)	5 (9.8)	----	----
	Female (27)	14 (27.4)	7 (13.7)	4 (7.8)	----	----
	Total (51)	29 (56.8)	13 (25.5)	9 (17.6)	----	----
Total Population		48	48	11	N/A	N/A
Total Population (%)		44.9	44.9	10.3	N/A	N/A

Note: Total sample size (N=107) for this table is smaller than the overall sample of Red fox examined due to the fact that age and sex were unknown for Red fox (N=5) collected during the 2001-2002 trapping year and were therefore not included in the overall analysis.

N/A – not applicable

Table 34: A comparison of multiple parasite infections with respect to age and sex, in 75 Eastern coyote (*Canis latrans*) in insular Newfoundland during the 2000-2003 trapping years.

	Number of Parasite Species (%)					
Age Class	**Sex (N)**	**0**	**1**	**2**	**3**	**4**
Adults	Male (40)	29 (58.0)	8 (16.0)	2 (4.0)	1 (2.0)	----
	Female (10)	6 (12.0)	4 (8.0)	0	0	----
	Total (50)	35 (70.0)	12 (24.0)	2 (4.0)	1 (2.0)	----
Juveniles	Male (13)	4 (21.1)	0	6 (31.6)	3	----
	Female (6)	4 (21.1)	2 (10.5)	0	0	----
	Total (19)	8 (42.1)	2 (10.5)	6 (31.6)	3 (15.8)	----
Young-of-the-year	Male (3)	0	3 (50.0)	----	----	----
	Female (3)	3 (50.0)	0	----	----	----
	Total (6)	3 (50.0)	3 (50.0)	----	----	----
Total Population		46	17	8	4	N/A
Total Population (%)		61.3	22.7	10.7	5.3	N/A

N/A – not applicable

3.5.1 Prevalence of co-occurring parasites.

Prevalence of the cestode *T. pisiformis* differed significantly between lynx and coyote (P = 0.000), with prevalence being higher in lynx (Table 35). Prevalence of *T. ovis krabbei* was significantly greater in coyotes than lynx (P = 0.013). The nematodes, *T. leonina* and *T. wilsoni* were more prevalent in lynx than coyote (P = 0.000). Prevalence of *T. canis* was significantly higher in coyotes (P = 0.006) than lynx or Red fox, and *C. vulpis* was most prevalent in Red fox (P = 0.000).

Table 35: A comparison of the prevalence (%) of co-occurring parasites in Canada lynx (*Lynx canadensis*), Red fox (*Vulpes vulpes*) and Eastern coyote (*Canis latrans*) from insular Newfoundland during the 2002-2003 trapping year.

Helminths	Host (N)			
	Lynx (N=129)	Red fox (N=107)	Coyote (N=48)	(P)
Cestodes				
Taenia pisiformis	31.0	----	2.1	0.000
Taenia macrocystis	39.5	----	----	N/A
Taenia laticollis	9.3	----	----	N/A
Taenia hydatigena	7.8	----	4.2	0.248
Taenia ovis krabbei	1.5	----	10.8	0.013
Diphyllobothrium latum	----	5.6	----	N/A
Mesocestoides spp.	----	3.7	2.1	0.414
Nematodes				
Toxascaris leonina	82.2	----	2.1	0.000
Troglostrongylus wilsoni	38.8	0.9	----	0.000
Toxocara canis	3.1	7.5	18.9	0.001
Toxocara cati	5.4	----	----	N/A
Nematodirus spp.	1.6	----	----	N/A
Uncinaria stenocephala	----	4.7	4.2	0.739
Physaloptera rara	----	0.9	6.3	0.059
Crenosoma vulpis	0.7	43.0	16.7	0.000
Angiostrongylus vasorum	----	----	2.1	N/A

N/A – not applicable

4. Discussion.

The mechanisms involved in the life cycle of a parasite transmitted between a predator and a prey species may depend on a variety of factors: relative population densities, sex and/or age-related changes, annual and/or seasonal changes in host and parasite abundance, host reproduction and survival, variation in the host's individual resistance to infection or the ability to kill the parasite once infected (Theis and Schwab, 1992). Seasonal vulnerability of parasites (ova and larval stages) to climatic conditions and dietary habits of the definitive and intermediate hosts are also important. Host density, morphology and diet may affect the composition and transmission rate of its parasite fauna (Smith *et al.* 1986).

4.1 Sex ratio and age structure.

The proportion of males to females in a host population is referred to as a sex ratio. This measure coupled with the age structure, reproductive performance, and mortality of a population may be used to develop strategies for population management. The age structure of a population indicates the numerical representation of individuals of a particular age within a population.

Previous studies have shown that sex ratios in trapped lynx can vary and often favour males (Parker *et al.* 1983; Quinn and Thompson, 1985; Levandier, 2003). Although Brand and Keith (1979) reported a balanced sex ratio of 1.00:1.00, Parker *et al.* (1983) and Quinn and Thompson (1985) reported sex ratios of males to females as 1.20:1.00 and 1.00:0.77 respectively. In contrast, Levandier (2003) reported a sex ratio of males to females as 0.78:1.00 in her sample of lynx in Newfoundland. The overall sex ratio of lynx in this study was 1.01:1.00. There were marginally more males than females in this study which may be the result of sex biased trapping pressures, whereby males may be more vulnerable to this method of capture than females because of increased mobility and their use of larger home ranges (Saunders, 1963 b).

The age structure of Newfoundland lynx was similar to other lynx populations in North America (Berrie, 1974; Brand and Keith, 1979; Parker *et al.* 1983; Quinn and Thompson, 1987). Young-of-the-year comprised 6.1% of all lynx sampled. Brand and Keith (1979) showed that a decrease in the recruitment of kits led to a progressive shift in the age structure of the population towards older cohorts. Low numbers of kits in the harvest may have been the result of reduced breeding rates in adult females, a cessation of breeding by juvenile females and/or a high infant mortality rate, or a lack of capture of these animals.

Juveniles and adults comprised 33.6% and 60.3% of the sample of trapped lynx. Declines in breeding and recruitment often coincide with a decline in Snowshoe hare populations. Samples of lynx were taken during the 1999-2003 trapping years which coincided with a peak in the Snowshoe hare population in 2000 at which point hare densities ranged from 1.0 - 1.8 hares per hectare compared to a low of 0 - 0.22 hares per hectare in 2004 when the population crashed (Reynolds *et al.* 2004).

Various studies on Red fox have reported equal sex ratios (Storm *et al.* 1976; Sheldon, 1992). Sex ratios of Red foxes can vary throughout the year due to natural mortality, availability of prey, coyote predation, etc. Red fox in this study showed a male biased sex ratio of 1.50:1.00 for the 2002-2003 trapping year. Jefferey (2002) reported a sex ratio of 1.20:1.00 in favour of males for 288 Red foxes collected between October and February in insular Newfoundland. She also reported young-of-the-year, juveniles and adults comprising 60.8%, 21.5% and 17.7% of her samples. Juveniles and adults in this study made up 47.7% and 52.3% of samples trapped during the 2002-2003 trapping year. The percentage of juveniles and adults in this study is higher than that of Jefferey (2002) and may be attributed to trapping pressures. No young-of-the-year were obtained in this study and may be due to the time of year (late fall–early winter) when foxes were trapped. Declines in Red fox densities and harvests have been reported concurrent with the establishment of coyotes (Halpin and Bissonette, 1986; Brady, 1994). Major and Sherbourne (1987) failed to trap any Red fox within core areas of coyote territory in over 7000 trap nights during a four year period in Maine. Red fox home ranges are usually located outside the boundaries of coyote territory as a result of interference competition between the two species.

The recent expansion of the Eastern coyote through the northeastern United States and Canada has been well documented (Richens and Hugie, 1974; Hilton, 1978; Moore and Millar, 1984; Parker, 1995); however, very little is known about this animal's current population dynamics in Newfoundland.

Sex ratios of coyote populations vary as a result of resource abundance, population expansion and intensity of predator control. Coyote sex ratios favouring males have been previously reported (Todd and Keith, 1976; Andrews and Boggess, 1978). Sex ratios of harvested coyote populations are usually balanced or slightly favour males. In

Alberta, Todd *et al.* (1981) reported a sex ratio for 735 coyotes, males to females as 1.08:1.00. Todd and Keith (1983) observed a male to female sex ratio of 1.40:1.00 during a coyote population decline in Alberta.

Moore and Millar (1984) reported balanced sex ratios for 292 Eastern coyotes in New Brunswick and Nova Scotia collected in 1979-1981. Dumond and Villard (2000) also reported a balanced sex ratio of 1.00:1.00 for 77 Eastern coyotes collected in late fall and early winter in eastern New Brunswick. An overall sex ratio of 2.90:1.00 biased towards males was found in this study. Uneven sex ratios may be due to greater mobility of one sex over the other (Todd and Keith, 1976) and therefore greater vulnerability to capture, uneven sex ratios at birth, and/or higher sex-specific mortality from other sources (Andrews and Boggess, 1978). Sex ratios appear to favour males in colonizing populations of coyotes (Parker, 1995) and such a high proportion of males, as seen in this study may be due to the movement of males into new territory.

Young-of-the-year, juveniles and adults comprised 8.0%, 25.3%, and 66.7% of coyotes examined during the three year trapping period in this study. These results are similar to those of Moore and Millar (1984) who stated that colonizing Eastern coyote populations appear to consist of a higher proportion of adults than longer established populations. Dumond and Villard (2000) suggested that an older age structure in coyote populations was due to low levels of exploitation by humans, low immigration rates and high mortality of offspring.

4.2 Morphology.

Morphological variation within a species population may be attributed to external or internal influences (Mayr *et al.* 1953). The most obvious external influence would be geographic isolation which generally occurs with respect to islands and any other situation whereby a genetically viable breeding population becomes isolated from the main species range (Hounsell, 1996). Another factor which may influence morphology is food availability, whereby a lack of food in a species' home range can cause the development of young to vary and the health of older age classes to be poor (Hounsell, 1996). Age and gender may also contribute to morphological variation in species (Mayr *et al.* 1953). Genetics play a very important role in a species morphology whereby differences in the size usually result from sexual reproduction that produces offspring different from parents, or by genetic mutations. Both instances may create an isolated population that is different from the original one (May *et al.* 1953; Hounsell, 1996). Eastern coyotes have a complex genetic origin and possess the potential for interbreeding with wolves and/or domestic dogs (Gompper, 2002).

Very little information is available on the morphology of lynx in Newfoundland, or indeed all of North America. Saunders (1964) examined the morphological characteristics of lynx in Newfoundland, and showed a difference between males and females with respect to body weight, basal skull length, and zygomatic breadth. He reported total body lengths ranging from 73.7 to 106.7 cm and weights which ranged from 5.0 to 11.8 kg with males being slightly longer and heavier than females. Van Zyll de Jong (1975) investigated the taxonomic status of Canada lynx in mainland populations and Newfoundland and his findings were similar to Saunders (1964) who noted that the geographic variation in the species was slight and that there was insufficient evidence to justify the distinction of a subspecies in Newfoundland. Levandier (2003) reported significant dimorphic differences in Newfoundland lynx with males from all age classes being heavier than females. Male and female lynx respectively averaged 10.9 kg and 8.13 kg in weight. Similarly, lynx on Cape Breton Island also exhibited dimorphic differences with males being heavier and longer than females. Males averaged 8.3 kg in weight and 93.0 cm in length, while average weight and lengths of females were 7.5 kg and 87.0 cm (Parker *et al.* 1983).

Significant dimorphic differences were noted in this study and are similar to others (Saunders, 1964; Parker *et al.* 1983; Levandier, 2003). Males were generally larger than females for most measurements through all age classes. Adult males averaged 8.02 – 9.68 kg in weight and 90.7 – 96.3 cm in length. Females were slightly smaller and averaged 7.11 – 7.99 kg in weight and 88.5 – 92.5 cm in length. Lynx in this study were slightly larger and heavier than those reported from mainland areas (Parker *et al.* 1983). Differences seen may be attributed to maturational changes as lynx aged, seasonal availability of food resources or trapping pressures (E. Baggs, pers comm., 2004).

The Red fox, *Vulpes vulpes*, is the largest of ten species in the genus *Vulpes* with variation in size occurring on an individual as well as on a geographical basis (Sheldon, 1992). In northern Canada, weights tend to be higher and according to Banfield (1974) and Ables (1975) males are consistently larger and heavier than females. In Ontario, male foxes averaged 4.1 kg in weight and 102.6 cm in length while females were slightly smaller averaging 3.4 kg in weight and 97.3 cm in length (Voigt, 1987).

Very little information is available on the morphology of Red fox in Newfoundland. Jefferey (2002) reported on the morphometrics of Red fox from six regions of insular Newfoundland. Average total body length of adults was 103.1 cm (inclusion of tail) and total weight of 5.1 kg. Significant dimorphic differences were noted in this study, and in all cases, males were larger than females with respect to all measurements, averaging 4.46 kg in weight and 107.6 cm in length, while females were slightly smaller averaging 4.02 kg in weight and 102.3 cm in length. Red fox in this study were slightly larger and heavier than those in mainland areas (Voigt, 1987) but smaller than those examined by Jefferey (2002).

The size and weight of the Eastern coyote in the wild can be overestimated due to their long pelage that masks a bone structure that is lighter than other members of the dog family (Voigt and Berg, 1987). Although large male Eastern coyotes can reach 23 kg, the average male weight is 16-18 kg and females generally weigh 2-5 kg less and lengths range from 120-150 cm (Parker, 1995). The body size of Eastern coyote populations is 27% larger than their western counterparts (Parker, 1995).

The nineteen subspecies of *C. latrans* have been studied extensively throughout most of its North American range (Bekoff, 1978), but very little work has been conducted on the morphology of the Eastern coyote in the eastern-most limits of its range, and none in insular Newfoundland. Weights and lengths of coyotes from Atlantic Canada are comparable to those in other regions of the northeast (Parker, 1995). A collection of 73 coyotes in New Brunswick in 1979-1981 showed mean weights for males and females as 16 kg and 15 kg respectively (Moore and Millar, 1986) Another study in New Brunswick showed that males averaged 14.6 kg in weight and 128.5 cm in length while females averaged 13.1 kg in weight and 123.4 cm in length (Dumond and Villard, 2000).

Total weights and lengths reported in this study are comparable but slightly lower than other Eastern coyote studies (Moore and Millar, 1986; Parker, 1995; Dumond and Villard, 2000). Males averaged 13.1 kg in weight (4.5 – 16.0 kg) and 117.7 cm in length while females averaged 10.2 kg in weight (3.1 – 13.0 kg) and 112.1 cm in length. Larger body size of Eastern coyote populations may be a response to prey size and abundance, or to possible hybridization with wolves and/or dogs (Samson and Crête, 1997; Gompper, 2002). Wayne and Lehman (1992) reported that coyotes sampled in the New England states have mitochondrial DNA genotypes that are shared by coyotes in Michigan, Minnesota, and Québec, and wolves from the south-eastern regions of Ontario and Quebec. Such similarities may be the result of coyote genotypes that have introgressed into the wolf population (Gompper, 2002). Hybridization is also possible with dogs, but the ecological significance of such hybrids may be minor, as morphological characteristics of dogs are rarely found in wild coyotes, and there has not been any report of dog alleles within northeastern coyote populations (Nowak, 1978). Larivière and Crête (1993) attributed larger body size of northeastern coyotes to a genetic adaptation to the use of larger prey.

4.3 Dietary habits.

As noted above, morphological differences in size often reflect the size of prey utilized by predators, with larger animals being able to prey on and consume both large and small prey species, and smaller animals relying mostly on small prey. Competing species may utilize different prey sizes in order to limit competition for food resources (Arjo *et al.* 2002).

The Canada lynx is a dietary specialist that relies heavily on the Snowshoe hare as its main prey item throughout most of its range, and all studies of lynx food habits have shown hares to be their dominant prey item (Saunders, 1963 b; Nellis *et al.* 1972; Brand and Keith, 1979; Parker *et al.* 1983; Ward and Krebs, 1985). The Snowshoe hare's cyclical nature in abundance and its importance in lynx diets has been well documented (Saunders, 1963 b; Brand *et al.* 1976; Brand and Keith, 1979; Parker *et al.* 1983). Specialist predators, like lynx, respond to fluctuating abundances of prey through demographic (changes in reproduction or survival) and/or behavioural adjustments (switching prey or habitats) in response to prey availability (O'Donoghue *et al.* 1998). Responses to prey abundance that ultimately lead to changes in kill rates or prey switching are termed functional responses. Switching is defined as feeding on a prey species disproportionately less when its relative abundance to other prey is low, and disproportionately more when it is high (O'Donoghue *et al.* 1998).

Small mammals such as Snowshoe hares and voles often exhibit population cycles. Oscillations in the numbers of a preferred prey item can influence the abundance of other prey species by altering predation pressures by predators that share a common food base. When the density of a preferred prey species declines, predators like lynx begin taking alternative prey thereby depressing the survival and numbers of the alternative species (Stuart-Smith and Boutin, 1995).

Snowshoe hares are also the primary source of food for Newfoundland lynx (Saunders, 1963 b; Levandier, 2003). Results of this study are similar to other lynx food habits studies (Saunders, 1964; Van Zyll de Jong, 1966 a; Nellis *et al.* 1972). The percent occurrence of Snowshoe hare fluctuated over four trapping years. The functional response of lynx to declining Snowshoe hare densities in this study was reflected by a greater representation of other prey species such as Red squirrel, voles and birds, as well as an increase in larger mammals, such as Woodland caribou and moose (presumably carrion).

Winter food habits of lynx in the Northwest Territories showed that the percent occurrence of Snowshoe hare was 83.3%, Ruffed grouse was 16.6% and Red squirrel was 55% (More, 1976). In Alberta, Nellis *et al.* (1972) reported prey items from 13 lynx digestive tracts, kill sites and scats. Although the sample was small and analyses were restricted to samples taken in December to March, the data showed that Snowshoe hare, Red squirrel and Ruffed grouse were the most important prey items with percent occurrences of 76.9%, 38.4% and 30.1% respectively. The percent occurrence of Snowshoe hare (68.7%), Red squirrel (8.1%) and birds (6.5%) in this study is comparable to that found by others based on the prey species utilized. Stuart-Smith and Boutin (1995) showed that predation on Red squirrels increased during a winter Snowshoe hare decline in the south-western region of the Yukon. The occurrence of Red squirrel in this study increased (2.0% - 12.1%) over the four year trapping period as the proportion of Snowshoe hare in lynx diets fluctuated.

In this study the percent occurrence of Woodland caribou increased from 1.3% during the 2000-2001 trapping year to 10.8% during the 2001-2002 trapping year, at which point the proportion of Snowshoe hare in the diet was at its lowest (54.1%). Lynx predation on caribou neonates has been documented in Newfoundland (Bergerud, 1971, 1983), but reports of predation on older, larger caribou are scarce (Saunders, 1963 b). Lynx were trapped in late fall and winter and the presence of caribou in lynx diets may have been the result of scavenging of carrion, i.e. hunter-killed animals or natural mortality.

Levandier (2003) examined stomach contents of 48 lynx in Newfoundland between 1998-1999, and reported Snowshoe hare as the most abundant prey item (53.0%), followed by birds (9.0%). Moose and Meadow voles comprised 2.0% each of the total food items taken. Results of this study are similar, with voles comprising 2.0% of stomach contents. There was one occurrence of moose recorded for the 2002-2003 trapping year. Saunders (1963 a) reported that moose comprised 71% of the volume of lynx stomach contents from animals trapped in the fall that was attributed to the use of carrion from hunter-killed animals. The one occurrence of fish in lynx stomach contents may have been due to consumption of bait laid by trappers.

Vegetation (mainly grasses) comprised 58.8% of lynx stomach contents. This amount is too high to be attributed to accidental ingestion while grooming or feeding on prey, or aberrant feeding behaviour after capture. Saunders (1963 a) showed that captive lynx readily eat green grass. Grass and other vegetation have been reported from lynx and bobcat scats and digestive tracts (Kight, 1962; Stewart, 1973). It has been suggested that lynx may utilize plant material as other carnivores do to supplement a high intake of animal fibre. Neibauer and Rongstad (1977) suggested that bulky vegetation may function as a scour in the digestive tract and serve as a laxative. Fritts (1973) suggested that this behaviour was purgative, rather than nutritional and that lynx may also use vegetation to serve as an anti-helminthic.

Red foxes are generalists and scavengers with respect to food habits, consuming plant and animal material alike, and readily change their diet with respect to prey availability and season (Jones and Theberge, 1983; Voigt, 1987). The diverse range of prey items they utilize indicate their omnivorous nature. Johnson (1970) reported on the food habits of Red foxes in the Isle Royale National Park in Lake Superior, and found that mammals such as Red squirrel, mice, Snowshoe hare, White-tailed deer, and vegetation were the most important food items. In British Columbia, Jones and Theberge (1983) reported Snowshoe hare, mice, voles, Arctic ground squirrel (*Spermophilus parryii*) and vegetation as the most important food items in Red fox diets, while less importance was placed on moose, beaver (*Castor canadensis*) and Mountain goat (*Oreamnos americanus*). Hockman and Chapman (1983) compared feeding habits of Red and Gray foxes (*Urocyon cinereoargenteus*) in Maryland and found that while both were opportunistic feeders, the remains of voles and Eastern cottontails (*Sylvilagus floridanus*) were recovered more frequently from Red foxes while vegetation was the major item found in Gray foxes.

To date the most recent study on the food habits of Red fox in Newfoundland is that by Tucker (2003) which reported Snowshoe hare (40%), and mice and voles (collectively) (34%) as the most prominent food items recovered. Birds accounted for 10% and fish for 6% of the diet, while plants accounted for 69% of all food items recovered.

The diet of Red foxes in insular Newfoundland reflects its omnivorous nature. Percent occurrence of Snowshoe hare and Meadow voles over two trapping years was 31.8% and 25.3% respectively. Although small mammals have been noted as the most important prey items in the Red fox's dietary regime, Masked shrews and Red squirrels only accounted for 3.3% and 2.2% of all foods taken. Percent occurrence of free-living invertebrates such as slugs, grasshoppers and fly larvae was 4.4%. Slugs serve as intermediate host for the infective larval stage of *A. vasorum* which is a source for transmission of this nematode to Red foxes and other canids. The presence of fly larvae may be the result of feeding on carrion. Hamilton (1935) noted the importance of carrion in Red fox diets during winter and times of low prey densities.

Another indication that the Red fox is extremely opportunistic is that it will readily exploit carrion, as shown by the high percent of caribou in this study (17.6%). Red foxes have also been known to patrol the shorelines of beaches and garbage dumps for food (E. Baggs pers comm., 2004). Percent occurrence of fish remains was 6.6%. However, many of the foxes utilized in this study were trapped for a Rabies eradication program, many of which may have been baited with fish offal. Vegetation accounted for the highest percent occurrence (58.2%), with blueberries and partridgeberries being the most common fruits.

Throughout North America the coyote has been reported as having the ability to change its diet both seasonally and spatially in response to prey diversity and availability (Samson and Crête, 1997; Patterson *et al.* 1998; Dumond and Villard, 2000). A study in south Texas (Andelt *et al.* 1987) showed that mammals comprised 64% of coyote diets, while insects and fruits comprised 10% and 20% respectively. Nellis and Keith (1976) noted the "catholic" (all encompassing) nature of coyote food habits in Alberta. Carrion accounted for approximately 50% of their diet over all seasons, but was most important during the winter. Microtine rodents and Snowshoe hare accounted for 25% and 3% of their diet respectively. Vegetation, mostly blueberries (*Vaccinium* spp.) were utilized heavily during the summer and autumn months.

Population dynamics of Western coyote populations differ between boreal forest and adjoining agricultural areas (Nellis and Keith, 1976). Todd (1985) examined the dietary habits of 1038 coyotes in both forest and agricultural habitats of Alberta during 1972-1975. Diets varied within and between habitats, with forest populations utilizing more Snowshoe hare and ungulates such as White-tailed deer, while farm carrion (not specified) was utilized more often by coyotes occupying farmland.

The Eastern coyote has been described as an opportunistic, generalist predator that tends to feed non-selectively (Parker, 1986; Patterson, 1994). Throughout much of the northeast the coyote must contend with lower prey diversity and abundance in relation to their western counterparts (Samson and Crête, 1997).

The diet of the Eastern coyote has been studied in many parts of the northeastern United States and Canada (Parker, 1986; Parker and Maxwell, 1989; Samson and Crête, 1997; Patterson *et al.* 1998; Dumond and Villard, 2000) and a pattern of dietary habits has surfaced; White-tailed deer and Snowshoe hare are important throughout the year, and fruits such as raspberries (*Rubus* spp.) and blueberries are more important during summer and late fall than that of other times. The importance of White-tailed deer, Snowshoe hare and fruits in the diet has been shown in Maine (Richens and Hugie, 1974), Québec (Samson and Crête, 1997), New Brunswick (Moore and Millar, 1986; Parker, 1995) and Nova Scotia (Patterson, 1994).

This was the first study of the food habits of the Eastern coyote in insular Newfoundland and showed that it consisted mostly of mammals, although differences in the percent occurrence of individual species did occur. Food items recovered reflect the opportunistic and unspecialized nature of coyotes in insular Newfoundland. Results of this study indicated that caribou was a principal prey item for coyotes in Newfoundland with a percent occurrence over a three-year period of 50.0% (N=33). Other items included moose (15.2%), small mammals such as voles (16.7%) and Red squirrel (1.5%), birds (7.6%), fish (9.1%) and vegetation (86.4%).

An important conservation and wildlife management issue involving Eastern coyotes is their impact on caribou and moose. As indicated above coyotes could significantly impact caribou populations, especially if the population were small or isolated (Dumond and Villard, 2000). In Gaspé National Park colonization by coyotes resulted in a decline in the park's caribou herd, in which case the limited number of calves that were killed by coyotes was sufficient to cause a decline in the population (Dumond and Villard, 2000). Since the arrival of the Eastern coyote to insular Newfoundland, there have been several confirmed and unconfirmed reports of coyote predation on adult caribou and calves. Curran and Mahoney (2004) reported 13.3% of mortalities of radio-collared calves (N=30) in the Middle Ridge caribou herd from June 4 to December 5, 2003 as the result of coyote predation.

Like the lynx, cyclic fluctuations of coyote populations have been recorded from fur returns since the early 1900's (Keith, 1963), and reflect the Snowshoe hare's 10-year cycle (O'Donoghue *et al.* 1998). O'Donoghue *et al.* (1998) showed that coyotes preferred hares to other prey at all densities and changes in their use of habitat followed that of hares. Snowshoe hare in this study had an occurrence of 25.8% over three years.

Dietary diversities are affected by the number of prey categories as well as the distribution of prey within each category (Zar, 1999). A more diverse diet is represented by several categories of prey with relatively equal distribution across the categories. Lynx diets were less diverse than either Red fox or coyote. Lynx dietary diversity ranged from 0.48 to 1.07 over four trapping years. The percent occurrence of alternative prey species increased as availability of Snowshoe hare declined. Dietary diversity for Red fox over two trapping years ranged from 1.57 to 1.87. Red fox diets showed the highest degree of dietary diversity and omnivory with respect to the range of small mammals (Snowshoe hare, voles, Masked shrews and Red squirrel), birds, fish and vegetation that were utilized. Coyote dietary diversity ranged from 1.33 to 1.68 over three trapping years with a greater reliance on Woodland caribou, Snowshoe hare and vegetation, and a slight usage of moose, small mammals and birds.

Resource partitioning often occurs among carnivores that share a common habitat or prey base. Sympatric carnivores often partition resources based on their morphological differences in size and such differences in turn are related to the size of prey consumed (Arjo *et al.* 2002). Larger predators can kill and consume both large and small animals, and thereby increase dietary diversity.

There is limited information available regarding dietary overlap between lynx, Red fox and coyote. Dietary overlap occurs when different predators utilize similar prey bases. White *et al.* (1995) reported a high degree of dietary overlap (C_{mh}=0.85) between coyotes and Swift foxes (*Velox velox*) in California. Kitchen *et al.* (1999) also reported a high degree of dietary overlap between coyotes and Swift foxes (C_{mh}=0.91) in Colorado during the pup-rearing season. In this study lynx and Red fox, and lynx and coyote diets were least similar (C_{mh}=0.38 and C_{mh}=0.25 respectively) while Red fox and coyote diets were most similar (C_{mh}=0.90), indicating a high potential for resource competition. A lack of dietary overlap between lynx and Red fox and coyotes is not necessarily indicative of a lack of competition between these animals but that lynx are simply exhibiting their specialist nature and are simply preying on a particular prey species (i.e. Snowshoe hare) more often then others. They too may be preying on similar prey items as Red fox and coyote, but to a much lesser extent.

The use of selected habitat by various carnivores may reduce interspecific competition and in turn reduce dietary overlap (Kitchen *et al.* 1999). Lynx and coyotes are often spatially segregated due to differing morphological adaptations to snow. The habitat utilized by lynx and their primary prey, Snowshoe hares, changes during the population cycle. When hares are abundant lynx use a greater proportion of the landscape as cover habitat, but when hare populations decline, only pockets of optimal lynx habitat are used by hares (Brand *et al.* 1976). Lynx will respond to such behaviour by greatly expanding or abandoning home ranges held during population peaks and will forage around patches of dense habitat with high hare activity (Brand *et al.* 1976; Mowat and Slough, 1998). Coyotes however utilize open habitats for hunting while Red foxes most often prefer brushy habitats (Harrison *et al.* 1989).

Coyotes and Red foxes are sympatric over much of their North American range, and although they often share a common food base, (Theberge and Wedeles, 1989) studies have shown that coyotes are inter-specifically superior to foxes, displacing them from certain habitats (Ables, 1975; Hilton, 1978). In sympatric populations, Red fox territories exist primarily around the periphery of coyote territories or are located largely outside coyote territories (Major and Sherburne, 1987; Sargeant and Allan, 1989). In addition to morphological differences in size and physiological need, subdominant species such as Red foxes exhibit behavioural strategies such as predator avoidance and habitat or prey partitioning to facilitate coexistence with coyotes.

The coexistence of similar canids partially depends on environmental productivity and diversity, resource partitioning and the degree to which shared resources are limited. (Arjo *et al.* 2002). Coyote and Red fox diets were most similar indicating that resource competition for food was most intense between these animals. Such competition may contribute to the exclusion of foxes by coyotes thereby resulting in decreased fox abundance (Cypher, 1993). Red foxes have restricted home ranges when they are sympatric with coyotes, and the extent of spatial overlap between sympatric species determines the potential for resource competition. For instance, foxes establish home ranges outside those of coyotes even when a coyote territory is in an area suitable as fox habitat (Voigt and Earle, 1983; Kitchen *et al.* 1999). There have been reports of coyotes killing Red foxes in traps, and chasing, or preventing them from entering coyote territory (Dekker, 1983; Voigt and Earle, 1983; Major and Sherbourne, 1987).

Coyotes were more dependent on Snowshoe hares than Red foxes. Red foxes exhibited a lower dependence on Snowshoe hare during times of low hare abundance because of their ability to utilize alternate prey species. In terms of exploitation competition, foxes may be able to persist in areas where hares are less abundant (Theberge and Wedeles, 1985).

4.4 Parasite prevalence and multiple parasitism.

Parasites encountered in a sample often reflect the diet of the host. Host morphology (large vs. small animals) and age can lead to different prey usage by members within the host population and can influence the diversity of the parasites found within the host.

Taenia pisiformis and *T. macrocystis* were the most prevalent cestodes recovered. Both parasites were recovered from lynx from all regions with the highest prevalence on the North East Coast. *Taenia pisiformis* was also recovered in coyotes from this region but with a much lower prevalence. Levandier (2003) reported high prevalence of *T.*

macrocystis in Newfoundland lynx collected from the Avalon Peninsula and North East Coast.

In contrast, *T. hydatigena* and *T. ovis krabbei* were more prevalent in coyotes, with *T. hydatigena* being more prevalent in Central Newfoundland, while *T. ovis krabbei* was most prevalent on the North East Coast. Boyd (1994) reported a prevalence of 57.3% for *T. hydatigena* in Arctic foxes on the West Coast of Newfoundland and stated that prevalence decreased northward into Labrador. He also reported a prevalence of 1.3% for *T. ovis krabbei* on the Northern Peninsula. *Taenia krabbei* was recovered from one lynx on the North East Coast. None of these cestodes were recovered from Red foxes. The higher prevalence of *T. krabbei* on the North East Coast is likely correlated with the eastern movement of coyote in this province and in turn the spread of *T. krabbei*. A lack of this parasite in Red foxes may be related to prey consumption.

Diphyllobothrium latum was recovered from Red foxes on the Northern Peninsula, and *Mesocestoides* spp. was recovered from Red fox at the same site and also the West Coast. *Mesocestoides* spp. was recovered from coyotes in Central Newfoundland and the North East Coast. Prevalence of *Mesocestoides* spp. was highest on the West Coast of Newfoundland and decreased northward and to the northeast. Forsey (1992) reported a decrease in prevalence of both these cestodes in Red fox from the Northern Peninsula to the West Coast.

Toxascaris leonina, an ubiquitous nematode of felids had the highest prevalence of all parasites in this study. Prevalence varied by region (68.8 - 83.3%) with the highest prevalence on the North East Coast. Levandier (2003) reported prevalence ranging from

81 – 100% for this nematode in all areas she examined. This nematode was recovered from one coyote on the North East Coast. Forsey (1992) recovered a prevalence of 9.7% for this nematode in Red foxes on the Northern Peninsula. It was not recovered from Red foxes in this study.

Toxocara canis, a common nematode of canids, was recovered from all hosts in this study, although it was more prevalent in Red fox and coyotes than lynx. Prevalence in lynx was highest on the Avalon Peninsula and Central Newfoundland while prevalence in Red fox and coyote was highest on the West Coast and North East Coast. Prevalence of *T. canis* was highest in juveniles for both canids. Adult hosts are relatively immune to infections with *T. canis* (Levine, 1980) which may explain the low prevalence in adult Red fox and coyotes in this study. Forsey (1992) recovered *T. canis* from Red foxes on the Northern Peninsula and West Coast, with the highest prevalence on the West Coast. Boyd (1994) did not recover *T. canis* from any of the Arctic foxes he examined from Labrador or Newfoundland's Northern Peninsula. Levandier (2003) did not recover this nematode from any of the lynx that she examined.

Physaloptera rara was recovered from Red fox on the Northern Peninsula and from coyotes on the North East Coast and West Coast with the highest prevalence occurring in coyotes on the West Coast. Prevalence did not differ with respect to either age or sex of these animals. This is the first record of this parasite in a large mammal in Newfoundland. It was previously recovered from one shrew collected from the Hawco's Pond area on the Avalon Peninsula (E. Baggs, pers comm., 2004).

Uncinaria stenocephala is an ubiquitous nematode of canids in northern regions (Levine, 1980). It was recovered from all hosts, with the highest prevalence in Red foxes and coyotes. It was recovered from the North East Coast and Northern Peninsula, with the highest prevalence on the Northern Peninsula. Eggs and larvae of this nematode are resistant to cold temperatures (Levine, 1980) which may explain a higher prevalence in the northern regions where it was recovered. Infections with this nematode may also be exacerbated due to denning activities of canids. Communal dens often compound parasite infections and increase the likeliness of transmission through contact with other infected individuals or create greater concentrations of the parasite (Tuller *et al.* 1976). Infections in the den may be reinforced through ingestion of infected feces or through self and/or mutual grooming.

Troglostrongylus wilsoni is commonly recovered from the lungs of lynx (Van Zyll de Jong, 1966 b) and bobcat (Klewer, 1958). It was recovered from lynx and one fox in this study with the greatest prevalence on the West Coast and the lowest on the North East Coast. Levandier (2003) reported the highest prevalence of this nematode in lynx from Central Newfoundland and the lowest on the North East Coast. Forsey (1992) did not recover it from any of the foxes she examined.

Crenosoma vulpis, a lungworm was recovered from all hosts with the highest prevalence in Red fox. Prevalence was highest in Red fox on the Northern Peninsula and decreased southward and was highest in coyotes on the North East Coast. Forsey (1992) indicated that prevalence of *C. vulpis* in Red foxes decreased northward. Jefferey (2002) reported a prevalence of 87% for *C. vulpis* in Red fox from six regions of Newfoundland with the highest prevalence occurring on the Avalon Peninsula and the South Coast. With respect to age, prevalence was highest in adult Red fox and juvenile coyotes. Jefferey (2002) also noted that prevalence was higher in juvenile Red fox.

In this study, *Angiostrongylus vasorum* was recovered only from one coyote on the North East Coast. Jefferey (2002) reported a prevalence of 56% for this parasite in Red foxes collected from the Avalon Peninsula, North East Coast and the South Coast/Burin Peninsula regions, with the highest prevalence occurring on the Avalon Peninsula. The infected coyote in this study from the North East Coast was not outside the area reported by Jefferey (2002) and there is no indication that the range of this parasite has expanded. She also examined eight coyotes, 38% had *C. vulpis* but none were infected with *A. vasorum*. *Angiostrongylus vasorum* was recovered from an infected coyote in the Foxtrap area in March 2003 on the Avalon Peninsula (Bourque *et al.* in press). It was also recovered from a lynx in July 2001 on the Avalon Peninsula (H. Whitney, pers comm., 2003). It was not recovered from any of the Red foxes in this study; many of which were collected from the Northern Peninsula and West Coast; areas outside the regions that many of Jefferey's (2002) specimens were collected. She states that the distribution of this parasite in Newfoundland may be limited by climate and that it occurs in regions of the province where mean winter temperatures do not drop below –4 °C (Ullah *et al.* 1992).

A parasite species assemblage refers to a single host individual that is infected with more than one helminth species (Bush *et al.* 1997). Concurrent infections with two or more helminths in one host commonly occur (Noble and Noble, 1971). The diversity of a multiple parasite community and abundance of its parasites are intimately linked to the density of the host population, availability of the intermediate, paratenic or reservoir hosts and dietary habits of the host.

Parasite diversity refers to the composition of a helminth community in terms of the number of species present in an individual host (Bush *et al.* 1997). In Manitoba, Samuel *et al.* (1978) reported that 40 of 43 coyotes and six of six Red foxes were infected with two or more co-occurring parasite species, 171 of 177 coyotes in Texas were infected with multiple species (Pence and Windberg, 1984). Tiekotter (1985) reported 63 of 75 bobcats in Nebraska were infected with two or more parasite species.

In this study 73% of lynx examined were infected with two or more co-occurring helminths. With respect to age, 78% of adult lynx were parasitized by two or more helminths. Levandier (2003) reported 75% of 48 Newfoundland lynx to be infected with two or more parasite species. Although there was a slight increase in multiple parasitism with age, no significant differences were noted. Parasite diversity was also similar between sexes.

Parasite diversity in Red fox and coyote was lower than in lynx. Approximately 10.3% and 16.0% of Red foxes and coyotes respectively harboured two or more co-occurring helminths. With respect to Red fox, 17.6% and 3.6% of juveniles and adults were infected with multiple parasite species, while 47.4% and 6.0% of juvenile and adult coyotes were infected with multiple parasite species. No female coyotes were parasitized by multiple species. Forsey (1992) reported a low diversity of parasites in Newfoundland Red foxes and stated that parasite diversity in Newfoundland's canid population would likely increase over time due to the establishment of the coyote in the province. Diversity of parasites in Red fox in this study is comparable to that of Forsey (1992) with the exception of infection with *P. rara*, which has not been previously reported in Newfoundland Red foxes. Jefferey (2002) reported that 65% of the foxes she examined had co-occurring infections with *C. vulpis* and *A. vasorum*. This is the first information available on multiple parasite infections in Newfoundland coyotes.

4.5 Parasitism and dietary overlap.

The Island of Newfoundland has been isolated from the remainder of North America since the last glaciation period (South, 1983). As a result, Newfoundland has a depauperate mammalian fauna (Smith and Threlfall, 1973) that may serve as one of many limiting factors with respect to helminths that may be able to proliferate on the island. Whenever there is a limited fauna, vital links such as intermediate and definitive hosts may be missing from parasite life cycles and therefore prevent successful completion of their life cycles, and thus maintenance of a particular parasite species.

Wild mammals serve as reservoir hosts for parasites that may infect domestic animals and vice versa. While many of these helminths are of little or no consequence to their hosts there are usually some in any geographic region that may demonstrate some degree of pathogenicity (Custer and Pence, 1981) that may depend on the number of parasites harboured. The introduction (natural or otherwise) of non-indigenous host species to the island may affect the island's parasite fauna through the introduction of exotic parasite species.

Members of the family Taeniidae are the most important cestodes in terms of their significance for human and animal health. The life cycles of most Taeniids are sylvatic (involve only wildlife), while a few are pastoral (involve domesticated animals) or involve components of both (Samuel *et al.* 2001). As with most cestodes, the adult stage causes little or no problem for the host unless present in large numbers but the larval stages of some species are markedly pathogenic. Predator-prey interactions are utilized by a variety of cestodes by which the intermediate stage is transferred to the definitive host (Theis and Schwab, 1992). Many tapeworms of carnivores utilize mammalian intermediate hosts such as rodents, lagomorphs and ungulates in the completion of their life cycles (Meyer and Olsen, 1988).

Taenia pisiformis has been reported from lynx in Alberta, the North West Territories and Ontario (Van Zyll de Jong, 1966 b; Smith *et al.* 1986), Red fox in the United States (Erickson, 1944; Miller and Harkema, 1968; Dibble *et al.* 1983) and coyotes in Ontario, Alberta and Manitoba (Freeman *et al.* 1961; Holmes and Podesta, 1968; Samuel *et al.* 1978). It was also reported from bobcats in Nebraska (Tiekotter, 1985). In Newfoundland, *T. pisiformis* has been reported from domestic dogs (Threlfall, 1969), Snowshoe hare (Bennett, 2001; Bridger, 2002), and lynx (Levandier, 2003) but has not previously been recovered from Red foxes (Threlfall, 1969; Forsey, 1992; Boyd, 1994).

Prevalence of *T. pisiformis* differs markedly among definitive hosts and geographic areas. Lagomorphs are considered the main intermediate host for *T. pisiformis* (Van Zyll de Jong, 1966 b; Holmes and Podesta, 1968), and canids the main definitive host (Miller and Harkema, 1968). Cysticercus larvae consist of fluid-filled sacs each with a single invaginated scolex that encysts on the mesenteries of hares and rabbits and are the likely source of infection for a definitive host (Custer and Pence, 1981). Each new metacestode develops a scolex and neck, and when the intermediate host is eaten by a carnivore, each scolex may then develop into an adult tapeworm in the gut (Schmidt and Roberts, 1996). The extent to which leporids are utilized influences the prevalence and abundance of *T. pisiformis* in any particular area. Due to the fact that rabbits are absent from insular Newfoundland, prevalence of this parasite may indeed be lower than in other regions where animals are able to utilize both hares and rabbits as prey (E. Baggs pers comm., 2004).

Taenia pisiformis was recovered from the intestines of 28.2% of lynx and 1.5% of coyotes examined. No specimens were recovered from Red foxes. Van Zyll de Jong (1966 b) reported *T. pisiformis* as the second most abundant cestode of lynx in Alberta and the North West Territories. Smith *et al.* (1986) reported a low prevalence (4%) for *T. pisiformis* recovered from lynx in Ontario. Erickson (1944) and Gier and Ameel (1959) reported prevalence's of 40% and 95% in Minnesota and Kansas coyotes respectively.

Almost all studies of the food habits of lynx have shown that the Snowshoe hare is their dominant prey item (Saunders, 1961; Van Zyll de Jong, 1966 a; Brand and Keith, 1979), particularly when hares are abundant. Snowshoe hare accounted for 68.7% of the lynx diet in this study during the 1999-2003 trapping years.

The prevalence of *T. pisiformis* in Newfoundland coyotes was much lower (1.5%) than that reported from Minnesota (39%) (Erickson, 1944), Alberta (31%) (Holmes and

Podesta, 1968) and Manitoba (67%) (Samuel *et al.*1978). Gier *et al.* (1978) reported that coyotes develop an active immunity against tapeworms. They did not find new infections superimposed upon sizeable infections of mature worms or a number of immature worms concomitant with a number of scolices that were known to have been ingested. In all cases Snowshoe hare was the main prey item in the coyote's diets. Prevalence of this parasite was lower in coyotes despite the fact that Snowshoe hare was an important prey item (25.8%) in their diet. In areas where *T. pisiformis* infection is high, coyotes are preying more on rabbits. Snowshoe hare may not be as good an intermediate host for this tapeworm which may account for the low prevalence of it in Newfoundland coyotes.

Taenia serialis is another common tapeworm of the Snowshoe hare found in Newfoundland (H. Whitney, pers comm., 2003) but was not recovered from either lynx Red fox or coyote in this study. The final hosts of this tapeworm are canids, namely dogs, wolves, coyotes or foxes, in comparison to *T. pisiformis* whose final hosts can include both canids and felids. The fact that this tapeworm was not found in any of the specimens may be due to the fact that the rate of infection of intermediate hosts may be low, or that intermediate hosts infected with *T. serialis* were not consumed.

Taenia macrocystis was recovered from 35.2% of lynx in this study. Felids are the definitive host for this tapeworm and it is prevalent in both lynx and bobcat throughout North America (Bursey and Burt, 1970; Tiekotter, 1985; Levandier, 2003). This parasite is also adapted to the close predator-prey relationship between felids and lagomorphs (Samuel *et al.* 1978). Strobilocercus larvae are similar to cysticerci with some evident strobilization (Schmidt and Roberts, 1996), and occur most frequently on and in the back musculature, abdominal mesenteries, on the diaphragm, encapsulated on the surface of the liver, on the pericardium and around the oesophagus of Snowshoe hares (Levandier, 2003).

Taenia macrocystis was not recovered from lynx in Alberta, the North West Territories (Van Zyll de Jong, 1966 b) or Ontario (Smith *et al.* 1986). Bursey and Burt (1970) reported a prevalence of 100% for this parasite in 14 lynx examined from Newfoundland. Levandier (2003) reported a prevalence of 77.1% for this parasite in 48 lynx from Newfoundland. Although in this study Snowshoe hare comprised 68.7% of the lynx diet over four trapping years, lynx utilized other prey items such as Red squirrel, voles, birds, and carrion, when hares were less abundant, which may account for a lower prevalence of this parasite.

Taenia hydatigena was recovered from 3.9% of lynx and 5.8% of coyote examined. This cestode has a cosmopolitan distribution in a variety of wild and domestic carnivores, usually canids and infrequently felids (Samuel *et al.* 2001). It has been reported from wolves in Alberta (Holmes and Podesta, 1968) and Québec (McNeill *et al.* 1984), mountain lions (*Felis concolor*) in Oregon (Rausch *et al.* 1983), Black bear in Québec (Fréchette and Rau, 1977), coyotes in Alberta (Holmes and Podesta, 1968) and Ontario (Freeman *et al.* 1961) and wolves and coyotes in Manitoba (Samuel *et al.* 1978). Threlfall (1969) and Smith (1970) reported *T. hydatigena* from dogs in Newfoundland. Forsey (1992) did not recover this cestode from Red foxes in insular Newfoundland. Boyd (1994) stated that *T. hydatigena* was the most prevalent cestode recovered from Arctic foxes from Newfoundland and Labrador.

The larval stage of this tapeworm is also a cysticercus that is primarily found in the muscles or liver of many ungulates, including moose, caribou and White-tailed deer (Custer and Pence, 1981). The distribution of this parasite depends on the density of cervid intermediate hosts. This parasite also utilizes rodents and lagomorphs as intermediate hosts. Larval stages of *T. hydatigena* have been found on the livers of Snowshoe hares from Newfoundland's Avalon Peninsula (E. Baggs pers comm., 2004). Snowshoe hare are likely accidental intermediate hosts of this parasite. Lynx may have acquired this parasite from Snowshoe hares and voles, or by scavenging on carrion, and coyotes may have acquired infections by preying on caribou in addition to hares and voles. Moose and caribou accounted for 1.0% and 2.7% of lynx prey items and 50.0% and 15.2% of coyote prey items respectively. Prevalence of this parasite was highest in coyotes but was absent from Red foxes despite the fact that caribou and moose comprised 17.6% and 2.2% of food items recovered. Boyd (1994) reported this cestode in Arctic foxes that migrated over pack-ice from Labrador to insular Newfoundland's West Coast and indicated that infections with this tapeworm might be site-specific.

Taenia laticollis was recovered from lynx and had a prevalence of 6.7%. Van Zyll de Jong (1966 b) and Smith *et al.* (1986) reported this parasite as the most common helminth in lynx from Alberta and Ontario respectively. Lagomorphs (Van Zyll de Jong, 1966b) transmit *T. laticollis* in addition to other Taeniids. Threlfall (1969) reported *T. laticollis* from two lynx (12 and 16 specimens respectively) in Newfoundland. *Taenia laticollis* has also been infrequently reported from coyotes and timber wolves in Ontario (Freeman *et al.* 1961). The fact that this cestode was not recovered from coyote or Red fox in this study may suggest the prevalence of this parasite in the intermediate hosts is low.

Taenia ovis krabbei was recovered from 0.3% of lynx and 8.7% of coyotes examined. *Taenia ovis krabbei* is frequently reported from timber wolves and coyotes. Cysticerci occur in the musculature of cervids, mostly moose and caribou and less often mule deer (*Odocoileus hemionus*) and White-tailed deer (Erickson and Highby, 1942; Samuel *et al.* 2001). The adult stage has also been reported in Black bears in New Brunswick (Duffy *et al.* 1994) and an Arctic fox in Newfoundland (Boyd, 1994). Similar to *T. hydatigena*, the distribution of *T. ovis krabbei* depends on the density of cervid intermediate hosts. However, unlike *T. hydatigena*, *T. ovis krabbei* has a more limited distribution that results from its specificity for certain intermediate hosts (mainly moose). Custer and Pence (1981) suggested that prevalence of this cestode is often lower in coyotes in areas where cervids are less frequently utilized as prey items.

Samuel (1972) reported *T. ovis krabbei* in 60% of moose found in ranges occupied by wolves, and in only 16% of moose where only coyotes and Red foxes occur. It would appear that the life cycle depends more on wolves as definitive hosts than coyotes. Because there are no wolves presently in Newfoundland, coyotes will likely occupy the niche as definitive host and continue to perpetuate the cycle with moose. There have been sporadic reports of this parasite recovered from moose in Newfoundland. A review of Wildlife Division records from 1987-1994 reported that 294 replacement moose licenses were issued to hunters due to infestation of meat with tapeworm cysts. During this time, reports of *T. ovis krabbei* showed a pattern of increase from the West Coast to the North East Coast (Ryan, 1995).

The spread of *T. ovis krabbei* would appear to be coyote mediated as levels of this parasite seem to be increasing in areas such as the North East Coast of insular Newfoundland where coyotes have colonized and moose populations are high. The Arctic fox (infected with this cestode) reported by Boyd (1994) originated from Labrador and entered insular Newfoundland via pack-ice. While this parasite poses no threat to humans and domestic animals (Samuel *et al.* 2001) it is not aesthetically pleasing and may affect local consumption of moose meat. Negative management implications for future hunting on the island will likely arise as this parasite continues to proliferate and further infect the island's moose populations.

Mesocestoides spp. was recovered from 3.7% of Red fox and 4.3% of coyotes in this study. *Mesocestoides corti* and *M. kirbyi* have been reported from wolves, coyotes and Red foxes (Holmes and Podesta, 1968; Freeman *et al.* 1961; Pence and Eason, 1980; Custer and Pence, 1981) and bobcats (Tiekotter, 1985). Forsey (1992) reported a prevalence of 9.7% for *M. variabilis* in Red foxes from Newfoundland's Northern Peninsula. Boyd (1994) also reported this species in three Arctic foxes taken from the Northern Peninsula and West Coast of Newfoundland. Boyd (1994) did not recover this species from Labrador Arctic foxes and suggested that there is an isolated population of this parasite on Newfoundland's Northern Peninsula. The use of sled-dogs to and from the island may have attributed to this.

Although the life cycle of this parasite is not completely known the first intermediate host is a coprophagous beetle (Sprecht and Voge, 1965). The infective stage, the tetrathyridium is known to occur in a variety of second intermediate hosts such as amphibians, reptiles and small mammals (Grundman, 1958). The tetrathyridial larval stage can proliferate via asexual reproduction by longitudinally splitting of the scolex either in the peritoneal cavity of the second intermediate host or in the intestine of the definitive host (Schmidt and Todd, 1978). Tiekotter (1985) stated that specimens of *M. corti* in Nebraska bobcats were probably acquired through the ingestion of small mammals such as rodents. Red foxes and coyotes likely acquired infections with this parasite by preying on voles, shrews and mice.

Reported prevalence of *Mesocestoides* spp. in coyote populations is usually low, and it has been suggested that the coyote may not be a suitable host for this parasite (Geir *et al.* 1978). The small size of this parasite, lack of hooks and benign action suggest that little damage is done to the host unless infections are extreme. In areas where arthropods and small mammals are a major part of Red fox and coyote diets, prevalence of this parasite would be expected to be higher. Pence and Menzier (1979) recorded a prevalence of 57% for coyotes in west Texas.

Diphyllobothrium latum was recovered from 5.6% of Red fox in this study. Definitive hosts for this parasite are fish-eating birds and mammals. *Diphyllobothrium latum* has been recovered from dogs in Canada (Nicholson, 1928; Wardle and McColl, 1937). Threlfall (1969) reported *D. latum* from one domestic dog and *D. dentriticum* from one domestic cat (*Felis domesticus*), while Smith and Threlfall (1973) reported *D.*

latum from one domestic dog in Newfoundland. Boyd (1994) reported it from one Arctic fox from Newfoundland's North East Coast and suggested that the infection may have occurred in southern Labrador before the fox migrated to insular Newfoundland on pack ice.

Plerocercoids of *Diphyllobothrium* spp. have been recovered from several species of Salmonids from insular Newfoundland (Sandeman and Pippy, 1967). These larvae may have been the plerocercoids of *D. dendriticum, D. latum* or *D. sebago* which were recovered from Herring gulls (*Larsus argentatus*) and Great black-backed gulls (*Larsus marinus*) (Threlfall, 1968 a, b). Red foxes often walk along the shorelines of rivers, ponds and beaches where fish and bird remains may be found. Fish remains accounted for 6.6% of Red fox food items. Local trappers collected many of the foxes used in this study and may have used fish or birds as bait.

Nematodes are one of the most frequently reported groups of internal parasites reported from wild carnivores and include a variety of lungworms, stomach worms and hookworms (Parker, 1995). Nematode life cycles exhibit a variety of forms among the many species of animals that may become infected. Nematodes of many species may have adverse affects on the health of both wild and domestic animals.

Toxascaris leonina was recovered from the stomach and intestines of 77.6% of lynx and 1.4% of coyotes in this study. It was not recovered from any of the Red foxes examined. It is one of the most prevalent helminths in wild canids from the Arctic to the warm southern latitudes of North America (Custer and Pence, 1981). Resistant eggs are passed in the feces of definitive hosts and infections are acquired by ingesting rodent paratenic hosts or fecal-contaminated soil, water and vegetation. Infections also occur via transplacental or transmammary routes (Sprent, 1959).

Van Zyll de Jong (1966 b) reported this nematode as the most abundant and frequent of all nematodes recovered from lynx in Alberta and the North West Territories. Smith *et al.* (1986) reported a prevalence of 97% for this nematode from lynx in Ontario and stated that it is widely distributed and shared among lynx and coyote in that area. *Toxascaris leonina* has also been reported from bobcats in Nebraska (Tiekotter, 1985), Red foxes, wolves and coyotes in Manitoba (Samuel *et al.* 1978), and Red foxes and coyotes in Minnesota (Erickson, 1944). *Toxascaris leonina* has been reported from domestic dogs (Threlfall, 1969), cats (Smith and Threlfall, 1973), lynx (Levandier, 2003) and Red foxes (Forsey, 1992) in Newfoundland. It was not reported in Arctic foxes in insular Newfoundland (Boyd, 1994). Levandier (2003) reported this nematode in 89% of lynx examined.

Toxocara canis was recovered from 4.5% of lynx, 7.5% of Red fox and 18.8% of coyote in this study. *Toxocara canis* is a common intestinal parasite of wild and domestic canids, and is rarely recovered from felids (Custer and Pence, 1981). Threlfall (1969) and Smith and Threlfall (1973) reported *T. canis* in domestic dogs in Newfoundland. It has also been reported in Red foxes from North Carolina and Georgia (Miller and Harkema, 1968) and wolves and coyotes from Alberta (Holmes and Podesta, 1968). Forsey (1992) reported a prevalence of 3.2% for *T. canis* in Red foxes from insular Newfoundland. Boyd (1994) did not recover this parasite from Arctic foxes from Newfoundland and Labrador. Small mammals comprised 23.2% and 14.7% of Red fox and coyote prey items and only 1.4% of lynx. Individuals often become infected via transplacental route or by ingesting infected rodent paratenic hosts. This may account for such a high prevalence of this parasite in fox and coyotes, than that of lynx. Gier and Ameel (1959) suggested that this nematode is probably transmitted to young-of-the-year before they leave the den by ingesting embryonated eggs in the feces of adults or by grooming.

Toxocara cati was recovered from the stomach and intestines of lynx in this study with a prevalence of 4.2%. This is a cosmopolitan parasite of felids and is rarely recovered from canids (Anderson, 2000). Threlfall (1969) and Smith and Threlfall (1973) reported *T. cati* from domestic cats in Newfoundland. It has also been reported from bobcats in Nebraska (Miller and Harkema, 1968; Tiekotter, 1985). Van Zyll de Jong (1966 b) recovered *T. cati* from lynx in Alberta, and each time infection co-occurred with *T. leonina.* Two lynx in this study had co-occurring infections with both nematodes. As with *T. leonina*, *T. cati* has two modes of transmission; direct transmission via ingestion of rodent paratenic hosts or transmammary transmission.

Nematodirus spp. was recovered from the gut of 0.9% of lynx in this study. The genus *Nematodirus* is a speciose group that includes nematodes characteristic of either bovid or cervid hosts (Samuel *et al.* 2001). Levels of prevalence and intensity vary according to the host, parasite and geographic locality. Eggs and larvae are resistant to desiccation and low temperatures, and are capable of over-winter survival (Samuel *et al.* 2001). Smith and Threlfall (1973) were the first to report *N. abnormalis* from domestic sheep (*Ovis aries*) in Newfoundland. *Nematodirus* spp. has been in one coyote, one moose, one horse, and three sheep in Newfoundland since 2001, and is capable of infecting caribou (H. Whitney, pers comm., 2005). This nematode was not recovered from either Red fox or coyote.

The lungworm *Troglostrongylus wilsoni* was recovered from 24.5% of lynx and 1.0% of Red fox in this study. The adult nematode often occurs singly or in bunches that often obstruct the airways of infected individuals. Van Zyll de Jong (1966 b) reported a prevalence of 19% for *T. wilsoni* from lynx in Alberta and the North West Territories. Smith *et al.* (1986) reported a prevalence of 54% for this parasite in lynx from Ontario. Levandier (2003) reported a prevalence of 37.5% in lynx examined in Newfoundland and also showed that prevalence increased with age.

The life cycle of *T. wilsoni* is not completely known, however, members of this genus often utilize gastropods as intermediate hosts. Of the lynx examined in this study no identifiable remains of gastropods were recovered from stomach contents. Levandier (2003) suggested that the absence of gastropods in the digestive tracts of lynx was not uncommon given the time of year that the collection of lynx occurred. Most lynx utilized in this study and that of Levandier (2003) were trapped during the fall and early winter when gastropod intermediate hosts would not have been available. It is possible that rodent paratenic hosts are the link to completion of this parasite life cycle (Anderson, 2000). Remains of gastropods were found in the stomach contents of one fox. Forsey (1992) did not recover the adult of this nematode from any of the Red foxes that she examined.

Crenosoma vulpis infects members of the orders Carnivora and Insectivora with shrews and rodents serving as reservoir or paratenic hosts for larger mammals such as lynx, Red fox and coyote (Bihr and Conboy, 1999). Many of the parasites of these small mammals require predator-prey interactions for transmittance. Red foxes and coyotes actively prey on rodents and shrews, and lynx often do so when hare populations decline.

Crenosoma vulpis was recovered from 0.3% of lynx, 43.0% of Red fox and 14.5% of coyote in this study. Adult *C. vulpis* are found in the airways of the lungs of Red fox, and are mostly known from this species throughout much of Europe and eastern North America (Bihr and Conboy, 1999). In addition to infecting a wide range of canid species (Anderson, 2000), this nematode has also been reported in Black bear, Brown bear (*Ursus arctos*), wolverines (*Gulo gulo*) and otter (*Lutra canadensis*) (Bihr and Conboy, 1999). Adult female *C. vulpis* have been recovered from the stomachs of shrews (E. Baggs, pers comm., 2004). Females are viviparous and release numerous L_1 larvae into the bronchi and bronchioles of the lungs. Larvae are then coughed up, swallowed, and passed in the feces at which time they may infect terrestrial gastropods. They mature to L_3 or infective stage larvae in the foot of a snail or slug at which point the infected intermediate host may be ingested by a definitive host (Jefferey, 2002). Infection with this worm typically produces a dry, non-productive cough that is elicited by tracheal palpation (Bihr and Conboy, 1999).

Red foxes become infected with this parasite by actively consuming gastropods, i.e. slugs and snails. Remains of slugs were recovered from the stomach contents of one Red fox and coyotes in this study. Red foxes and coyotes were trapped year round, while lynx were trapped during fall and winter. This may account for the lack of gastropods recovered in lynx and therefore a low prevalence of this parasite. Previous studies in

Newfoundland have reported the occurrence of *C. vulpis* in Red foxes (Threlfall, 1969; Smith and Threlfall, 1973; Forsey, 1992; Jefferey, 2002) and Arctic foxes (Boyd, 1994). Levandier (2003) did not report this nematode from lynx.

Angiostrongylus vasorum, otherwise referred to as the French Heartworm, is a metastrongyloid nematode parasite that infects the pulmonary arteries and right ventricle of wild and domestic canids (Conboy, 2000) and was recovered from one coyote in this study. Wild foxes serve as infection reservoirs for domestic dogs, and canids acquire infections by the ingestion of gastropod intermediate hosts. Infections with *A. vasorum* characteristically involve a gradual onset of respiratory and/or cardiac disease, chronic cough, dyspnea as well as exercise intolerance, gagging and weight loss are the most common clinical signs of infection (Conboy, 2000).

Jefferey (2002) reported a prevalence of 56% for *A. vasorum* in 366 Red foxes in insular Newfoundland. She also examined eight coyotes, none of which were infected with French Heartworm. When and how this parasite came to Newfoundland from Europe is unclear. Red foxes may have been imported to insular Newfoundland for hunting purposes over the last few centuries, and the parasite may have been brought here by way of infected dogs, snails or slugs (H. Whitney, pers comm., 2003). In either case, this parasite would have had ample opportunity to mix with local dogs and foxes. There have been several reports of *A. vasorum* infection in domestic dogs in the eastern region of Newfoundland's Avalon Peninsula. Of particular concern is the possible spread of this parasite to Atlantic Canada (Bourque *et al.* 2002). Proliferation of this parasite would be possible in areas with similar biological and climatic conditions conducive to the spread of *C. vulpis*, as well as similar intermediate and reservoir hosts (Bourque *et al.* 2002).

Orthoptera and Coleoptera serve as intermediate hosts for members of the genus *Physaloptera* (Petri and Ameel, 1950) and rodent paratenic hosts play an important role in their transmission. High prevalences of *P. rara* have been reported in coyotes from the semiarid regions of Kansas and Texas, where there is a greater diversity and abundance of intermediate hosts, such as dung beetles and other arthropods that make up the coyote diet in these regions (Custer and Pence, 1981). *Physaloptera rara* has also been found in the muscles of Ruffed grouse, and Bonaparte weasels (*Mustela cicognanii*) (Erickson, 1944). Larval stages of *P. rara* have been recovered in shrews from the Hawco's Pond area on the Avalon Peninsula of Newfoundland (E. Baggs, pers comm., 2004).

Physaloptera rara was recovered from 0.9% of Red fox and 5.8% of coyotes in this study. This is the first record of this parasite in Newfoundland canids. Stomach worms of the genus *Physaloptera* spp. especially *P. rara* are frequently reported from wild canids (Custer and Pence, 1981). Erickson (1944) reported *P. rara* in 3.7% of wolves, 16.9% of coyotes and 81.5% and 22% in Gray and Red foxes, respectively in Minnesota. *Physaloptera rara* was not recovered from lynx in this study however, the species *P. praeputialis*, a felid stomach worm, has occasionally been reported from lynx in North America (Van Zyll de Jong, 1966 b; Smith *et al.* 1986).

Grasshoppers and beetles, in addition to small mammals are regularly reported in the stomach contents of both Red foxes and coyotes. Trace remains of grasshoppers were recovered from both in this study, in addition to Ruffed grouse and shrews. Red foxes and coyotes may be actively acquiring this parasite by preying on infected small mammals, and birds that may be serving as transport hosts for *P. rara* larvae. These animals were most likely infected in the summer or fall by ingesting infected insects or rodent paratenic hosts. The origin of this parasite on the island may be the result of the introduction of shrews, voles, mice or coyotes to insular Newfoundland (E. Baggs, pers comm., 2004).

Uncinaria stenocephala was recovered from 0.3% of lynx, and 4.7% and 2.9% of Red fox and coyotes respectively. Of the two most important hookworms of wild canids, *U. stenocephala* is most often found in Northern regions, while *Ancylostoma caninum* is more common at southern latitudes. Hookworm eggs are passed in the feces of definitive hosts and hatch into juvenile larvae within days. The juvenile worm develops into an infective stage larvae and can penetrate the skin of a potential host and migrate through its body and can cause substantial damage (Anderson, 2000). Eggs may also be transmitted to young-of-the-year through ingestion of infected feces in the den area (Custer and Pence, 1981) or via transmammary or transplacental transmission.

Smith *et al.* (1986) reported *U. stenocephala* as an infrequent helminth in lynx that is possibly acquired through the use of overlapping home ranges of lynx and coyote. This nematode has also been reported from Red foxes, wolves, and coyotes (Holmes and Podesta, 1968; Samuel *et al.* 1978; Seesee *et al.* 1983). Smith and Threlfall (1973) reported it from one domestic dog in Newfoundland. Forsey (1992) and Boyd (1994) recovered it from both Red and Arctic foxes respectively.

Many studies on the helminth fauna of lynx, Red fox, and coyote have related parasites found to the food habits of each host (Erickson, 1944; Freeman *et al.* 1961; Van Zyll de Jong, 1966 a; Holmes and Podesta, 1968). Holmes and Podesta (1968) suggested that the prevalence of helminths with different intermediate hosts appear to reflect the diet of the host in question.

Many of the parasites found in this study require intermediate hosts for immature stages reflect the food habits of each host, and possibly the availability and distribution of host prey species. The amount and type of food eaten by a host often reflects the abundance and diversity of parasites. The helminth fauna of lynx is reflective of its specialist nature due to the dominance of a single prey species, the Snowshoe hare in their diet. Higher prevalence of rodent-transmitted helminths in Red fox and coyotes are indicative of a higher percent occurrence of small mammals in their diet. In addition to mammals, vegetation plays an important role in the transmission of parasite eggs and larval stages that in most cases are ingested by an intermediate or definitive host. Large amounts of vegetation in a host species diet may allow for increased opportunity for certain helminth infections. In an area where prey numbers and prey diversity is limited, such as Newfoundland, all three hosts may share similar helminths in response to the extent that they share the same prey. Dietary overlap was lowest among lynx and the two canids, and was highest among Red fox and coyotes.

Many of the helminths recovered in this study are primarily parasites of felids, and include *Taenia macrocystis, T. laticollis, Troglostrongylus wilsoni, Toxascaris leonina* and *Toxocara cati*. Smith *et al.* (1986) also reported *T. laticollis, T. cati* and *T.*

wilsoni as being exclusive parasites of lynx in northern Ontario, and indicated that *T. leonina* was shared amongst lynx and other canids. Although this parasite has been reported from lynx, Red fox and coyotes (Freeman *et al.* 1961; Holmes and Podesta, 1968; Dibble *et al.* 1983) it was only recovered from lynx and coyote in this study, with the highest prevalence occurring in lynx. *Taenia laticollis* has occasionally been reported from coyotes and wolves in North America (Freeman *et al.* 1961). *Toxocara cati* rarely occurs in dogs (Sprent, 1959) and has not been reported from wild canids in North America.

Taenia hydatigena and *T. ovis krabbei* have been frequently reported from wild canids in North America (Holmes and Podesta, 1968) and were both recovered from lynx and coyote in this study. Prevalence of *T. ovis krabbei* was much higher in coyote. The relatively few coyotes that had *T. ovis krabbei* suggested that continued propagation of this cestode may depend largely on coyotes and their prey as they expand throughout insular Newfoundland. *Physaloptera rara, U. stenocephala* and *T. canis* were recovered from both canids. Smith *et al.* (1986) stated that parasites found infrequently in lynx (< 20% prevalence) are primarily parasites of canids, and that there is little sharing among lynx and canids.

The diversity of parasites in Red fox and lynx populations may be changing due to the recent establishment of the coyote in insular Newfoundland. Parasite diversity of both hosts in this study was comparable to others (Dibble *et al.* 1983; Holmes and Podesta, 1968; Smith *et al.* 1986). Although there was a diverse parasite fauna recovered from these hosts, the absence of other parasite species on insular Newfoundland (*E.*

granulosus, *E. multilocularis*, *Taenia rilyei*, *Alaria* spp.) that have been recovered from them in other areas of their range is reflective of the limited diversity of intermediate and definitive hosts in insular Newfoundland and the isolation of the island from continental North America. For instance, the hydatid cysts of *E. granulosus* are often found in the lungs of Labrador caribou. There have not been any reports of this parasite in insular Newfoundland, yet there may be ample opportunity for this parasite to enter by way of infected wolves to the island. This could possibly infect island populations of moose and caribou (Whitney, 2004).

Conclusion

The morphology, dietary habits, and helminth fauna of 366 Canada lynx, 112 Red fox, and 75 coyotes collected during 1999-2003 from six regions of insular Newfoundland was examined. The following findings are reported:

- Sex ratios in lynx were balanced, while a bias towards males occurred in Red fox and coyote samples. Adult animals comprised the majority of samples.
- Morphometric data was similar to other studies, with males generally being larger than females.
- Dietary diversity and overlap was highest in Red fox and coyote diets.
- Snowshoe hare was the most important food item in lynx diets during four trapping years, while Red fox depended more on other prey items including Meadow voles. Woodland caribou accounted for the highest percent occurrence in coyote diets.
- Twelve, seven, and ten helminth species were recovered from lynx, Red fox and coyote respectively.
- *Taenia pisiformis*, *T. macrocystis*, and *Toxascaris leonina* were most prevalent in lynx, followed by *Crenosoma vulpis* in Red fox, and *T. ovis krabbei, Toxocara canis* and *C. vulpis* in coyote.
- Significant differences with respect to intrinsic and extrinsic factors were noted for each host. Based on prevalence patterns and parasite species

diversity, there are three main areas of parasite infection in insular Newfoundland; the Northern Peninsula, West Coast and North East Coast, with prevalence increasing in a West to East direction.

- Seventy-three percent of lynx, 10.3% of Red fox and 16.0% of coyotes were parasitized by two or more co-occurring parasite species.
- Multiple parasite infections were significantly higher in juvenile Red fox and coyotes.
- This study represents the first record of *Physaloptera rara* from Red fox and coyotes in insular Newfoundland.
- Diversity of parasite species in insular Newfoundland may be increasing due to the establishment of Eastern coyote populations.
- Future research is needed to examine the continued role of Eastern coyotes in structuring Newfoundland's ecosystems and the effect it is having on prey populations.

References

Ables, E.D. 1975. Ecology of the red fox in America. Pp. 216-236 *in* M. W. Fox, ed. Wild Canids: Their systematics, behavioural, ecology and evolution. Van Nostrand Reinhold, New York, New York. U.S.A.

Adorjan, A.S., and G.B. Kolenosky. 1969. A manual for the identification of hairs of selected Ontario mammals. Res. Rep. (Wildlife). No. 90. Res. Branch Ontario Department of Lands and Forest, Toronto, Ontario.Canada. 64 pp.

Andelt, W. F., J.G. Kie, F.F. Knowlton, and D. Cardwell. 1987. Variation in coyote diets associated with season and successional changes in vegetation. Journal of Wildlife Management. 51: 273 – 277.

Anderson, R.C. 2000. Nematode parasites of vertebrates: their development and transmission. CABI Pub., New York, New York, U.S.A. 650 pp.

Andrews, R.D., and E.K. Boggess. 1978. Ecology of coyotes in Iowa. Pp. 249-265 *in* M. Bekoff, ed. Coyotes: biology, behaviour and management. Academic Press, New York, New York, U.S.A.

Arjo, W.M., D.H. Pletscher, and R.R. Ream. 2002. Dietary overlap between wolves and coyotes in northwestern Montana. Journal of Mammalogy. 83(3): 754-766.

Baggs, E.M. 2004 (personal communication). Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada.

Banfield, A.W.F. 1974. The Mammals of Canada. University of Toronto Press, Ontario, Canada. 438 pp.

Baron, R.W. 1970. The occurrence of *Echinococcus multilocularis* Leukart, 1863 and of other helminths in red fox, *Vulpes vulpes*, in southern Manitoba. Canadian Journal of Zoology. 48: 1132.

Bekoff, M. 1977. *Canis latrans*. Mammalian Species. No. 79. 9 pp.

Bekoff, M. 1978. Coyotes: biology, behaviour and management. Academic Press, New York, New York, U.S.A. 384 pp.

Bennett, K.E. 2001. An analysis of the parasites of a mid-winter population of *Lepus americanus* on insular Newfoundland during a cyclical peak. Honours Thesis, Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 49 pp.

Bergerud, A. 1971. The population dynamics of Newfoundland caribou. Wildlife Monographs. No.25: 1-55.

Bergerud, A. 1983. Prey switching in a simple ecosystem. Scientific American. 249(6): 130-141.

Berrie, P. M. 1974. Ecology and status of lynx in interior Alaska. Pp. 4-41 *in* R. Eaton, ed. The World's Cats. World Wildlife Safari, Winston, Oregon, U.S.A.

Bihr, T., and G.A. Conboy. 1999. Lungworm (*Crenosoma vulpis*) infection in dogs on Prince Edward Island. Canadian Veterinary Journal. 40 (8): 555 – 559.

Bourque, A., G. Conboy, L. Miller, H. Whitney, and S. Ralhan. 2002. *Angiostrongylus vasorum* infection in two dogs from Newfoundland. The Canadian Veterinary Journal. 43: 876-879.

Bourque, A., H. Whitney, and G. Conboy. *Angiostrongylus vasorum* infection in a coyote from Newfoundland and Labrador. Journal of Wildlife Diseases (In press).

Bowman, D.D. "Respiratory system parasites of the dog and cat (Part II): Trachea and Bronchi, and Pulmonary Vessels". 20-April-2000. Department of Microbiology and Immunology, College of Veterinary Medicine, Cornell University, Ithaca, New York, U.S.A. retrieved Sept 24, 2003 http://www.ivis.org. 9 pp.

Boyd, R.D. 1994. A preliminary investigation of the helminth parasite fauna of the alimentary tract and visceral organs of the arctic fox, *Alopex lagopus* Linnaeus, from Newfoundland. Honours Thesis, Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 53 pp.

Brady, J.F. 1994. Black Rock Forest deer population management report 1984-1994, unpublished report, Black Rock Forest, Cornwall, New York, U.S.A.

Brand, C.J., and L.B. Keith. 1979. Lynx demography during a snowshoe hare decline in Alberta. Journal of Wildlife Management. 43: 827-849.

Brand, C.J., L.B. Keith, and C.A. Fischer. 1976. Lynx responses to changing snowshoe hare densities in central Alberta. Journal of Wildlife Management. 40: 416-428.

Bridger, K.E. 2002. An analysis of the enteric parasite fauna of the snowshoe hare *Lepus americanus* on the island portion of Newfoundland and Labrador. Honours Thesis, Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 47 pp.

Brower, J.E., and J. H. Zar. 1984. Field and laboratory methods for general ecology. 2nd ed. William C. Brown Publishing, Dubuque, Iowa, U.S.A. 226 pp.

Bursey, C.C., and M.D.B. Burt. 1970. *Taenia macrocystis* (Diesing, 1850), its occurrence in Eastern Canada and Maine, U.S.A., and its life cycle in wild felines (*Lynx rufus* and *L. canadensis*) and hares (*Lepus americanus*). Canadian Journal of Zoology. 48: 1287–1293.

Bush, A. O., K.D. Lafferty, J.M. Lotz, and A.W. Shostak. 1997. Parasitology meets ecology on its own terms: Margolis *et al.* revisited. Journal of Parasitology. 83(4): 575-583.

Conboy, G.A. "Canine *Angiostrongylus* (French Heartworm)." 30-May-2000. International Veterinary Information Service, Ithaca, New York, U.S.A. retrieved Sept 24, 2003 http://www.ivis.org. 5 pp.

Crowe, D.M. 1972. The presence of annuli in bobcat tooth cementum layers. Journal of Wildlife Management. 36(4): 1330-1332.

Curran, R.C., and S.P. Mahoney. 2004. Causes and percentages of mortality of radio-collared caribou calves for the Middle Ridge Herd, June 4 – December 5, 2003. Field Report. Natural Heritage Branch, Department of Environment and Conservation. 2 pp.

Custer, J.W., and D.B. Pence. 1981. Helminths of wild canids from the Gulf Coastal Prairies of Texas and Louisiana. Journal of Parasitology. 67: 289–307.

Cypher, B.L. 1993. Food item use by three sympatric canids in southern Illinois. Transactions of the Illinois State Academy of Science. 86 (3): 139-144.

Davidson, W.R., M.J. Appel, G.L. Doster, O.E. Baker, and J.F. Brown. 1992. Diseases and parasites of red foxes, gray foxes, and coyotes from commercial sources selling to fox-chasing enclosures. Journal of Wildlife Diseases. 28(4): 581-589.

Deblase, A.F., and R.E. Martin. 1981. Manual of Mammalogy with Keys to the Families of the world. 2nd ed. Wm. C. Brown Company Publishers, Dubuque, Iowa, U.S.A. 436 pp.

Dekker, D. 1983. Denning and foraging habits of red foxes *Vulpes vulpes*, and their interaction with coyotes, *Canis latrans*, in central Alberta, 1972-1981. Canadian Field-Naturalist. 97(3): 303-306.

Dibble, E.D., W.F. Font, and D.D. Wittrock. 1983. Helminths of the Red Fox, *Vulpes vulpes* L., in west central Wisconsin. Journal of Parasitology. 69(6): 1110–1115.

Dodds, D.G. 1955. Food habits of the Newfoundland red fox. Journal of Mammalogy. 36: 291.

Duffy, M.S., T.A. Greaves, and M.D.B. Burt. 1994. Helminths of the black bear, *Ursus americanus*, in New Brunswick. Journal of Parasitology. 80: 478 – 480.

Dumond, M., and M.A. Villard. 2000. Demography and body condition of coyotes (*Canis latrans*) in eastern New Brunswick. Canadian Journal of Zoology. 78: 399-406.

Erickson, A.B. 1944. Helminths of Minnesota Canidae in relation to food habits and a host list and key to the species reported from North America. American Midland Naturalist. 32(2): 358 – 372.

Erickson, A.B., and P.R. Highby. 1942. Parasites of woodland caribou. Journal of Parasitology. 28(5): 423.

Evans, H.E., and A. DeLahunta. 1971. Miller's guide to the dissection of the dog. W.B. Saunders and Company, Philadelphia, Pennsylvania, U.S.A. 361 pp.

Foreyt, W.J., and K.M. Foreyt. 1982. Internal parasites of coyotes (*Canis latrans*) in Washington and Idaho. Northwest Science. 56(1): 14-16.

Forsey, E.S. 1992. A preliminary investigation of the helminth parasite fauna of the alimentary tract and visceral organs of the red fox, *Vulpes vulpes* Linnaeus, from the Northern Peninsula to the southwest coast of insular Newfoundland. Honours Thesis, Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 39 pp.

Forsyth, A. 2000. Mammals of North America: temperate and arctic regions. Bookmakers Press, Inc., Kingston, Ontario, Canada. 350 pp.

Fréchette, J.L., and M.E. Rau. 1977. Helminths of the black bear in Québec. Journal of Wildlife Diseases. 13: 432 – 434.

Freeman, R.S., A. Adorjan, and D.H. Pimlott. 1961. Cestodes of wolves, coyotes and coyote-dog hybrids in Ontario. Canadian Journal of Zoology. 39: 527 – 532.

Fritts, S.H. 1973. Age, food habits and reproduction of the bobcat (*Lynx rufus*) in Arkansas. Master of Science Thesis, University of Arkansas, Arkansas, U.S.A. 80 pp.

Gier, H.T. 1968. Coyotes in Kansas. Kansas Agricultural Experimental Station Bulletin. 393: 118 pp.

Gier, H.T. 1975. Ecology and behaviour of the coyote (*Canis latrans*). Pp. 247-262 *in* M.W. Fox, ed. Wild Canids: Their systematics, behavioral ecology and evolution.Van Nostrand Reinhold, New York, New York, U.S.A.

Gier, H.T., and D.J. Ameel. 1959. Parasites and diseases of Kansas coyotes. Kansas State University Agricultural Experiment Station, Technical Bulletin. 91: 34 pp.

Gier, H.T., S.M. Kruckenburg, and R.J. Marler. 1978. Parasites and Diseases of Coyotes. Pp. 37-69 *in* M. Bekoff, ed. Coyotes: biology, behaviour and management. Academic Press, New York, New York, U.S.A.

Gompper, M.E. 2002. The ecology of the northeast coyote: current knowledge and priorities for future research. WCS Working Paper No. 17. 48pp.

Grundman, A.W. 1958. Cestodes of mammals from the Great Salt Lake desert region of Utah. Journal of Parasitology. 44: 425 – 429.

Hall, M.C. 1919. The adult Taeniid cestodes of dogs and cats, and of related carnivores in North America. Proceedings of the U.S. National Museum. 55: 1-95.

Hamilton, W.J., Jr. 1935. Notes on the food habits of red foxes in New York and New England. Journal of Mammalogy. 16: 16-22.

Hamilton, W.J., Jr. 1974. Food habits of the coyote in the Adirondacks. New York Fish and Game Journal. 21: 177-181.

Haplin, M.A., and J.A. Bissonette. 1986. The history of the occurrence of the red fox in Maine: presettlement to 1984. Maine Agricultural Experiment Station Miscellaneous Publications. 683: 1-38.

Harrison, D.J., J.A. Bissonette, and J.A. Sherburne. 1989. Spatial relationships between coyotes and red foxes in Eastern Maine. Journal of Wildlife Management. 53(1): 181-185.

Hilton, H. 1976. The physical characteristics, taxonomic status and food habits of the eastern coyote in Maine. Master of Science Thesis. University of Maine, Orono, Maine, U.S.A. 67 pp.

Hilton, H. 1978. Systematics and ecology of the eastern coyote. Pp.209-228 *in* M. Bekoff, ed. Coyotes: biology, behaviour and management. Academic Press, New York, New York, U.S.A.

Hockman, J.G., and J.A. Chapman. 1983. Comparative feeding habits of red foxes (*Vulpes vulpes*) and gray foxes (*Urocyon cinereoargenteus*) in Maryland. American Midland Naturalist. 110(2): 276-285.

Holmes, J.C., and R. Podesta. 1968. The helminths of wolves and coyotes from the forested regions of Alberta. Canadian Journal of Zoology. 46: 1193–1203.

Horn, H.S. 1966. Measurement of "overlap" in comparative studies. American Naturalist 100: 419-424.

Hounsell, S.L. 1996. Morphological study of the Canada lynx on the island of Newfoundland. Honours Thesis, Department of Biology, Lakehead University, Thunder Bay, Ontario, Canada. 34 pp.

Hutchenson, K. 1970. A test for comparing diversities based on the Shannon formula. Journal of Theoretical Biology. 29: 151-154.

Jefferey, R. A. 2002. Distribution of *Angiostrongylus vasorum* and *Crenosoma vulpis* in red foxes (*Vulpes vulpes*) in Newfoundland, Canada. Master of Science Thesis, Department of Biology, Lakehead University, Thunder Bay, Ontario, Canada. 65 pp.

Johnson, W.J. 1970. Food habits of the red fox in Isle Royal National Park, Lake Superior. American Midland Naturalist. 84(2): 568-572

Jones, D.M., and J.B. Theberge. 1983. Variation in red fox, *Vulpes vulpes* summer diets in northwest British Columbia and southwest Yukon. Canadian Field-Naturalist. 97(3): 311-314.

Keith, L.B. 1963. Wildlife's ten-year cycle. University of Wisconsin Press, Madison, Wisconsin, U.S.A. 201 pp.

Khalil, L.F., A. Jones, and R.A. Bray. 1994. Keys to the Cestode Parasites of Vertebrates. CAB International. Willingford, Oxon, United Kingdom. 751 pp.

Kight, J. 1962. An ecological study of the bobcat (*Lynx rufus* Schreber) in west central South Carolina. Master of Science Thesis, University of Georgia, Georgia, U.S.A. 52 pp.

Kitchen, A.M., E.M. Gese, and E.R. Schauster. 1999. Resource partitioning between coyotes and swift foxes: space, time, and diet. Canadian Journal of Zoology. 77: 1645 – 1656.

Klewer, H.L. 1958. The incidence of helminth lung parasites of *Lynx rufus rufus* (Schreber) and the life cycle of *Anafilaroides rostratus* Gerichler, 1949. Journal of Parasitology. 44: 29.

Knowlton, F.F. 1964. Aspects of coyote predation in south Texas, with special reference to white-tailed deer. Ph.D. Thesis, Purdue University, West Lafayette, Indiana, U.S.A. 189 pp.

Larivière, S. and M. Crête. 1993. The size of eastern coyotes (*Canis latrans*): A comment. Journal of Mammalogy. 74(4): 1072-1074.

Levandier, M.A.S. 2003. An analysis of the enteric parasites of lynx, *Lynx canadensis subsolanus* Bangs, occurring on insular Newfoundland. Honours Thesis, Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 59 pp.

Levine, N.D. 1980. Nematode parasites of domestic animals and of man. 2nd ed. Burgess Publishing Co., Minnesota, U.S.A. 477 pp.

Major, J.T. and J.A. Sherburne. 1987. Interspecific relationships of coyotes, bobcats and red foxes in Western Maine. Journal of Wildlife Management. 51: 606 – 616.

Margolis, L., G.W. Esch, J.C. Holmes, A.M. Kuris and G.A. Schad. 1982. The use of ecological terms in parasitology (report of an *ad hoc* committee of the American Society of Parasitologists). Journal of Parasitology. 68(1): 131-133.

Mayr, E.E., E.G. Linsley, and R.L. Usinger. 1953. Methods and Principles of Systematic Zoology. McGraw-Hill Book Company Inc. New York, New York. USA. 336 pp.

McCord, C.M., and J.E. Cardoza. 1983. Pp. 728-756 *in* J.A. Chapman, and G.A. Feldhamer, ed. Wild mammals of North America: Biology, management and economics. The Johns Hopkins University Press, Baltimore, Maryland, U.S.A. 1147 pp.

McGrath, M. J. 2003. (personal communication). Department of Environment and Conservation, Government of Newfoundland and Labrador.

McNeill, M.A., M.E. Rau, and F. Messier. 1984. Helminths of wolves (*Canis lupus* L.) from southwestern Quebec. Canadian Journal of Zoology. 62: 1659 – 1660.

Meades, W.J., and L. Moores. 1994. Forest Site Classification Manual: A Field Guide to the Damman Forest Types of Newfoundland. 2nd ed. Forestry Canada, St. John's, Newfoundland, Canada. 200 pp.

Meyer, M.C., and O.W. Olsen. 1988. Essentials of Parasitology. 3rd ed. Wm. C. Brown Company Publishers, Dubuque, Iowa, U.S.A. 289 pp.

Miller, G.C., and R. Harkema. 1968. Helminths of some wild mammals in the south western United States. Proceedings of the Helminthological Society. 35(2):118 – 125.

Moore, G.C., and J.S. Millar. 1984. A comparative study of colonizing and longer established eastern coyote (*Canis latrans*) populations. Journal of Wildlife Management. 48(3): 691-699.

Moore, G.C., and J.S. Millar. 1986. Food habits and average weights of a fall-winter sample of eastern coyotes, *Canis latrans*. Canadian Field-Naturalist. 100(1): 105-106.

More, G. 1976. Some winter food habits of lynx in the southern Mackenzie District, N.W.T. Canadian Field-Naturalist. 90: 499-500.

Mowat, M G., and B.G. Slough. 1998. Some observations on the natural history and behavior of the Canada lynx, *Lynx canadensis*. Canadian Field-Naturalist. 112(1): 32-36.

Murray, D.L., S. Boutin, and M. O'Donoghue. 1994. Winter habitat selection by lynx and coyotes in relation to snowshoe hare abundance. Canadian Journal of Zoology. 72: 1444-1451.

Nellis, C.H., and C.B. Keith. 1976. Population dynamics of coyotes in central Alberta 1964-1968. Journal of Wildlife Management. 40: 389-399.

Nellis, C.H., S.P. Wetmore, and L.B. Keith. 1972. Lynx-prey interactions in central Alberta. Journal of Wildlife Management. 36: 320-329.

Nicholson, D. 1928. Fish tapeworm, intestinal infection in man: the infestation of fish in Manitoba lakes. Journal of Canadian Medical Association. 19: 25-33.

Neibauer, T.J., and O.J. Rongstad. 1977. Coyote food habits in northwestern Wisconsin. *in* R.L. Phillips and C. Jonkel, eds. Proceedings of the 1975 Predator Symposium. Montana Forest and Conservation Experimental Station, University of Montana, Missoula, Montana, U.S.A. 268 pp.

Noble, E.R., and G.A. Noble. 1971. Parasitology, the biology of animal parasites. 3rd ed. Lea and Febiger, Philadelphia, Pennslyvannia, U.S.A. 617 pp.

Nowak, R.M. 1978. Evolution and taxonomy of coyotes and related *Canis.* Pp. 3-15 *in* M. Bekoff, ed. Coyotes: biology, behaviour and management. Academic Press, New York, New York, U.S.A.

O' Donoghue, M., S. Boutin, C.J. Krebs, D.L. Murray and E.J. Hofer. 1998. Functional responses of lynx and coyotes to the snowshoe hare cycle. Ecology. 79(4): 119-1208.

Parker, G.R. 1986. The seasonal diet of coyotes *Canis latrans,* in northern New Brunswick. Canadian Field-Naturalist. 100(1): 74-77.

Parker, G. R. 1995. Eastern coyote: the story of its success. Nimbus Publishing Ltd. Halifax, Nova Scotia, Canada. 254 pp.

Parker, G.R., and J.W. Maxwell. 1989. Seasonal movements and winter ecology of the Coyote, *Canis latrans* in northern New Brunswick. Canadian Field-Naturalist. 103(1): 1-11.

Parker, G.R., J.W. Maxwell, L.D. Morton and G.E.J. Smith. 1983. The ecology of the lynx (*Lynx canadensis*) on Cape Breton Island. Canadian Journal of Zoology. 61: 770–786.

Patterson, B.R. 1994. Surplus killing of white-tailed deer, *Odocoileus virginiansus*, by coyotes, *Canis latrans*, in Nova Scotia. Canadian Field-Naturalist. 108: 484-487.

Patterson, B.R., L.K. Benjamin, and F. Messier. 1998. Prey switching and feeding habits of eastern coyotes in relation to snowshoe hare and white-tailed deer densities. Canadian Journal of Zoology. 76: 1885 – 1887.

Pence, D.B., and S. Eason. 1980. Comparison of the helminth faunas of two sympatric top carnivores from the rolling plains of Texas. Journal of Parasitology. 66: 115 – 120.

Pence, D.B., and W.P. Menzier. 1979. Helminths of the coyote, *Canis latrans*, from the rolling plains of Texas. Journal of Parasitology. 9: 339-344.

Pence, D.B., and L.A. Windberg. 1984. Population dynamics across selected habitat variables of the helminth community in coyotes, *Canis latrans*, from south Texas. Journal of Parasitology. 70(5): 735-746.

Pence, D.B., H.P. Samoil, and J.E. Stone. 1978. Spirocercid stomach worms (Nematoda: Spirocercidae) from wild felids in North America. Canadian Journal of Zoology 56: 1032-1042.

Petri, L.H., and D.J. Ameel. 1950. Studies on the life cycle of *Physaloptera rara* Hall and Wigdor 1918, and *P. praeputialis* Linstow 1889. Journal of Parasitology. 36: 40.

Pozio, E., D.B. Pence, G. La Rosa, A. Casulli, and S.E. Henke. 2001. *Trichinella* infection in wildlife of the southwestern United States. Journal of Parasitology. 87(5):1210-1213.

Quinn, N.W.S., and G. Parker. 1987. Lynx Pp. 683 – 694 *in* M. Novak, J.A. Baker, M.E. Obbard and B. Malloch, eds. Wild Furbearer Management and Conservation in North America. Ministry of Natural Resources, Ontario, Canada.

Quinn, N.W.S., and J.E. Thompson. 1985. Age and sex of trapped lynx, *Felis canadensis*, related to period of capture and trapping technique. Canadian Field-Naturalist. 99(2): 267-269.

Quinn, N.W.S., and J.E. Thompson. 1987. Dynamics of an exploited Canada lynx population in Ontario. Journal of Wildlife Management. 51: 297-305.

Radomski, A. A., and D. B. Pence. 1993. Persistence of a recurrent group of intestinal helminth species in a coyote population from southern Texas. Journal of Parasitology. 79: 371-378.

Rausch, R.L., C. Maser, and E.B. Hoberg. 1983. Gastrointestinal helminths of the cougar, *Felis concolor* L., in northeastern Oregon. Journal of Wildlife Diseases. 19: 14 – 19.

Ray, J.C. 2000. Mesocarnivores of Northeastern North America: Status and conservation issues. WCS Working Paper. No. 15. 84 pp.

Reynolds, J.J., B.K. Adams, and M.J. McGrath. 2004. Status report on snowshoe hare population monitoring in insular Newfoundland, 1999 to 2004. Internal Report. Department of Environment and Conservation, Wildlife Division, Government of Newfoundland and Labrador. 6 pp.

Richens, V.B., and R.D. Hugie. 1974. Distribution, taxonomic status and characteristics of coyotes in Maine. Journal of Wildlife Management. 38: 447-454.

Ryan, M. 1995. Parasitic cysts occurring in moose *Alces alces* and (possibly) caribou *Rangifer tarandus* on island Newfoundland. Inland Fish and Wildlife Division, Government of Newfoundland and Labrador. 15 pp.

Samson, C. and M. Crête. 1997. Summer food habits and population density of coyotes, *Canis latrans*, in boreal forests of southeastern Québec. Canadian Field - Naturalist. 111:227-233.

Samuel, W.M. 1972. *Taenia krabbei* in the musculature of moose: a review, Pp. 18-41 *in* Transaction of the Eighth North American Moose Conference and Workshop, Thunder Bay, Ontario. Ontario Ministry of Natural Resources, Toronto, Ontario, Canada.

Samuel, W.M., S. Ramalington, and L.N. Carbyn. 1978. Helminths of coyotes (*Canis latrans* Say.), wolves *(Canis lupus* L.) and red foxes (*Vulpes vulpes* L.) of southwestern Manitoba. Canadian Journal of Zoology. 56: 2614-2617.

Samuel, W.M., M.J. Pybus, and A.A. Kocan. 2001. Parasitic Diseases of Wild Mammals. 2nd ed. Iowa State University Press, Ames, Iowa, U.S.A. 559 pp.

Sandeman, I.M., and J.H.C. Pippy. 1967. Parasites of freshwater fishes (Salmonidae and Coregonidae) of insular Newfoundland. Journal of Fisheries Research Board of Canada. 24 (9): 1911 – 1943.

Sargeant, A.B. and S.H. Allen. 1989. Observed interactions between coyotes and red foxes. Journal of Mammalogy. 70: 631 – 633.

Saunders, J.K., Jr. 1961. The biology of the Newfoundland lynx (*Lynx canandensis subsolanus* Bangs). Ph.D. Thesis, Cornell University, Ithaca, New York, New York, U.S.A. 109 pp.

Saunders, J.K., Jr. 1963a. Food habits of the lynx in Newfoundland. Journal of Wildlife Management. 27(3): 384 – 390.

Saunders, J.K., Jr. 1963b. Movements and activities of lynx in Newfoundland. Journal of Wildlife Management. 27(3): 390–400.

Saunders, J.K., Jr. 1964. Physical characteristics of the Newfoundland lynx. Journal of Mammalogy. 45: 36-47.

Schmidt, G.D. 1968. *Oncicola canis* (Kaupp, 1909) (Acanthocephala) from *Felis lynx* in Alaska. Journal of Parasitology 54(5): 930.

Schmidt, J.M., and K.S. Todd. 1978. Life history of *Mesocestoides corti* in the dog (*Canis familiaris*). American Journal of Veterinary Research 39: 1490 – 1493.

Schmidt, G.D., and L.S. Roberts. 1996. Foundations of Parasitology. 5th ed. The McGraw-Hill Companies Inc, Dubuque, Iowa, U.S.A. 659 pp.

Seesee, F. M., M.C. Sterner, and D.E. Worley. 1983. Helminths of the coyote (*Canis latrans* Say) in Montana. Journal of Wildlife Diseases. 19(1): 54 – 55.

Sheldon, J.W. 1992. Wild dogs: the natural history of the non-domestic Canidae. Academic Press, Inc., San Diego, California, U.S.A. 248 pp.

Smith, F.R., and W. Threlfall. 1973. Helminths of some mammals from Newfoundland. American Midland Naturalist. 90(1): 215-218.

Smith, J.D., E.M. Addison, D.G. Joachim, L.M. Smith, and N.W.S. Quinn. 1986. Helminth parasites of Canada lynx (*Felis canadensis*) from Northern Ontario. Canadian Journal of Zoology. 64: 358–364.

Sokal, R.R., and F.J. Rohlf. 1995. Biometry. 3rd ed. W.H. Freeman and Company, New York, New York, U.S.A. 887 pp.

South, S. G. 1983. Biogeography and ecology of the island of Newfoundland. G. R. South ed. The Hague, Boston, Massachusetts, U.S.A. 723 pp.

Sprecht , D, and M. Voge. 1965. Asexual multiplication of *Mesocestoides tetrathyridia* in laboratory animals. Journal of Parasitology. 51:268-272.

Sprent, J.F.A. 1959. The life history and development of *Toxocara cati* (Schrank 1788) in the domestic cat. Parasitology. 46(1): 54-78.

SPSS Inc. 1999. SPSS for Windows. Version 11.5 [computer program]. SPSS Inc., Chicago. U.S.A.

Stanley, W.C. 1963. Habits of the red fox in northeastern Kansas. University of Kansas Museum of Natural History, Miscellaneous publication. 34: 1-31.

Stewart, R.R. 1973. Age, distribution, reproductive biology and food habits of Canada Lynx (*Lynx canadensis* Kerr) in Ontario. Master of Science Thesis, University of Guelph, Guelph, Ontario, Canada. 76 pp.

Stiles, C.W., and C.E. Baker. 1935. Key-catalogue of parasites reported for carnivora with their possible health importance. United States National Institute Health Bulletin. 163: 913-1223.

Storandt, S.T., D.R. Virchow, M.W. Dryden, S.E. Hygnstrom, and K.R. Kazacos. 2002. Distribution and prevalence of *Echinococcus multilocularis* in wild predators in Nebraska, Kansas, and Wyoming. Journal of Parasitology 88(2): 420-423.

Storm, G.L., R.D. Andrews, R.L. Phillips, R.L. Bishop, D.B. Siniff, and J.R. Tester. 1976. Morphology, reproduction, dispersal and mortality of Midwestern red fox populations. Wildlife Monographs. No. 49: 82 pp.

Stuart-Smith, A.K., and Stan Boutin. 1994. Predation on red squirrels during a snowshoe hare decline. Canadian Journal of Zoology. 73. 713 – 722.

Theberge, J.B., and C.H.R. Wedeles. 1989. Prey selection and habitat partitioning in sympatric coyote and red fox populations, southwest Yukon. Canadian Journal of Zoology. 67: 1285-1290.

Theis, J.H., and R. G. Schwab. 1992. Seasonal prevalence of *Taenia taeniaeformis*: relationship to age, sex, reproduction and abundance of an intermediate host (*Peromyscus maniculatus*). Journal of Wildlife Diseases. 28(1): 42-50.

Thornton, J.E., R.R. Bell., and M.J. Reardon. 1974. Internal parasites of the coyote in southern Texas. Journal of Wildlife Diseases. 10: 232-232

Tiekotter, K.L. 1985. Helminth species diversity and biology of the bobcat, *Lynx rufus* (Schreber), from Nebraska. Journal of Parasitology. 71(2): 227 – 234.

Threlfall, W. 1968a. The helminth parasites of three species of gulls in Newfoundland. Canadian Journal of Zoology. 46: 827 – 830.

Threlfall, W. 1968b. Studies on the helminth parasites of the American herring gull (*Larsus argentatus* Pont.) in Newfoundland. Canadian Journal of Zoology. 46: 1119-1126.

Threlfall, W. 1969. Further records of helminths from Newfoundland mammals. Canadian Journal of Zoology. 47: 197–201.

Todd, A.W. 1985. Demographic and dietary comparisons of forest and farmland coyote, *Canis latrans*, populations in Alberta. Canadian Field – Naturalist. 99(2): 163-171.

Todd, A.W., and L.B. Keith. 1976. Responses of coyotes to winter reductions in agricultural carrion. Alberta Wildlife Technical Bulletin. No.5: 1-32.

Todd, A. W., and L. B. Keith. 1983. Coyote demography during a snowshoe hare decline in Alberta. Journal of Wildlife Management. 47: 394 – 404.

Todd, A.W., L.B. Keith, and C.A. Fischer. 1981. Population ecology of coyotes during a fluctuation of snowshoe hares. Journal of Wildlife Management. 45(3): 629-640.

Tucker, W.E. 2003. Diet of the red fox *Vulpes vulpes* on the island of Newfoundland. . Honours Thesis, Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 35 pp.

Tuller, B.F., K.T. Berchielli, and E.P. Saggese. 1976. Some implications of communal denning and pup adoption among red foxes in New York. New York Fish and Game Journal. 23: 92-94.

Tumilison, R. 1987. *Felis lynx*. Mammalian Species No. 269: 1-8.

Ullah, W., A. Beersing, A. Blouin, C.H. Wood, and A. Rodgers.1992. Water resources atlas of Newfoundland. Water Resources Division, Department of Environment and Lands, Government of Newfoundland and Labrador, St. John's. 79 pp.

Van Zyll de Jong, C.G. 1966a. Parasites of the Canadian Lynx, *Felis* (*Lynx*) *canadensis* (Kerr). Canadian Journal of Zoology. 44: 500–509.

Van Zyll de Jong, C.G. 1966b. Food habits of the lynx in Alberta and the Mackenzie District, N.W.T. Canadian Field-Naturalist. 80: 18-23.

Van Zyll de Jong, C.G. 1975. Differentiation of the Canada lynx, *Felis* (*Lynx*) *canadensis subsolanus*, in Newfoundland. Canadian Journal of Zoology. 53: 699-705.

Voigt, D.R. 1987. Red Fox. Pp. 379-392 *in* M. Novak, J.A. Baker, M.E. Obbard and B. Malloch, eds. Wild Furbearer Management and Conservation in North America. Ministry of Natural Resources, Ontario, Canada.

Voigt, D.R. and B.D. Earle. 1983. Avoidance of coyotes by red fox families. Journal of Wildlife Management. 47: 852 – 857.

Voigt, D.R., and W.E. Berg. 1987. Coyote. Pp. 345-356 *in* M. Novak, J.A. Baker, M.E. Obbard and B. Malloch, eds. Wild Furbearer Management and Conservation in North America. Ministry of Natural Resources, Ontario, Canada.

Wayne, R.K., and N. Lehman. 1992. Mitochondrial DNA analyses of the eastern coyote: Origins and hybridization. Pp. 9-22 *in* A.H. Boer, ed. Ecology and Management of the Eastern coyote. Wildlife Research Unit, University of New Brunswick.. 194 pp.

Ward, R.M.P., and C.J. Krebs. 1985. Behavioural response of the lynx to declining snowshoe hare abundance. Canadian Journal of Zoology. 63: 2817–2824.

Wardle, R.A., and E.L. McColl. 1937. The taxonomy of *Diphyllobothrium latum* (L.) in western Canada. Canadian Journal of Research. 15: 163 – 175.

White, P.J., K. Ralls., and C.A. Vanderbilt White. 1995. Overlap in habitat and food use between coyotes and San Joaquin kit foxes. Southwest Naturalist. 40: 342-349.

Whitney, H. 2003. (personal communication). Department of Natural Resources, Government of Newfoundland and Labrador.

Whitney, H. 2004. Parasites of Caribou (3): Tapeworm Cysts. Wildlife Diseases Facts Sheet. Department of Natural Resources, Government of Newfoundland and Labrador. 2 pp.

Whitney, H. 2005. (personal communication). Department of Natural Resources, Government of Newfoundland and Labrador.

Yorke, W., and P.A. Maplestone. 1969. The nematode parasites of vertebrates. Hafner Publishing, New York, New York. USA. 536 pp.

Zar, J.H. 1999. Biostatistical Analysis. 4th ed. Prentice Hall Publishers. Upper Saddle River, New Jersey, New York, U.S.A. 718 pp.

Appendix

Helminths of Canada lynx (*Lynx canadensis*), Red fox (*Vulpes vulpes*) and coyote (*Canis latrans*) in the Holarctic.

Host	Phylum	Reported in the Holarctic	Location	Reference
Definitive	Platyhelminthes	*Taenia rileyi*	Intestine	Van Zyll de Jong (1966 a); Smith *et al.* (1986)
Canada lynx (*Lynx canadensis*)		*Taenia pisiformis**	Intestine	Van Zyll de Jong (1966 a); Smith *et al.* (1986)
		*Taenia laticollis**	Intestine	Van Zyll de Jong (1966 a); Threlfall (1969)
		Taenia multiceps (scolices only)	Intestine	Van Zyll de Jong (1966 a)
		*Taenia macrocystis**	Intestine	Bursey and Burt (1970); Levandier (2003)
	Nemathelminthes	*Toxascaris leonina**	Intestine, stomach	Threlfall (1969); Levandier (2003)
		*Troglostrongylus wilsoni**	Lung	Van Zyll de Jong (1966 a); Levandier (2003)
		Toxocara cati	Intestine, stomach	Sprent (1983)
		Physaloptera praeputialis	Stomach	Smith *et al.* (1986)
		Cylicospirura felineus	Stomach	Pence *et al.* (1978)
		Spirocerca lupi	Esophagus, stomach	Samuel *et al.* (2001)
		Aelurostrongylus spp.	Lung	Bowman (2000)
		Oslerus spp.	Trachea	Bowman (2000)
	Platyhelminthes	*Alaria americanae*	Intestine	Van Zyll de Jong (1966 a)
	Acanthocephala	*Oncicola canis*	Intestine	Schmidt (1968)
Red fox (*Vulpes vulpes*)	Platyhelminthes	*Taenia serialis*	Intestine	H. Whitney (personal communication, 2003)
		Taenia pisiformis	Intestine	Stanley (1963); Samuel *et al.* (1978)
		Taenia crassiceps	Intestine	Stanley (1963); Samuel *et al.* (1978)
		Dipylidium caninum	Intestine	Miller and Harkema (1968)
		*Diphyllobothrium latum**	Intestine	Forsey (1992)

		Mesocestoides spp.*	Intestine	Forsey (1992)
		Echinococcus multilocularis	Intestine	Samuel *et al.* (1978)
		Echinococcus granulosus	Intestine	Samuel *et al.* (1978)
	Nemathelmithes	*Dirofilaria immitis*	Heart	Davidson *et al.* (1992)
		*Toxascaris leonina**	Intestine, stomach	Samuel *et al.* (1978); Forsey (1992)
		*Uncinaria stenocephala**	Intestine	Miller and Harkema (1968); Threlfall (1969)
		*Crenosoma vulpis**	Lung	Smith and Threlfall (1973); Jefferey (2002)
		Physaloptera rara	Stomach	Dibble *et al.* (1983)
		*Toxocara canis**	Intestine	Miller and Harkema (1968); Forsey (1992)
		Ancylostoma caninum	Intestine	Miller and Harkema (1968)
		Dioctophyme renale	Kidney	Davidson *et al.* (1992)
		Trichinella spiralis	Tongue	Davidson *et al.* (1992)
		Trichuris spp.	Caecum, large intestine	Davidson *et al.* (1992)
		*Angiostrongylus vasorum**	Heart	Jefferey (2002)
	Platyhelminthes	*Alaria americanae*	Intestine	Samuel *et al.* (1978)
		Metorchus conjunctus	Liver	Stiles and Baker (1935)
Eastern coyote (*Canis latrans*)	Platyhelminthes	*Taenia pisiformis*	Intestine	Freeman *et al.* (1961); Holmes and Podesta (1968)
		Taenia hydatigena	Intestine	Freeman *et al.* (1961); Holmes and Podesta (1968)
		Taenia multiceps (Multiceps spp.)	Intestine	Erickson (1944); Holmes and Podesta (1968)
		Taenia laticollis	Intestine	Freeman *et al.* (1961)
		Taenia crassiceps	Intestine	Seesee *et al.* (1983)
		Taenia serialis	Intestine	Butler and Grundman (1954)
		Taenia ovis krabbei	Intestine	Erickson (1944)
		Mesocestoides spp.	Intestine	Butler and Grundman (1954)
		Diphyllobothrium latum	Intestine	Holmes and Podesta (1968)
		Dipylidium caninum	Intestine	Butler and Grundman (1954); Gier and Ameel (1959)
		Echinococcus multilocularis	Intestine	Holmes and Podesta (1968)
		Echinococcus granulosus	Intestine	Freeman *et al.* (1961); Holmes and Podesta (1968)
	Nemathelminthes	*Toxascaris leonina*	Intestine, stomach	Butler and Grundman (1954); Holmes and Podesta (1968)
		Toxocara canis	Intestine	Butler and Grundman (1954); Holmes and Podesta (1968)

	Uncinaria stenocephala	Intestine	Holmes and Podesta (1968)
	*Angiostrongylus vasorum**	Heart	Bourque et al.(in press).
	Physaloptera rara	Stomach	Erickson (1944); Gier and Ameel (1959), Thornton *et al.* (1974)
	Dirofilaria immitis	Heart	Custer and Pence (1981)
	Capillaria aerophila	Large intestine	Seesee *et al.* (1983)
	Filaroides olseri	Trachea	Erickson (1944); Holmes and Podesta (1968)
	Ancylostoma caninum	Intestine	Holmes and Podesta (1968)
	Dioctophyme renale	Kidney	Holmes and Podesta (1968)
	Trichinella spiralis	Tongue	Seesee *et al.* (1974); Pozio *et al.* (2001)
	Trichuris spp.	Caecum, large intestine	Gier and Ameel (1959)
Platyhelminthes	*Alaria americanae*	Intestine	Holmes and Podesta (1968); Thornton *et al.* (1974)
	Metorchus conjunctus	Liver	Holmes and Podesta (1968)
Acanthocephala	*Oncicola canis*	Intestine	Seesee *et al.* (1983); Radomski and Pence (1993)

* - previously reported in Newfoundland