THE ECOLOGY OF BRYOFAUNA IN NORTHERN, COASTAL LABRADOR, CANADA: A STUDY OF THE EFFECTS OF ELEVATION, MOSS DEPTH, SEASONALITY AND LATITUDE ON MOSS FAUNA DISTRIBUTION PATTERNS

MATTHEW JAMES BOECKNER

The Ecology of Bryofauna in Northern, Coastal Labrador, Canada: A Study of the Effects of Elevation, Moss Depth, Seasonality and Latitude on Moss Fauna Distribution Patterns

by

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Abstract

Nematodes, tardigrades, bdelloid rotifers, oribatid mites and collembolans (the dominant bryofauna) were obtained and identified from the moss species *Dicranum polysetum* at various elevations within 3 towns of northern, coastal Labrador, Canada: Nain, Hopedale and Makkovik. A preliminary field collection took place in October, 2001 followed by 2 further collections in June and August, 2002 which focused more on quantitative data. Twenty three nematode genera, 18 tardigrade species, 3 rotifer genera, 15 oribatid mite genera and 1 collembolan genus were identified during the study. All findings were new records for Labrador and many were significant national discoveries.

A quantitative sampling design and multivariate analyses (non-metric multidimensional scaling) were used to examine differences in bryofaunal community structure across 4 environmental gradients: elevation, horizon depth/desiccation tolerance, seasonality and latitude. The nematodes contributed the most to understanding how variable environmental gradients affect bryofauna community structure as they had the greatest relative abundance throughout the study. The tardigrades and oribatid mites also exhibited some significantly variable distributions with regard to the environmental parameters, although fewer total specimens represented them. Bdelloid rotifers and collembolans were not quantitatively analyzed due to extremely low representation in the dataset.

It was determined that moss horizon depth had the greatest effect on nematode, tardigrade and oribatid mite distributions. In some cases elevation and seasonality also accounted for much of the variability in bryofaunal distribution patterns but results were often variable between geographic locations. The effect of latitude on distribution patterns did not show any significant relationship to bryofaunal distribution and was likely too small of a gradient to greatly affect the bryofaunal communities.

Some biotic relationships between bryofaunal groups were inferred and the general application of the moss fauna as a biological indication system was evaluated. Additionally, guidelines were given for the use of such an indicating system that would result in optimal effectiveness.

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The identification of the various bryofaunal groups was a daunting task that was greatly aided by the expertise of a team of biologists each with their own knowledge within the area of bryophilous invertebrates. Dr. Jean Finney-Crawley provided expertise essential in confirming the nematode genera, while Dr. Michael Collins and Lois Bateman aided in the classification of the tardigrades and rotifers, respectively. Additionally, the skills of Drs. Heather Proctor (University of Alberta) and Roy Norton (State University of New York) were vital in the identification of the oribatid mite genera while confirmation of the collembolan specimens was completed by Javier Arbea (Department of Biology and Geology, IES Alhama, Spain). Furthermore, I would like to thank Julie Gosse and Jill Janes for their aid in sample collection; the MUCEP students Heidi Fry, Chris Dunn, Megan Grant and Constantinos Kasimos for assisting with specimen extractions and Eric Lamb (University of Alberta) for providing critical insight into statistical methods. Finally, I wish to express my deepest appreciation and gratitude to Colleen Marshall (Mom), Kevin McEwan and Sarah Dean who offered the ceaseless encouragement and support needed to carry this thesis to fruition.

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Chapter 1

Introduction

1.1 The Bryofauna

Water surrounding the leaves of mosses supports organisms from a wide range of taxonomic groups, varying from bacteria and single celled ciliates to multicellular organisms (Corbet and Lan, 1974; Hingley, 1999; Zullini, 1970). This study focused on 5 of the dominant groups of organisms (Kinchin, 1987, 1989, 1990; Steiner, 1994, 1995a, 1995b) that were expected to inhabit mosses from 3 sites in northern coastal Labrador: nematodes, tardigrades, bdelloid rotifers, oribatid mites and collembolans. These 5 groups of invertebrates form complex and dynamic communities within the moss cushions. However, the relation of bryofaunal community structure to varying physical conditions is poorly known (Heatwole, 1983; Kinchin, 1989) and was investigated in this study. Special attention was given to the nematodes, tardigrades and bdelloid rotifers due to their high abundance within mosses.

1.1.1 Moss Meiofauna

The dominant meiofauna of the moss environment and key foci of this study were the bryophilous nematodes, tardigrades and rotifers, each of which has been studied to varying degrees within Canada and throughout the world.

Nematodes are among the most abundant multicellular animals and are either free-living or parasitic on plants and animals; some are marine while others inhabit fresh and brackish water or terrestrial environments. Nematodes are highly variable in size measuring anywhere from less than 1 mm to over 1 m in length. Plant parasitic nematodes are either ectoparasitic or endoparasitic. Various life stages of ectoparasitic, endoparasitic and free-living nematodes are readily found in the wet interstitial spaces between moss leaves.

Free-living nematode distribution throughout the world does not seem to be related to major geographical features such as mountain ranges, ocean barriers, or climatic zones (Nicholas, 1975) and many species seem to be cosmopolitan throughout highly variable environments. For example, *Dorylaimus stagnalis* and *Plectus cirratus* have been found within soil in Denmark and mosses in the high elevations of the Pamirs in Tajikistan, as well as the Baltic sea, and a third species *Aphelenchoides parietinus* inhabited these 3 environments plus thermal springs in New Zealand and saline waters in Germany (Nicholas, 1975). Although Nicholas (1975) emphasized widespread distribution for many species irrespective of varying habitat, he pointed out that some studies have conclusively shown that distribution and abundance of some nematode species can be linked quantitatively to varying ecological and geographical conditions (Johnson *et al.*, 1972).

Canadian studies on soil and litter nematodes (Appendix 1) are all fairly recent and have been conducted for parts of British Columbia (Hayes *et al.*, 1999; Panesar *et al.*, 2000, 2001; Forge and Simard, 2001), Nunavut (Cockell *et al.*, 2001), Manitoba (Dowsett *et al.*, 1984), Ontario (Allen *et al.*, 1988; Little and Maun, 1997) Quebec (Bélair, 1989; Bélair *et al.*, 2001, 2002), New Brunswick (Sweeney *et al.*, 1998), Prince Edward Island (Kimpinski *et al.*, 1993; Edwards and Kimpinski, 1997) and insular Newfoundland (Cuthbert, 1990). In addition to a few preliminary biological surveys (Kimpinski *et al.*, 1993; Dowsett *et al.*, 1984; Cockell *et al.*, 2001; Forge and Simard, 2001) studies of soil nematode communities in Canada have focused on factors such as the role and impact of nematodes as plant or animal parasites (Watson, 1986; Allen *et al.*, 1988; Bélair, 1989; Kimpinski *et al.*, 1993; Edwards and Kimpinski, 1997; Little and Maun, 1997; Hayes *et al.*, 1999; Bélair *et al.*, 2001, 2002) and their ability to act as ecological indicators of environmental impact (Yeow *et al.*, 1999; Panesar *et al.*, 2000, 2001). Canadian soil nematode communities have been studied extensively usually either to determine management techniques for parasitic nematodes or to gain overall information on soil health (Freckman and Ettema, 1993; Neher *et al.*, 1995; Bongers and Ferris, 1999; Hayes *et al.*, 1999; Yeates, 1999). However, few studies on nematodes that inhabit bryophilous environments have been completed. Some surveys on moss nematodes have been conducted globally and a limited number of other studies have attempted to discuss some of the ecological factors that shape nematode communities in mosses (Zullini and Peretti, 1986; Kinchin, 1989; Steiner, 1994, 1995b; Sohlenius and Bostrom, 2001). No previous Canadian studies have been devoted to the ecology of bryophilous nematodes communities.

Tardigrades are highly specialized non-segmented invertebrates commonly referred to as the water bears because of their respective habitat and appearance (Rupert and Barnes, 1994). Tardigrades typically range from 100 to 500 μm in length but some larger species can reach lengths of more than 1mm (Kinchin, 1994; Nelson, 1991). Most tardigrades are found in the water films surrounding the leaves of mosses but some may also inhabit marine environments (Kinchin, 1994). The 2 most common types of tardigrades are the Eutardigrades (naked tardigrades) and the Heterotardigrades (armored tardigrades), both of which have been found extensively within moss environments.

Of the 3 groups of bryophilous meiofauna studied, Canadian tardigrades have received the most ecological attention (Appendix 2). However, very few extensive studies have been completed on them. Tardigrades were first recorded from various locations within Canada by Richters (1908) and Murray (1910) during exploratory scientific expeditions. The tardigrades in parts of New Brunswick were later studied during the 1960's and 1970's (Argue, 1971, 1972, 1974) as well as species from Axel Heiberg Island, Nunavut (Weglarska, 1970; Weglarska and Kuc, 1980), Quebec (Iharos, 1973) and the Yukon Territory (Pilato, 1977). Two studies conducted on Vancouver island in the 1980's and 1990's (Kathman, 1989, 1990; Kathman and Nelson, 1989), and further studies in the Yukon Territory (Dastych, 1987; Manicardi, 1989), Northwest Territories (Van Rompu *et al.*, 1991, 1992) and New Brunswick (Argue, 1971, 1972, 1974) represent more recent contributions to the tardigrades of Canada. The most comprehensive study of tardigrades in Newfoundland and Labrador was conducted from 1997-2001 (Collins and Bateman, 2001; Bateman and Collins, 2001) and described the ecological distribution of tardigrades throughout the island of Newfoundland. These studies identified 31 tardigrade species including 5 that had no previous record within Canada (Appendix 2).

Rotifers are a small group of aquatic or semi-aquatic invertebrates. They typically range from 100-1000 μm in length, while some may reach 2 mm. It is the monogonontan rotifers that predominate the zooplankton of most marine and freshwater aquatic systems, but it is the bdelloid rotifers that commonly inhabit the film of water surrounding the leaves of mosses (Nogrady *et al.*, 1993; Donner, 1956, 1975). There are a total of 363 species of Bdelloidea within 18 genera known throughout the world and they differ from other rotifers (Monogononta) in that they are obligatory parthenogenic reproducers and are capable of anhydrobiosis (Ricci, 1987). Ricci (1987) attributed these differences to adaptations of the bdelloids to fluctuating environmental conditions (i.e. desiccation) typical of mosses. Most species of soil and moss bdelloids belong to the genera *Habrotrocha* and *Macrotrachela* (Ricci, 1987).

Monogonontid rotifers have been surveyed within various aquatic environments within Canada (Nogrady, 1989) and have been studied for their importance in commercial production of mussels, fish, etc. (Koch, 1929; Odell and Harris, 1933; Myers, 1936; Burger, 1973; Ramcharan *et al.,* 1996; Dodson *et al.*, 2000; Johannson *et al.*, 2000; Patoine *et al.*, 2000; Arnott *et al.*, 2001; Thorp and Casper, 2002). Canadian studies pertaining to the bdelloid rotifers, however, are very few. In fact, the bdelloids in general tend to be an infrequently studied group probably due to the difficulty of identifying preserved specimens and securing quantitative samples (Bateman, 1975).

Studies that have been conducted on the fauna of bryophytes often detailed the presence of bdelloids to varying degrees. Milne (1889), Murray (1909, 1911), Heinis (1910), Harring (1921), Bryce (1929), Wulfert (1940), Burger (1948), Donner (1950) and Nogrady (1962) were some of the first to study bdelloids and their ecology. Murray (1911) was the first to document the bdelloids of Canada collected from British Columbia and Ontario. Later additions to the bdelloid records of Canada include surveys conducted by Harring (1921) in the Canadian Arctic, Koch (1929) and Odell and Harris (1933) in New Brunswick and Ontario, as well as Ahlstrom (1940, 1943) from British Columbia and Ontario. A more recent study by Bateman (1975) quantitatively examined monogonontid and bdelloid populations within *Sphagnum* of Eastern Newfoundland and determined how these rotifer populations reacted to seasonal changes. A later study by

Bateman (1987) identified a bdelloid associated with the leaves of the pitcher plant, *Sarracenia purpurea* in Newfoundland. With the exception of Bateman's (1975, 1987) work, quantitative studies investigating the ecology of bdelloid communities within Canada are absent.

Tardigrades, nematodes and bdelloid rotifers dominate the meiofauna of mosses due largely to their capability to tolerate the wide range of environmental stresses typical of such environments (Wright, 1990; Steiner, 1994). The meiofauna utilize the film of water that surrounds the leaves of mosses called bryotelmata (Kinchin, 1994). When mosses are prone to desiccation, tardigrades, bdelloid rotifers and many nematodes enter and stay in a state of suspended animation called anhydrobiosis until adequate moisture returns, allowing continuation of normal activities (See section 1.3.1). Densities of the moss meiofauna have been described as inconsistent and changing over time (Kinchin, 1994). Nematodes, tardigrades and bdelloid rotifers often form densely abundant communities within mosses. Fantham and Porter (1945) found the nematodes to be the most abundant of the bryofauna often exceeding 4600 specimens per gram of moss. Generally moss cushions support relatively low densities of tardigrades, however, numbers as high as 823 specimens per gram of moss have been observed (Morgan, 1977). There have not been any precise bryophilous bdelloid counts made. Few studies have been able to quantify the relationship between the bryophilous meiofauna and variable environmental conditions (See section 1.3).

1.1.2 Moss Arthropods

Arthropods are also represented within moss communities and, because they are not dependent on a film of water to facilitate locomotion, they tend to be more adapted to drier parts of the moss. Kinchin (1990) found that moss arthropod communities tended to be richest in cushions that support few aquatic fauna (tardigrades, bdelloids, nematodes) and vice versa. Overgaard-Nielsen (1948) and Kinchin (1990) also indicated that most trophic interactions between the arthropods and aquatic meiofauna existed when the moss cushion underwent transition from wet to dry conditions. Many groups of arthropods utilize the moss environment for various stages of their life cycle, however the dominant bryophilous types are the collembolans and the oribatid mites (moss mites) (Kinchin, 1990). Collembolans lack cuticular coverings over many parts of their bodies and are more prone to desiccation than are the mites (Kinchin, 1990). Oribatid mites can reach densities of up to 500 000 specimens per square meter of moss (Behan *et al,*. 1978) while collembolans can reach densities as high as 240 000 per square meter (Bengtson *et al.*, 1974).

Canadian collembolan studies have focused on soils from Manitoba (Ferguson, 2001) and forest litter from British Columbia (Fjellberg, 1992) but have not considered the bryophilous collembolan communities. Canadian studies on moss mites have revealed representatives from 75 families, 69 of which have been found in samples taken from eastern Canada (Marshall *et al.*, 1987). Generally, these studies have been conducted in soil or litter layers of forests (Dwyer *et al.*, 1998) but not the moss systems exclusively.

1.2 Bryofaunal Biotic Relationships

Some studies have attempted to determine the biotic relationships that exist within soil and moss communities. Soil nematodes are commonly prey for small arthropods (Brown, 1954; Murphy and Doncaster, 1957) and tardigrades (Doncaster and Hooper, 1961). Nematodes can also be attacked by several species of fungi (Duddington, 1955). Conversely, plant, fungal and bacterial feeding nematodes are common within soil systems and are often present in moss communities. The nematode genus *Dorylaimus* and many species within the genus *Tylenchus,* are predators, often feeding on other nematodes (Nicholas, 1975).

Bryophilous tardigrades may be predaceous, bactivorous, fungivorous or phytophagous (Kinchin, 1987). Carnivorous tardigrades commonly feed upon nematodes, rotifers and other tardigrades. The tardigrades *Macrobiotus hufelandi* (Overgaard-Neilsen, 1948) and *Milnesium tardigradum* (Kinchin, 1994) have been observed preying on rotifers and Ramazzotti and Maucci (1983) observed the tardigrade *Milnesium tardigradum* feeding on a variety of other tardigrades. Tardigrades are also known to be parasitized by some types of fungus (Dewel and Dewel, 1987). Kinchin (1994) indicated that population cycles in competitors, predators or parasites may influence tardigrade populations and preliminary findings by Hallas and Yeates (1972) indicated a positive correlation between numbers of *Macrobiotus harmsworthi* and its nematode prey. However, there have been no further studies to support or refute these findings.

Very little work has been conducted on the feeding habits of bdelloid rotifers. Direct observation has revealed that bdelloids predominantly utilize their ciliated coronas to filter/vortex feed, however it is also common to find tardigrade remains within large predatory species (Kinchin, 1994).

Collembolans are opportunistic feeders and are known to feed upon moss, algae, fungal hyphae, bacteria and decaying plant matter (Petersen and Luxton, 1982; Lartey *et* *al.*, 1989; Kinchin, 1990; Varga *et al.*, 2002), while many predatory types feed upon juvenile nematodes (Brown, 1954). Many moss mites are bryophagous (Gerson, 1969) and others feed upon fungi and bacteria that grow between the moss leaves (Kinchin, 1990). Some Oribatids, including members of the Prostigmatid and Mesostigmatid groups, can also be predaceous upon nematodes and other smaller arthropods (Kinchin, 1990).

Only a fraction of moss fauna are bryophagous (consuming the moss itself). Davis (1981) calculated that only 0.04% of the bryophyte production is consumed by the bryofauna of Antarctic tundra mosses. Similar analysis of relationships between the bryofauna has yet to be carried out (Kinchin, 1994).

1.3 Factors Affecting Distribution and Density of Bryofauna

1.3.1 Moisture

The density of meiofauna within a moss cushion is probably affected most by water availability. Tardigrades, nematodes and rotifers rely upon an aquatic environment to enable metabolic processes as well as to allow movement within the moss. Nelson (1975) as well as Burger (1948), Bartos (1951), Francez (1980), Kathman and Cross (1991) and Ingemar-Jonsson (2003) found that it is not so much the species of moss, as its characteristic amount of moisture that determines its meiofaunal complement. Sohlenius and Bostrom (2001) determined that nematode abundance and distribution in organic soil horizons was directly dependant upon moisture levels. Similarly, Ricci (1987) determined that the availability of water was the major factor affecting bdelloid rotifer distribution.

Mihelcic (1954) categorized mosses into 3 groupings based on their moisture regime. These included the permanently wet mosses, those that frequently dried out, and those that remained dry for extended periods. Because water plays such an integral role in survival, mosses at the dry end of the moisture gradient tend to be inhabited by more specialized bryofauna than those mosses that are usually wet (Kinchin, 1994). These specializations include the ability of the organisms to undergo some form of anhydrobiosis. Anhydrobiosis is the term given to the form of cryptobiosis that arises from lack of water. During anhydrobiosis, the organism almost completely dries up and metabolic activity comes nearly to a halt. The organism will then maintain this dehydrated state until adequate moisture returns, thus allowing rehydration and continuation of metabolic processes. While bryophilous tardigrades and rotifers tend to be uniformly adapted to anhydrobiosis, bryophilous nematodes have been shown to vary in anhydrobiotic ability from genus to genus (Hyman, 1951). Kinchin (1990) pointed out that this adaptation of aquatic bryofauna to anhydrobiosis is probably an example of convergent evolution. Members of the genera *Mononchus*, *Dorylaimus*, *Plectus*, *Monhystera*, *Cephalobus*, *Trilobus*, *Tripyla*, *Tylenchus* and *Aphelenchus* are characteristic of mosses that undergo temperature and desiccation extremes (Hyman, 1951) and are believed to exhibit a high degree of anhydrobiotic ability.

Klironomos and Kendrick (1995) also considered moisture to be one of the most important variables that influenced microarthropod community structure. During periods of extended drought the moss arthropods, however, are far less adapted to anhydrobiosis than the aquatic meiofauna and must seek out moist moss environments, an option not available to the passively dispersing meiofauna (Kinchin, 1990). Although collembolans are very prone to desiccation (Kinchin, 1990), Bonnet *et al.* (1975) determined that some species of collembolan were able to withstand varying degrees of desiccation better than others. For example, *Entomobrya muscorum* could withstand 10 hours in an environment of 30% moisture while *Tomocerus vulgaris* could only survive 1 hour under these conditions. Similarly, Hammer (1972) found distinctly different oribatid species occurring within environments of variable levels of moisture. Conversely, too much moisture has been determined to have a negative affect on the oribatid community. Dwyer *et al.* (1998) determined that oribatid densities decreased in very wet soils, often those occurring near open or running water.

1.3.2 Dispersal

As mentioned previously, when moss conditions are not suitable oribatids and collembolans leave (actively disperse from) the moss cushion in search of more favorable habitats. The meiofauna considered in this study, however, are reliant upon passive distribution since their rate of active dispersal is minimal. Tardigrades, nematodes and rotifers actively move at a pace that is adequate for within-moss dispersal, however they must rely upon water, wind and larger animals for long distance (passive) dissemination (Dobers, 1915; Bartos, 1951; Maguire, 1963; Donner, 1965). Ramazzotti and Maucci (1983) calculated the maximum rate of progression of a large unhindered tardigrade species (*Macrobiotus* sp.) as 17.7 cm/h. This is comparable to the rate of progression for rotifers and nematodes. Because of their extensive abilities to tolerate long periods of desiccation in a dehydrated state during which they may be blown with soil and debris to other locations, wind has been documented as a form of bryofaunal passive dispersal mainly for bdelloid rotifers and tardigrades (Kristensen, 1987). Dobers (1915), Bartos

(1951) and Donner (1965) detailed the key importance of water to rotifer distribution (i.e. heavy rain, flooding, etc.).

1.3.3 Moss Horizon

Distribution of the moss meiofaunal community within each moss cushion is also dependent upon water, as the film of water surrounding leaves and stems facilitates migration to various parts of the moss. Acrocarpous moss cushions consist of 3 horizontal layers that are clearly distinguished in some species, but more difficult to identify in others. The upper-most horizon is the canopy layer (A), under which is the stem layer (B), followed by the lowermost rhizoid layer (C) (Kinchin, 1989). The canopy layer is the most productive layer securing the most oxygen and sunlight, however it is also most prone to desiccation (Overgaard-Neilsen, 1948). The lowest C-layer of the moss consists of humus and is least prone to desiccation. It is this layer which is least productive with low amounts of free oxygen and sunlight penetration. *Dicranum polysetum* (used throughout this study) is an acrocarpous moss species which is widely distributed throughout Canada and exhibits distinct separation between successive horizons. This species grows in dense clumps, is typical of drier, more exposed environments and is seldom found in saturated, acidic habitats such as bogs, marshes and fens (Newmaster *et al.*, 1997). Free-living moss fauna take part in diurnal vertical migrations throughout these layers depending on prevailing environmental conditions in order to secure optimal nutrition while avoiding desiccation (Overgaard-Neilsen, 1948). The degree to which each species will migrate has been linked to their individual desiccation tolerance. Overgaard-Neilsen (1948) divided moss nematode populations into

3 general ecological groupings based on the frequency of their presence throughout the moss cushion. These groupings were:

1. Nematodes that migrated from rhizoid layer to the canopy when the moss was damp (e.g. *Plectus*)
2. Nematodes that migrated only from the rhizoid layer to the stem layer in saturated cushions (e.g. *Aphelenchoides*).
3. Nematodes that resided only in the rhizoid layer, never migrating vertically (e.g. *Dorylaimus*).

Overgaard-Neilsen (1948) indicated that species such as *Aphelenchoides parietinus*, *Plectus cirratus* and *Plectus rhizophilus* that can both swim and tolerate desiccation, dominated mosses that dry out periodically.

Vertical distribution of plant parasitic nematodes has also been linked to the depth of root penetration into the soil, litter or moss (Bassus, 1962). Bassus (1962) found that the bacterial feeders *Cephalobus, Plectus* and *Monhystera* were found in the upper "superficial" regions of moss/litter while plant parasitic "root feeders" such as members of the Hoplolaimidae and Dorylaimidae dominated the deeper zones. Conversely, he found that members of the fungal feeding and ectoparasitic nematode genera *Tylenchus* and *Aphelenchoides,* as well as predators belonging to the genus *Mononchus,* were more uniformly distributed throughout the sample depth. In a similar study by Sohlenius and Bostrom (2001) superficial moss and litter layers of a Swedish Scots pine forest were also dominated by *Plectus*, while a majority of *Acrobeloide*s species occurred in deeper layers.

Hallas (1978) described the vertical distribution of tardigrades within moss layers. He found that tardigrades associated with the C-layer were consistent with true soil dwelling species, whereas B-layer tardigrades were commonly litter species, and those associated with the A-layer were the most specialized bryophilous species. Wright

(1990) looked at tardigrade vertical migrations during periods of desiccation, and found that all but 1 tardigrade species (*Echiniscus testudo*) took part in some degree of vertical migration during desiccation within the moss *Grimmia pulunata* but did not determine if this trend was common among different species of moss. Analysis of distribution throughout the moss cushion, including any study of their vertical migrations, is lacking for rotifers. However, Kinchin (1994) indicated that bdelloid rotifers were usually associated with tardigrades because of their similar rates of active dispersal, moisture requirements and anhydrobiotic abilities.

Distribution of moss arthropods within the moss cushion has not been documented. However, some studies have looked at oribatid mite vertical distribution within soils and found that both species diversity and abundance decreased with increasing soil depth (Dwyer *et al.*, 1998). It was assumed that this was probably due to the greater abundance of food resources near the surface and the difficulty of penetrating deeper soil layers. Haarlov (1955) and Mitchell (1978) found that vertical distribution of collembolans and mites throughout the soil was correlated with moisture and depth of horizons.

1.3.4 Elevation

Although studies have been conducted to determine the role that elevation plays in soil fauna abundance and distribution, such studies on moss fauna are limited. Powers *et al.* (1998) found that soil biodiversity decreased as elevation increased but that a greater abundance of soil fauna occurred within the higher elevation sites. This relationship remained, even with small (40m) changes in elevation. In the same study the nematode *Scottnema lindsayae* and members of the genus *Eudorylaimus* dominated each elevation.

Elevation has also been linked to the density of tardigrades and there are indications that some species are characteristic of certain altitudes (Rodrigues-Roda, 1951; Ramazzotti, 1956; Bertrand, 1975; Dastych, 1980). For example, in an analysis of Polish tardigrades, Dastych (1980) found that *Echiniscus spitsbergensis*, *Macrobiotus willardi* and *Echiniscus granulatus* dominated low elevations while *Macrobiotus harmsworthi*, *Echiniscus wendti* and *Milnesium tardigradum* were typical of higher elevations.

Recent studies have begun to show that tardigrades show a large range of physical habitat preferences. Some species seem adapted to many habitat extremes where others seem to be limited to fairly specialized environments. Dastych (1985) found elevation to be one of the 3 most significant variables that affected tardigrade species composition within the mosses of West Spitsbergen. He found a net decrease in the number of tardigrade species per moss sample as elevation increased. Wright (1990) also examined tardigrade populations with regard to elevation and discovered distinct differences in tardigrade communities at various altitudes. He categorized species found at lower elevations as being hygrophilic ecotypes intolerant of frequent desiccation (*Macrobiotus hufelandi, Hypsibius dujardini*). Conversely, species occurring at high elevations, where frequent and long lasting desiccation was evident, were classified as xerophilic ecotypes (*Milnesium tardigradum, Hypsibius oberhaeuseri*). However, because so few elevational studies have been conducted on the tardigrades much remains unknown as to how various species are affected by varying altitudes.

There are no studies relating bryophilous bdelloid rotifers, collembolans and mites to elevation. However, Seyd *et al.* (1996) encountered distinctly different soil/litter oribatid populations at different altitudes in the British Isles, but concluded that community distinctions between the higher and lower regions were more closely related to glaciation than to differential survival of species at differing altitudes.

1.3.5 Seasonality

Seasonality has been studied as a significant factor that affects soil nematode density, but has not received universal acceptance. Cuthbert (1990) found that seasonal patterns of nematode distribution and abundance were difficult to evaluate. Similarly, Franz (1942) and Neilsen (1949) disputed any consistent seasonal pattern. However, peaks in nematode abundance during early summer and late autumn have been noted in temperate forest floor litter/soil (Yeates, 1972; Popovici, 1980) as well as in peat soils of England (Banage, 1966) and in moss occurring on forest floors in Germany (Bassus, 1962). In Sweden, Sohlenius and Bostrom (2001) found that proportions of fungal and bacterial feeding moss nematodes were nearly equal during summer months but bacterial feeders dominated during the winter months. Berney and Bird (2001) determined that the abundance of opportunistic bacterial feeding nematodes was linked to the proliferation of bacterial populations often associated with an increased rate of organic soil deposition characteristic of early spring and autumn.

Periodic sampling by researchers has quantified some seasonal trends in bryophilous tardigrade population dynamics (Kinchin, 1994) but data are still largely missing for many species and seasons. Morgan (1977) investigated the relationship between tardigrade population density and seasonality but was unable to determine any significant patterns. Population studies in Antarctica have shown peaks in tardigrade abundance immediately after the ice had melted marking the beginning of the austral summer (Jennings, 1976; Everitt, 1981).

Bdelloid rotifer communities are generally stable across seasons (Madalinski, 1961) with only slight differences recorded between winter and summer fauna (Koste, 1976). However, Zullini and Ricci (1980) were able to show that *Philodina flaviceps* was more abundant in early spring than at any other time of year. Bateman (1975) determined that bdelloid rotifer populations of peatlands in Newfoundland diminished slightly in numbers during winter months. Generally, however, relationships of seasonality to the bdelloids as well as other bryophilous meiofaunal populations have not been quantitatively studied and are not fully understood.

Orbatid mites have shown trends of reproductive seasonality including Mitchell's (1976) Canadian findings that egg maturation tends to take place in spring-summer. Studies regarding collembolan reactions to seasonality are absent.

1.3.6 Latitude

Little work has been done on latitudinal distributions of bryofauna, but some general trends have been observed. Nicholas (1975) stated that free-living nematode populations are quite widespread and species were not greatly governed by factors such as climactic zones (i.e. latitude). Nelson (1991) indicated that tardigrades are more common in polar and temperate regions than in tropical regions of the world. Tardigrades also make up a large component of the microfauna of Antarctica (Murray, 1906, 1910; Jennings, 1976; Davis, 1981; Everitt, 1981; Dastych, 1984; McInnes and Ellis-Evans, 1987; Usher and Dastych, 1987). Small-scale latitudinal effects on tardigrade populations have not been considered and may be evident in the latitudinal gradient that exists between the collection sites of this study. The latitudinal distribution of bdelloid rotifers has received little attention, however, Ricci (1987) indicated that 42% of known bdelloids were cosmopolitan, while the rest exhibited distributions ranging from widespread to endemic.

Oribatid mites do not seem to be confined to any particular latitudinal range and make up the dominant group of organic soil arthropods globally (Olszanowski and Niedbala, 2000). Similar studies regarding collembolan reactions to latitude are absent.

1.4 Moss Fauna as Biological Indicators

Biological indication is commonly defined as "the use of an organism or a community of organisms to obtain information about the quality of the environment in which it is located" (Wittig, 1993). Bio-indicators can be used to monitor the effect of stress on communities of organisms and thus determine the degree to which an organism, or community of organisms has deviated from the normal (baseline) condition. For a bio-indicator to be useful, there must be initial or baseline data with which to compare the stressed system. Without baseline data, the degree to which the stress is affecting the system cannot be assessed. The most useful bio-indicators exist when the stress factor is sub-lethal, and when the indicating organisms have different sensitivities or tolerances to the same stress (Mhatre and Pankhurst, 1997). These indicators may interpret natural phenomena, for example, using tree ages within a forest population to indicate the period since the last fire disturbance (Mhatre and Pankhurst, 1997), or they can be used to ascertain the effect of anthropogenic disturbances. For example, lichens are often used as bio-indicators of air pollution due to their sensitivity to industrial emissions (*e.g.* Ferry *et al.*, 1973; Hawksworth and Rose, 1976; Salanki, 1986). However the suitability of mosses as bio-indicators has yet to be evaluated (Rühling and Tyler, 1971; Goodman *et al.*, 1975; Yule and Lloyd, 1984).

The use of nematodes, tardigrades, rotifers, oribatid mites and collembolans as biological indicators has only recently been investigated. Generally, the few studies that have been completed relate to the use of soil and marine sediment fauna and not bryofauna as biological indicators (Hanel, 2000; Mhatre and Pankhurst, 1997; Yeow *et al.*, 1999; Boyd *et al.*, 2000).

Some studies have made use of nematode populations as bio-indicators of disturbance (e.g. Mhatre and Pankhurst, 1997; Yeow *et al.*, 1999; Panesar *et al.*, 2000, 2001), yet few have included moss nematodes. A study conducted by Zullini and Peretti (1986) determined that moss nematode communities were very sensitive to lead pollution and that certain species abundances significantly declined in the presence of lead. Thus, the nematode community structure acted as the bio-indicator of disturbance.

Sladecek (1983), Donner (1978) and Koste (1976) studied the effects of water pollutants, temperature and food types on bdelloids occurring within mosses in or around streams and rivers. Each showed how bdelloid rotifers could be utilized as indicator species.

Bryophilous tardigrades, oribatid mites and collembolans have not been examined to the same degree as the nematodes and bdelloid rotifers and their usefulness as bio-indicating populations is less understood. Currently, the only studies that investigated the biological indicating abilities of all 5 bryofaunal groups were those of Steiner (1994, 1995a, 1995b) who studied the effects of air pollution on moss dwelling animals (nematodes, tardigrades, bdelloid rotifers, collembolans and oribatid mites) in Zurich, Switzerland and determined trends exhibited by moss fauna as bio-indicators of disturbances in air quality. He found that tardigrade and nematode moss populations are sensitive to changes in air quality, and that certain species declined in number while others flourished with respect to an air pollution gradient. He also determined that mite and collembolan community richness decreased along a gradient of increasing pollution. Steiner (1995b) concluded that measures in abundance of 4 nematodes (*Chiloplectus* cf. *andrassyi*, *Aphelenchoides* sp., *Paratripyla intermedia*, *Mononchidae* sp.) and 2 tardigrades (*Macrobiotus persimilis*, *Isohysibius prosostomus*) were highly correlated with air pollution and thus these bryofauna could serve as indicators of air quality disturbance for the region of Zurich studied. In comparison to the other moss fauna, Steiner (1995a) determined that the moss arthropods were less sensitive to pollution. However, conclusive as this study was, it lacked replication and few similar studies have been completed to support the range of geographic applicability of Steiner's (1994, 1995a, 1995b) results.

1.5 Aims of the Study

1.5.1 To survey the bryofauna (October 2001) that inhabit the acrocarpous moss *Dicranum polysetum* at 3 sites in northern, coastal Labrador and discuss any preliminary elevational distribution patterns evident for the 5 dominant groups (nematodes, tardigrades, bdelloid rotifers, oribatid mites and collembolans).

1.5.2 To analyze the distribution of bryofauna (June and August, 2002) with respect to 4 environmental variables (elevation, moss depth, seasonality and latitude) and to compare the results with findings of similar studies conducted worldwide to determine genera/species distribution trends with respect to variable environmental extremes.

1.5.3 To investigate Canadian distributions and biotic interactions for the identified bryofaunal specimens.

1.5.4 To assess the ability of the moss faunal communities to function as a system for bio-indication and suggest ways in which to maximize accuracy when utilizing the bryosystem as a monitor of environmental disturbance.

Chapter 2

Materials and Methods

2.1.1 Moss Species

As the majority of studies indicate that bryofauna show no significant preference for certain species of moss, a single acrocarpous species was collected throughout this study: *Dicranum polysetum* (Figure 2.1). *Dicranum polysetum* was chosen because of its widespread distribution along northern, coastal Labrador as well as the fact that the horizons within it were clearly visible. Additionally, this moss species tends to grow in drier habitats and is not typical of acidic or saturated environments (Newmaster *et al.*, 1997) and thus usually exhibits a distinct depth related moisture gradient throughout its horizons.

2.1.2 Site Description

Newfoundland and Labrador is the most easterly of the Canadian provinces comprised of the island of Newfoundland (108,860 square kilometres situated in the northwest Atlantic) and a large portion of the Labrador Peninsula (292,670 square kilometres). Labrador makes up about 3% of the total area of Canada and its triangular geography is bordered northeasterly by the Atlantic Ocean (Figure 2.2).

With its many islands and inlets it has been estimated that Labrador has approximately 8,050 kilometres of coastline stretching from Blanc Sablon, Quebec in the south to the most northern tip of Cape Chidley (approx. 1,127 linear kilometres). Labrador's coast is often undulating and mountainous with the highest peaks rising north of Nain in the Torngat Mountains. A high degree of glaciation has eroded the peaks of

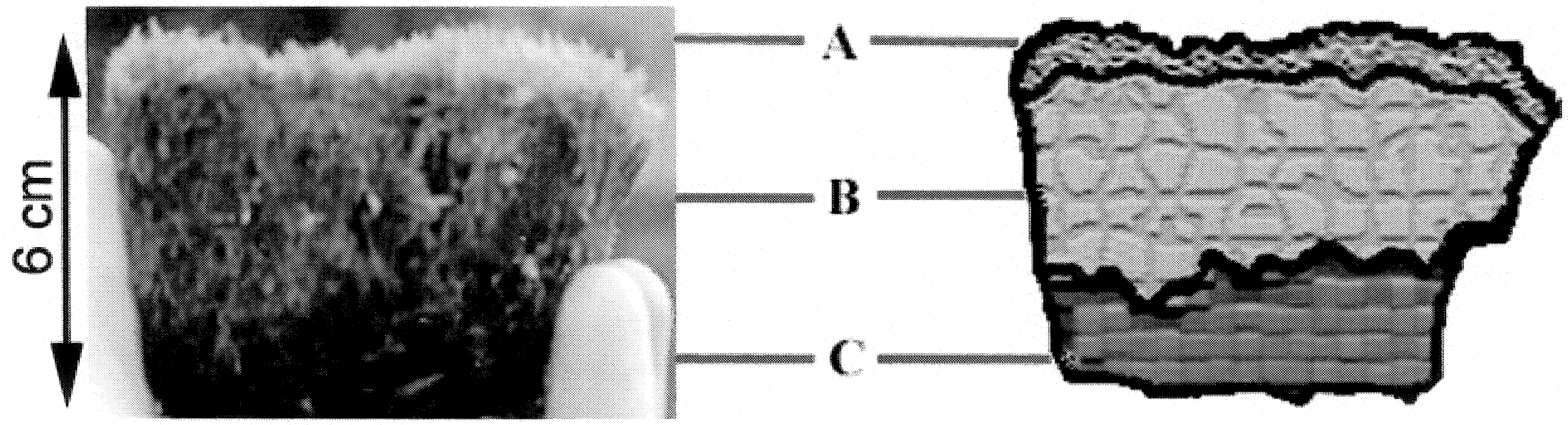


Figure 2.1. Acrocarpous moss: *Dicranum polysetum* sampled throughout the study. Labels correspond to moss horizons A, B and C.

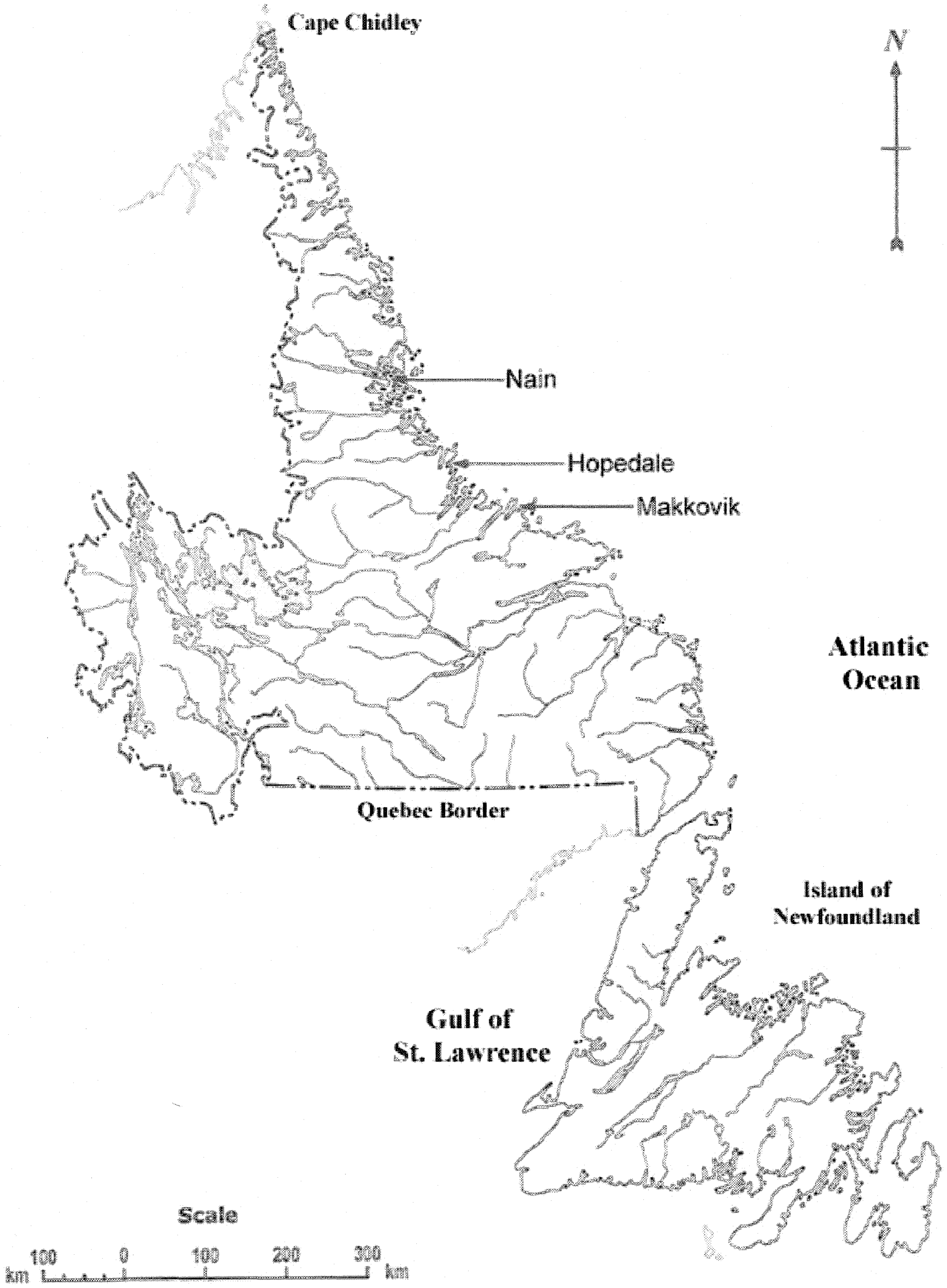


Figure 2.2. The province of Newfoundland and Labrador. The location of each study town is indicated: Nain, Hopedale and Makkovik.

the mountain ranges within and south of Nain (Kiglapait, Kaumajet and Mealy mountain ranges) into the blunt-topped hills characteristic of the coastline today (Parsons, 1970).

Samples were collected from within 3 towns along Northern, coastal Labrador, Canada. The northernmost site was Nain situated at 56 32' N 61 42' W, followed by Hopedale at 55 27' N 60 13' W and the most southern site, Makkovik at 55 05' N 59 10' W (Figure 2.2). The Labrador coastline is often very rugged and barren placing the 3 coastal towns of Nain, Hopedale and Makkovik within the sub-arctic/open woodland vegetative zone (Parsons, 1970). The vegetation within this zone is generally characterized by mosses, lichens, shrubs and widely spaced white and black spruce, the latter being usually absent in more exposed areas. Labrador is located between 50° and 60° North latitude and as such is classified as a northern environment associated with a cold climate (Parsons, 1970). Labrador's climate is generally more severe in the coastal regions due to the chilling effect from the Labrador Strait and high amounts of precipitation associated with the ocean environment. Table 2.1 shows the average monthly climate trends (1972-2000) for the northernmost study town of Nain (Environment Canada, 2002). There was only one weather station that represented the northern coast of Labrador, thus, there was no climactic data specific to Hopedale and Makkovik. Because of a combination of lingering snowfall and snow-cover, freezing rain and daily minimum temperatures, the growing season is generally quite short for the coastal towns of Labrador, not usually exceeding 4 months.

2.2 Preliminary Survey

Surveys of the bryofaunal communities occurring within the moss species *Dicranum polysetum* in 3 towns of northern, coastal Labrador were carried out in

Table 2.1. Average monthly climate trends (1972-2000) for Nain, Labrador (Environment Canada, 2002)

Nain, Labrador	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Daily Mean Temperature (°C)	-18.5	-18.3	-12.3	-4.9	1.0	6.2	10.1	10.7	7.0	1.1	-5.1	-12.8	-3.0
Daily Minimum Temperature (°C)	-23.1	-22.9	-17.3	-9.5	-3.0	1.4	5.2	5.7	3.0	-2.1	-8.3	-16.8	-7.3
Snowfall (cm)	77.2	55.3	82.5	58.7	28.8	16.0	0	0	2.6	26.9	63.8	80.3	492.2
Days with Freezing Rain	0.5	0.7	1.1	1.8	0.6	0.1	0	0	0.1	0.1	0.7	0.7	6.2
Mean Snow Depth (cm)	69	84	104	95	26	0	0	0	0	1	15	47	37

October, 2001. Also, a preliminary investigation into the effects of elevation on moss fauna distribution was conducted.

2.2.1 Field Collection

A total of 54 moss samples were collected in October 2001 from 3 horizon depths (A, B and C) in 2 nearby moss cushions at 3 elevations (low, medium and high relative to total height of study hill) of increasing altitude along large hills within each of the 3 sample towns (Nain, Hopedale and Makkovik). With the aid of contour maps and GPS triangulation the study site elevations were approximated for each of the towns (Figure 2.3). Nain had the largest study hill and the greatest differences between altitudes of successive sample sites. In Nain, the lowest elevation measured 50m, followed by the medium at 500m and the highest altitude at 800m. Makkovik's study hill had the next greatest altitude; low, medium and high elevations were 50m, 150m and 300m respectively. The study hill with the lowest total altitude was Hopedale, where low, medium and high elevations measured 50m, 100m and 200m respectively.

Since this portion of the study was intended to provide a qualitative species survey for each site, grab-samples were collected without regard for standardization. Therefore, sample sizes, moisture content and other environmental factors were highly variable for the October 2001 preliminary collection and thus statistical analysis was not feasible, however, some preliminary elevational trends were noted. Mosses collected in October had recently been covered with snow, and the Makkovik and Hopedale samples were frozen upon collection. The low elevation samples taken from Nain (sampled twice, 1a and 1b) were from a relatively sheltered area, whereas all of the other samples collected

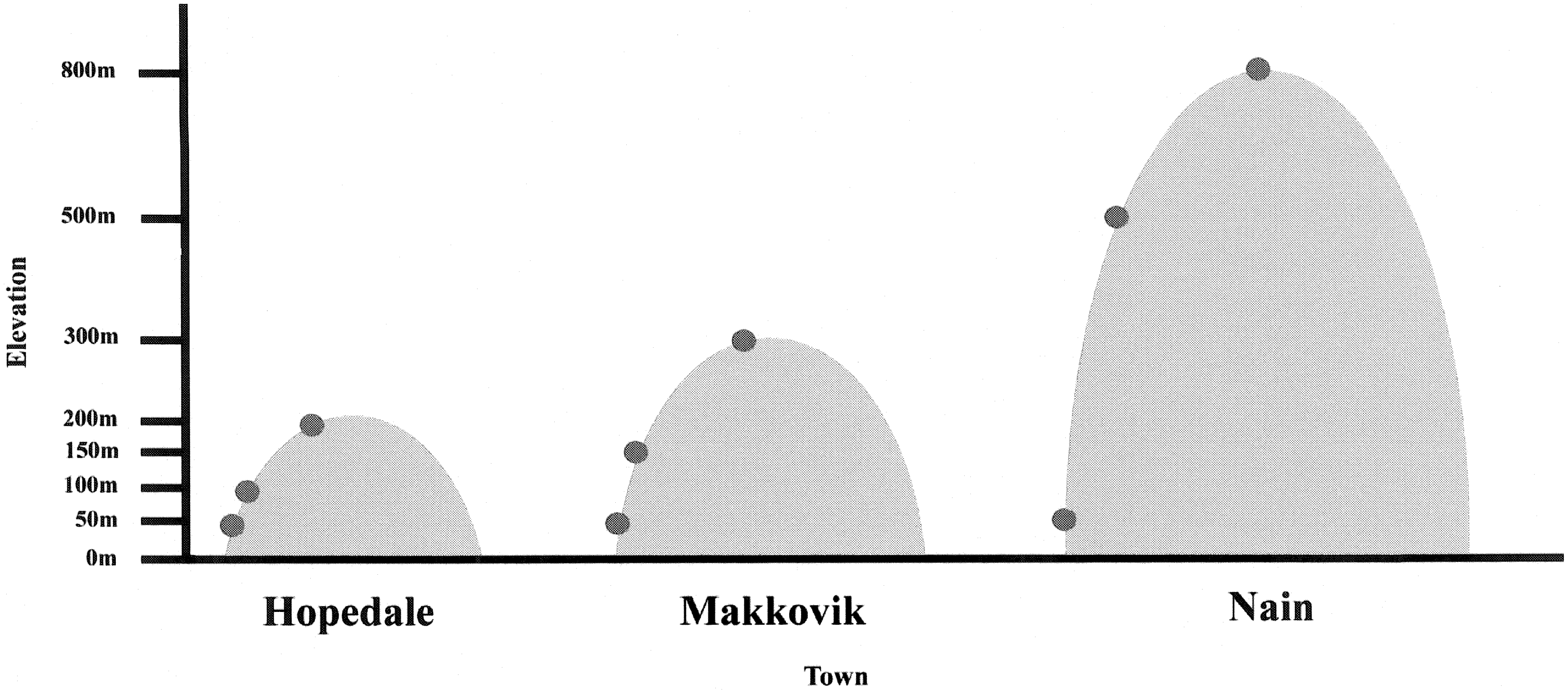


Figure 2.3. Sample site elevations for each town in northern, coastal Labrador (2001 and 2002 collections). Red circles indicate location of study site.

were from more exposed sites. Moisture content of the samples also varied between sites because of recent precipitation patterns.

Moss samples that were to be used to extract nematodes, oribatid mites and collembolans were kept moist and in sealed plastic bags. However, since tardigrades and bdelloid rotifers are highly tolerant of desiccation, replicate samples were collected and placed in paper bags and allowed to dry. Moist samples were refrigerated while dry samples were kept at room temperature and free of moisture until the time of extraction.

2.2.2 Extraction, Preparation and Identification of Bryofauna

For extraction of the bryofauna each moss sample was soaked separately in distilled water for up to 24 hours, after which the samples were shaken and squeezed to remove as much liquid as possible. The samples were then soaked and squeezed a second time to ensure that nearly all (> 90%) of the bryofauna were removed (Bateman, 1975) and then discarded. Using a stereomicroscope with a magnification of at least 25x, active and inactive tardigrades, nematodes, rotifers, collembolans and mites were removed by hand using glass pipettes or nematode picks/loops. The mites and collembolans extracted were placed in 85% ethanol solution until ready for identification.

Preparation of tardigrade specimens was completed using methods developed by Nelson (1999). Nematodes were processed and mounted in glycerine using Hooper's (1970) technique with as many as 40 nematodes per slide. Bdelloid rotifers tended to contract their cuticle upon fixation and thus had to be identified while alive. Before mounting in Hoyer's medium, the oribatid mites and collembolans were removed from the ethanol and placed in a lactic acid clearing solution for a minimum of 24 hours (Balogh, 1972), which digested the especially heavy exoskeletal parts allowing better transmission of light by compound microscope and facilitated more accurate identifications.

Identification of each of the bryofaunal groups was a daunting task that was significantly aided by the expertise of a team of biologists each having particular specialization with the various groups (See acknowledgements). Due to the extensive diversity of nematode and oribatid species, these groups were only identified to genus. Identification of the nematodes was aided by the works of Goodey (1951, 1963), Platt and Warwick (1988) and Siddiqi (2000). Tardigrade identification relied largely on the work of Ramazzotti and Maucci (1983). The bdelloid rotifers were identified utilizing the works of Bartos (1951), Donner (1965) and Bateman (1975). Identification of oribatid mite and collembolan genera was aided by the works of Balogh (1972) and Christiansen and Bellinger (1980), respectively.

2.2.3 Analysis

In addition to establishing genus/species lists for the bryofauna of northern, coastal Labrador, the genera/species were also evaluated (pooled % abundance) based on their predominance within the total specimen set. Sample sizes, moisture content and other environmental factors being highly variable for the samples of October 2001 statistical analysis was not conducted on these samples. However some preliminary elevational trends were indicated for the nematodes, tardigrades and oribatid mites by examining genera/species predominance along an altitudinal gradient. Furthermore, the datasets of each of the 3 towns were also merged to determine preliminary relationships of elevation to species richness. The rotifers and collembolans were represented by too few specimens to be useful in determining elevational trends.

2.3 Ecological Distribution Study

Quantitative sample collections were conducted in June and August, 2002 and were designed to quantitatively analyze the relationships that existed between the moss fauna communities and 4 environmental variables: elevation, moss depth/desiccation tolerance, seasonality and latitude. On each sampling occasion, each site was sampled in triplicate to strengthen quantitative analysis.

2.3.1 Field Collection

A total of 162 moss samples were collected in June and August 2002 from 3 horizon depths (A, B and C) in 3 nearby moss cushions at 3 elevations (low, medium and high relative to total height of study hill) of increasing altitude along large hills within each of the 3 sample towns (Nain, Hopedale and Makkovik).

Elevation – Where possible the sample sites and elevations were the same as those used during the previous 2001 preliminary survey (Figure 2.3). The only changes in sample sites were negligible and were conducted for the purpose of reducing extraneous variables acting upon the sample moss. For example, to remove the effects of overhead cover on exposure and insolation, the low elevation site in Nain had to be moved nearly 4m in height from the sample site of the 2001 collection.

Moss depth/horizon - Directly following the extraction of the moss cores, the horizons were separated using sharp surgical scissors, labelled and stored separately. This was done to prevent any cross migration of species from one horizon to another, so that differences in community structure between horizons A, B and C would not be compromised.

Seasonality - Two field collections took place during the year 2002. The first, in June was to collect samples representative of northern, coastal Labrador's spring season. The second collection, completed in August, was representative of Labrador's late summer/early fall season. The samples from these 2 seasons were analysed for the existence of any differential survival or reproductive rates for the bryofauna between 2 seasons. Presence of tardigrade eggs was checked to determine reproductive seasonality. General abundance of each species was used to determine the season of higher faunal density as well as season of higher activity for individual species.

Latitude - Samples were collected within the same 3 towns that were surveyed in the 2001 collections: Nain, Hopedale and Makkovik. Given the increasingly northern positions of these 3 towns (Figure 2.2) consideration was given to the effects of a latitudinal gradient on bryofaunal dispersal.

Standardization of Extraneous Variables - In order to confidently explain sample trends, interference by extraneous variables on the samples had to be reduced. Thus, the 2002 sample sites were chosen based on the ability to minimise the effect of extraneous variables such as exposure, insolation, moisture content, slope, horizon depth and sample size.

In order to reduce interaction of variations in exposure and insolation with the ecological analysis of the bryofaunal communities, only sites lacking overhead cover and surrounding protection were chosen for collection. Because northern, coastal Labrador is characterized by mainly low growing vegetation it was possible to obtain samples which were relatively uniform in their degree of exposure and insolation. Additionally, care was taken to ensure that each study hill was facing the east.

Although it was not possible to ensure similar patterns in precipitation on the various sample dates, to minimize moisture content differences samples were taken at a relatively constant slope, thus ensuring some degree of similarity in run-off between each. Wherever possible samples that exhibited a gradient from highly moist C-horizon to relatively dry A-horizon were collected. Special note was made of any situations where the moss was either completely saturated or entirely dried in the event that outlying variances in ecological trends needed to be accounted for.

Water run-off is greater for sites of high slope than for sites of low slope. Similarly, the angle at which wind and sun hit the surface of a moss cushion is also affected by the degree of slope. Thus a relatively constant degree of slope was maintained to further reduce the effects upon moisture content, exposure and insolation as variables between each site. Moss samples with a slope ranging between 10° and 30° to the horizon only were collected.

A coring device was used during sample extractions to ensure uniform moss sample sizes (Figure 2.4). The device had a solid metal design with a sharp serrated leading edge that enabled cores to be extracted from dense or semi-frozen mosses. The coring device extracted cylindrical samples with a diameter of 1.75 cm and a depth that traversed the 3 moss horizons. The average sample size of the moss cores (A, B and C horizons intact) was 20cm^3. Care was taken to ensure that the coring device was cutting *through* the moss horizons and not just compacting each layer. The tool was rinsed with water between sample extractions to prevent cross contamination of bryofauna.

Moss cushion thickness, and thus internal horizon depth, varied depending on the growing surface. For example, mosses growing in crevices or concave bowls tended to

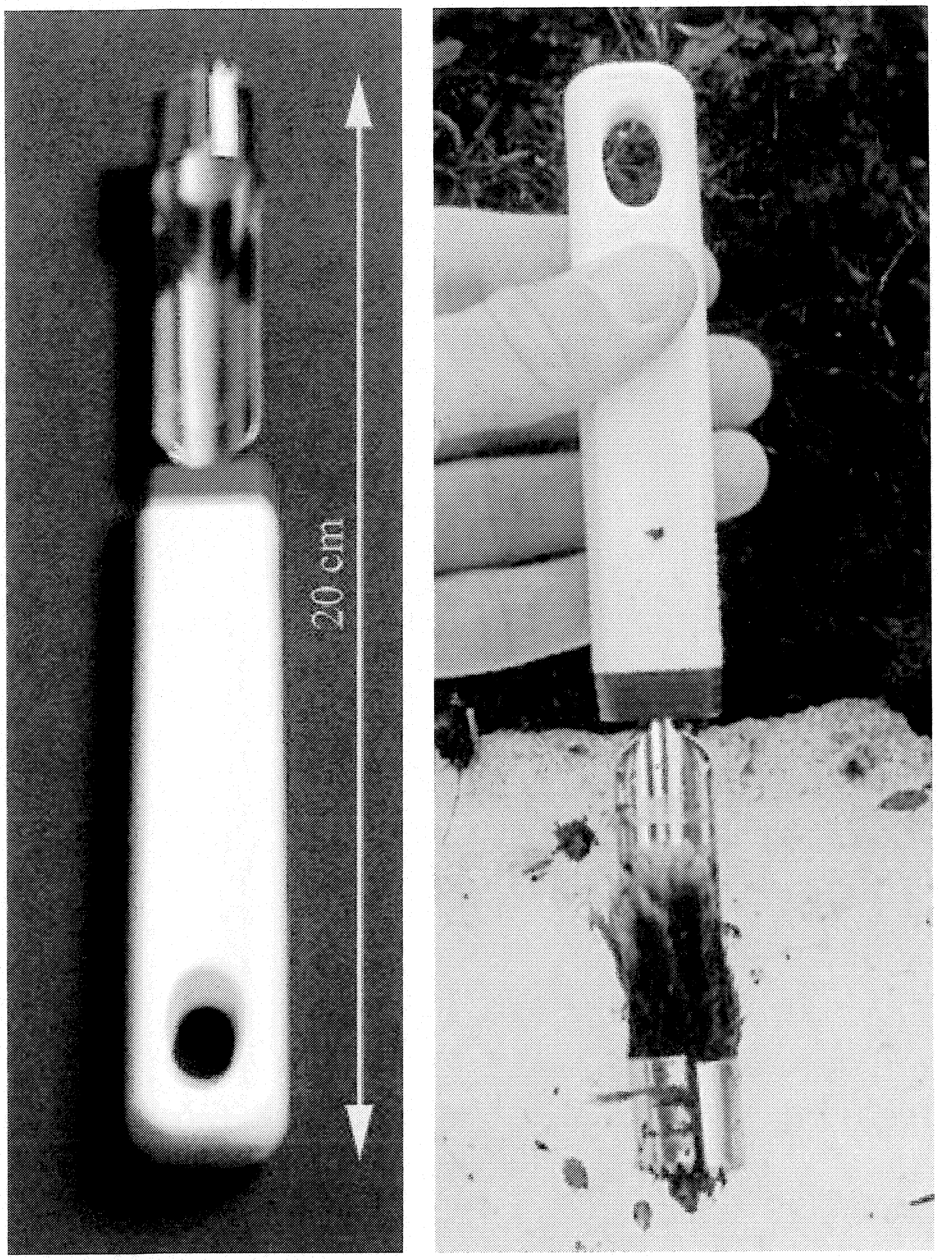


Figure 2.4. Coring device used to extract moss samples of uniform size.

form thicker cushions than those that grew on more exposed convex surfaces such as large boulders. As much as possible collections of moss cushions of "average" thickness were made, and overall sample depth was held as close to constant as possible. If discrepancies did occur in sample width, the samples were standardized by trimming each horizon as shown in Figure 2.5. The A horizon was consistently the most thin of the horizons (averaged 2cm) while the B and C horizons were generally thicker (averaged 3 cm each).

Storage - While in the field, samples were stored in small "zip-lock" bags for transport. Unlike the preliminary survey of October 2001, which had 1 moss sample for the tardigrades and rotifers and another for the nematodes and other bryofauna, in the 2002 collections all bryofauna except the rotifers were extracted from the same moss sample, which was kept moist in a sealed plastic bag (sampled in triplicate at each elevation, see section 2.3). Having all the bryofauna extracted from the 1 moss sample enabled the datasets and statistical analysis to encompass the complete community structure of the moss. Thus, biotic relationships were more easily identified and the different groups of bryofauna could be directly compared to one another with regard to the environmental variables. Utilizing this method, however, the bryofauna needed to be extracted more quickly from the samples so that organisms more prone to asphyxiation (tardigrades and rotifers) had less of a chance to expire and decay. Because of the difficulties inherent when working with bdelloid rotifers, separate moss samples were collected from which the bdelloids were extracted. Care was taken to keep the samples relatively moist and cool until returned to the laboratory where they could be refrigerated at a temperature of 5°C.

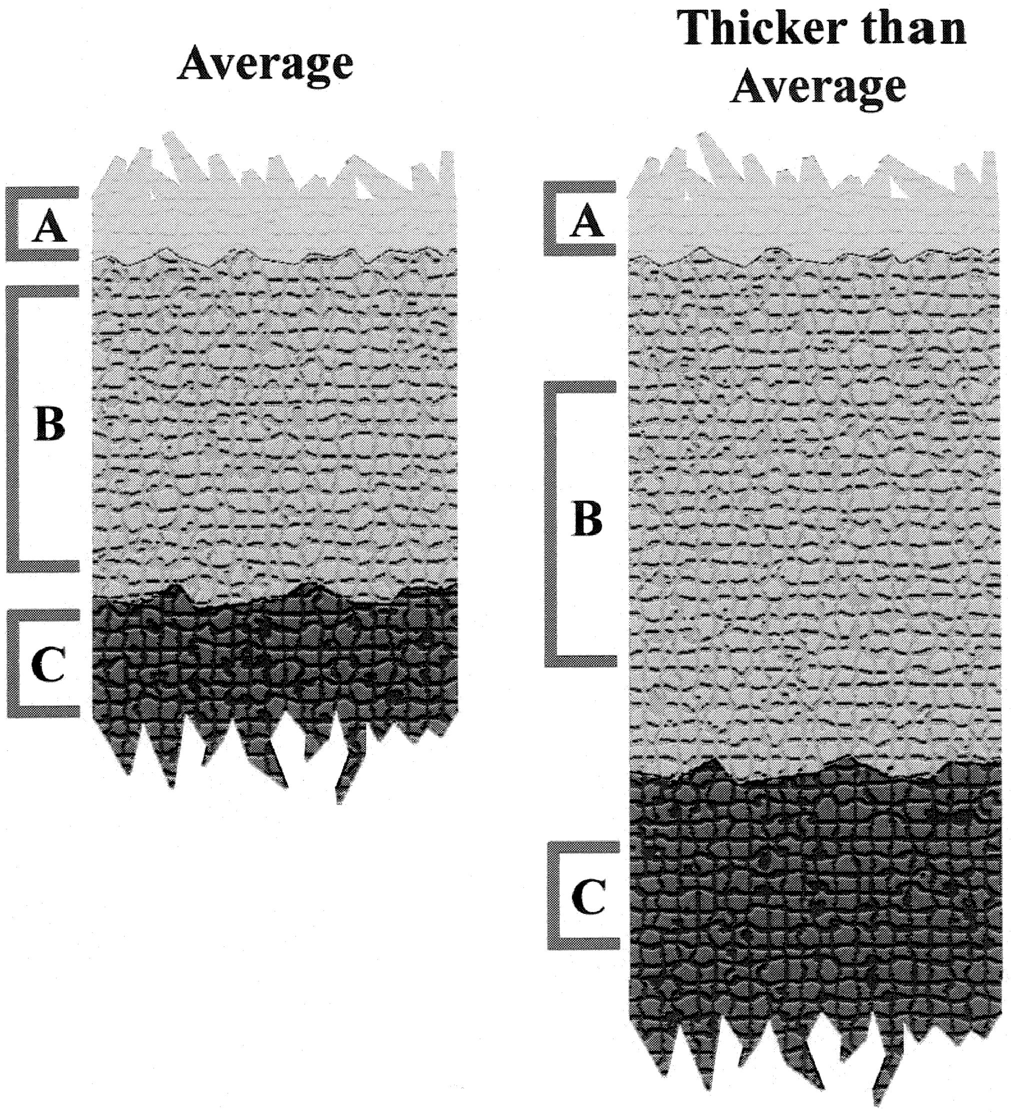


Figure 2.5. Procedure for standardization of moss horizon thickness. Red lines indicate where horizon separations were made for thicker than average moss samples.

2.3.2 Extraction, Preparation and Identification

Extraction, preparation and identification of the June and August 2002 samples followed the same techniques established during the October 2001 preliminary collections.

2.3.3 Analysis

In addition to broadening the genus/species lists for the bryofauna of northern, coastal Labrador the genera/species were also evaluated (pooled % abundance) based on their predominance within the total specimen set.

The dataset was then analysed to determine the effect that the 4 environmental variables had upon bryofaunal distributions. The method chosen for analysis was non-metric multidimensional Scaling (NMS). NMS is one of the most recommended ordination techniques in ecology because it is very well suited to data that may or may not be normally distributed (McCune and Mefford, 1999). This analysis has fewer assumptions than other comparable ordination models and runs less risk of producing misleading results. However, being non-parametric in nature this model is less robust than comparable metric methods (McCune and Mefford, 1999). A Sorenson distance measure was used in the analysis because it is more suited to ecological data than Euclidian measures (McCune and Mefford, 1999).

The nematodes were by far the most abundant of the bryofauna (~90%) and thus had a more quantitatively sound dataset. Therefore, to maintain the strength in ecological trends by reducing the interference of the other less abundant bryofauna, the nematodes were first analysed on their own, then later merged with the datasets of the tardigrades and oribatid mites. Relatively few specimens represented the collembolans and bdelloid rotifers and they could not be quantitatively analysed so only general trends were inferred for these groups.

2.4 Canadian Distributions and Biotic Relationships

Species lists were made and investigations of past studies were conducted to determine previous national findings and known trophic habits. Inference was made as to probable biotic relationships shared by various bryofauna based on those species that are most positively correlated and respective feeding habits.

2.5 Assessment of the Bryofauna as Biological Indicators

Quantitative data collected within this study represented the baseline conditions for the ecology of these communities. The potential of these bryofaunal communities as biological indicators is discussed.

Chapter 3

Results

3.1 Preliminary Survey (October 2001)

3.1.1 Identified Specimens and Relative Abundances

3.1.1.1 Nematodes

The October 2001 survey of bryofauna inhabiting *Dicranum polysetum* in northern, coastal Labrador produced 861 nematode specimens belonging to 17 genera. The 4 genera that dominated the entire nematode specimen set were *Plectus* (284), *Eudorylaimus* (279), *Panagrolaimus* (112) and *Prismatolaimus* (108). The remaining genera made up less than 10% of the total number of specimens: *Monhystera* 1 (18), *Aphelenchoides* (12), *Rhabditis* (11), *Prionchulus* (9), *Labronema* (6), *Ogma* (6), *Daptonema* (6), *Steineria* (3), *Acrobeloides* (2), *Mononchus* (2), *Achromadora* (1), *Tylenchus* 2 (1) and *Bunonema* (1).

3.1.1.2 Tardigrades

The October 2001 survey of tardigrades yielded 17 species and 2 specimens that may be separate species but have yet to be identified. The 2 unidentified specimens were of the *Diphascon* (1) and *Macrobiotus* (1) genera. Of the tardigrades identified all but 2 of the species were of the eutardigrade type (1 *Calohypsibius*, 4 *Diphascon*, 3 *Hypsibius*, 4 *Macrobiotus*, 1 *Mesocrista*, 1 *Milnesium*, 1 *Minibiotus* and 1 *Platycrista*). *Macrobiotus hufelandi* (103) occurred in 59% of the sites and made up 23% of the 440 specimens. *Diphascon ramazzotti* (95) occurred in 41% of the sites and made up 22% of the 440 specimens. Only 3 other species were represented by more than 10 specimens: *D. pingue*(12), *H. convergens* (13) and *Minibiotus intermedius* (23). The 2 species of heterotardigrades identified were, *Proechiniscus hanneae* and *Echiniscus wendti.* No eggs were found within the moss samples of the October, 2001 survey.

3.1.1.3 Bdelloid Rotifers

The initial survey of the bdelloid rotifers of northern, coastal Labrador identified 39 specimens belonging to 3 genera: *Adineta, Habrotrocha* and *Macrotrachela*. The genus *Macrotrachela* was the most abundant and was represented by 22 specimens in 11 varieties, 4 that were identified as the species *M. aculata* (1)*, M. multispinosa* (1), *Macrotrachela plicata hirundinella* (1) and *Macrotrachela punctata* (1). The remaining 7 types could not be identified past the genus *Macrotrachela* but were significantly different from one another and may have been separate species. The second most abundant genus was *Habrotrocha*, which was represented in this survey by 5 specimens in 2 groups (*Habrotrocha* 1 (4) and *Habrotrocha* 2 (1)). The final genus *Adineta* was represented by 2 species *A. steineri* (1) and *A. vaga* (2).

3.1.1.4 Oribatid Mites and Collembolans

The initial survey of moss mites in October 2001 yielded only 8 specimens belonging to 5 genera: *Cepheus* (1)*, Epidamaeus* (1)*, Fuscozetes* (1)*, Mycobates* (1) and *Nothrus* (2). Only 1 genus in the family Isotomidae were identified from the 13 collembolan specimens collected in October 2001: *Folsomia* (6). Low numbers of specimens prevented the identification of the mites and collembolans beyond genus.

3.1.2 Preliminary Elevational Trends

3.1.2.1 Nematodes - Distribution of the nematode genera was analyzed to determine any elevational relationships. Table 3.1 shows the number of nematodes of each genus found at each elevation within the 3 northern, coastal towns. Two samples were collected from

Table 3.1. Nematode genera identified relative to elevation in 3 towns of northern, coastal Labrador (October, 2001). The low elevation in Nain was sampled twice (1a and 1b).

	Nain Elevation				Hopedale Elevation			Makkovik Elevation		
	1a	1b	2	3	1	2	3	1	2	3
Achromadora		1								
Acrobeloides				1				1		
Aphelenchoides		1	3	7				1		
Bunonema					1					
Daptonema								6		
Eudorylaimus	14	28	34	42	26	10	76	24	5	20
Labronema						2	4			
Monhystera 1					1	7	6	3		1
Mononchus				1				1		
Ogma					2				3	1
Panagrolaimus	29	49	11	8	2	2	11			
Plectus	62	97	9	29	13	5	15	32	5	17
Prionchulus	8					1				
Prismatolaimus					100			2	5	1
Rhabditis		1				10				
Steineria	3									
Tylenchus 2					1					

the low elevation in Nain (1a and 1b). This was because there were inadequate amounts of moss in the lower altitudes and a second nearby sample site was needed. Table 3.2 shows which elevations yielded which nematode genera and thus the relationship elevation may have had on species richness and abundance when the data from each of the 3 towns were merged.

3.1.2.2 Tardigrades - The tardigrades were also evaluated based on where they were typically found along an elevational gradient. The abundance of each species at each altitude within the 3 towns is given in Table 3.3. Table 3.4 merges the tardigrade findings of the 3 towns to determine any generalized elevational trends in species richness and abundance.

3.1.2.3 Bdelloid Rotifers, Oribatid Mites and Collembolans – The low abundance of bdelloids identified precludes any formulation of trends regarding the bdelloid rotifers, oribatid mites and collembolans across an elevational gradient. However, Tables 3.5, 3.6 and 3.7 indicate where and in what abundance the rotifer, mite and collembolan specimens were found, respectively.

3.2 Ecological Study (June and August, 2002)

3.2.1 Identified Specimens and Relative Abundances

The nematodes and tardigrades made up the majority of bryofaunal specimens identified during the 2002 studies (~98%). Appendices 3, 4 and 5 provide the raw data for the nematodes, tardigrades and oribatid mites respectively, while the bdelloid rotifers, and collembolans had low representation and therefore no raw data were presented for these 2 groups.

Table 3.2. Nematode genera richness relative to elevation: respective altitudes pooled across all 3 towns (October, 2001).

	Low	Med	High
Achromadora	✓		
Acrobeloides			
Aphelenchoides	✓	✓	✓
Bunonema	✓		
Daptonema	✓		
Eudorylaimus	✓	✓	✓
Labronema		✓	✓
Monhystera 1	✓	✓	✓
Mononchus	✓		✓
Ogma	✓	✓	✓
Panagrolaimus	✓	✓	✓
Plectus	✓	✓	✓
Prionchulus	✓	✓	
Prismatolaimus	✓	✓	✓
Rhabditis	✓	✓	
Steineria	✓		
Tylenchus 2	✓		
Species/Elevation	**15**	**10**	**9**

Table 3.3. Tardigrade species identified relative to elevation in 3 towns of northern, coastal Labrador (October, 2001).

	Nain			Hopedale			Makkovik		
	Elevation			Elevation			Elevation		
	1	2	3	1	2	3	1	2	3
C. ornatus									1
D. nodulosum			2			2			
D. pingue			5		1		4		
D. ramazzotti	71	4	8	1	7	1	1	1	
D. scoticum			1		1				
D. sp.			1						
E. wendti							1		
H. convergens		2							6
H. dujardini		1			1				
H. microps						1			
M. echinogenitus		1		1	1	1			
M. harmsworthi							1		
M. hufelandi	33	11	36	2	1	6	7		7
Mesocrista spitzbergensis			3						
Milnesium tardigradum						1			
Minibiotus intermedius					1		20		
Platicrista angustata			1						
Proechiniscus hanneae						2			
Unknown			3		1		3		1

Table 3.4. Tardigrade species richness relative to elevation: respective altitudes pooled across towns (October, 2001).

	Low	Med	High
C. ornatus			✓
D. nodulosum			✓
D. pingue	✓	✓	✓
D. ramazzotti	✓	✓	✓
D. scoticum		✓	✓
E. wendti	✓		
H. convergens		✓	✓
H. dujardini		✓	
H. microps			✓
M. echinogenesis	✓	✓	
M. harmsworthi	✓	✓	✓
M. hufelandi	✓	✓	✓
Mesocrista spitzbergense			✓
Milnesium tardigradum			✓
Minibiotus intermedius	✓	✓	
Platicrista angustata			✓
Proechiniscus hanneae			✓
Species/Elevation	**7**	**9**	**13**

Table 3.5. Abundance of bdelloid rotifers in relation to town and elevation in 3 towns of northern, coastal Labrador (October, 2001).

	Nain			Hopedale			Makkovik		
	Elevation			Elevation			Elevation		
	1	2	3	1	2	3	1	2	3
Adineta steineri			1						
Adineta vaga								1	1
Habrotrocha #1			1				3		
Habrotrocha #2				1					
Macrotrachela #1	5								
Macrotrachela #2			3						
Macrotrachela #3				3					
Macrotrachela #4				1					
Macrotrachela #5					1				
Macrotrachela #6						1			
Macrotrachela #7							1		
Macrotrachela aculata									1
Macrotrachela multispinosa	1								
Macrotrachela plicata hirundinella				1					
Macrotrachela punctata				1					

Table 3.6. Abundance of oribatid mites identified in relation to town and elevation in 3 towns of northern, coastal Labrador (October, 2001).

	Nain			Hopedale			Makkovik		
	Elevation			Elevation			Elevation		
	1	2	3	1	2	3	1	2	3
Cepheus							1		
Epidamaeus		1							
Fuscozetes				1				1	
Mycobates			1	1					
Nothrus							2		

Table 3.7. Abundance of collembolans identified in relation to town and elevation in 3 towns of northern, coastal Labrador (October, 2001).

	Nain Elevation			Hopedale Elevation			Makkovik Elevation		
	1	2	3	1	2	3	1	2	3
Folsomia sp.		1		1		3		1	
Unidentified		1	1				1		

3.2.1.1 Nematodes - The June and August 2002 ecological survey of bryophilous nematodes inhabiting northern, coastal Labrador produced 6270 specimens belonging to 21 genera (Appendix 3). The genus *Plectus* dominated in number (40%) while the next most abundant specimens belonged to the genera *Aphelenchoides* (13%), *Eudorylaimus* (9.3%), *Prismatolaimus* (8%), *Monhystera* 1 (7.2%), *Achromadora* (6.7%), *Tylenchus* 1 (4.2%), *Teratocephalus* (2.6%) and *Euteratocephalus* (2.1%). The remaining genera made up less than 1% of the total number of specimens: *Bunonema* (0.9%), *Acrobeloides* (0.8%), *Tylencholaimus* (0.8%), *Wilsonema* (0.8%), *Labronema* (0.5%), *Monhystera* 2 (0.5%), *Daptonema* (0.3%), *Mononchus* (0.3%), *Ogma* (0.2%), *Tylenchus* 1 (0.2%), *Hemicycliophora* (0.1%) and *Zeldia* (0.1%). Thirteen of the genera identified were common to both study years, however, *Panagrolaimus, Rhabditis*, and *Steineria* were only found in the 2001 collection while *Euteratocephalus, Hemicycliophora, Monhystera* 2, *Teratocephalus, Tylencholaimus, Tylenchus* 1, *Wilsonema* and *Zeldia* were found only in the 2002 samples.

3.2.1.2 Tardigrades - The June and August 2002 ecological survey of bryophilous tardigrades from northern, coastal Labrador produced 265 specimens representative of 11 species and 3 types that may be separate species but have yet to be identified (Appendix 4). The 3 unidentified specimens are from the genera *Diphascon, Echiniscus* and *Macrobiotus*. Of the genera identified all but 1 were Eutardigrade types (5 *Diphascon*, 1 *Hypsibius*, 3 *Macrobiotus*, 1 *Mesocrista* and 1 *Minibiotus*). The species that dominated in abundance were *Macrobiotus hufelandii* (25%), *M. echinogenitus* (16.8%), *D. pingue* (8.2%) and *M. harmsworthi* (8.2%). The remaining species each contributed less than 4% of the total abundance: *D. scoticum* (3.4%), *Mesocrista spitzbergense* (2.4%), *D.*

nodulosum (1.4%), *D. ramazzotti* (1.4%), *H. convergens* (1%), *Minibiotus intermedius* (1%) and *D. recamieri* (0.7%). The heterotardigrade identified was from the genus *Echiniscus* and represented 1.4% of the total tardigrade specimens. All but 1 of the tardigrade eggs were collected from the August 2002 samples. A total of 36 tardigrade eggs were found. Twenty-seven of the eggs belonged to the species *M. echinogenitus* while the remaining 9 eggs have yet to be identified including the single egg from the June 2002 sample.

3.2.1.3 Bdelloid Rotifers - Five bdelloid species plus 2 groups that could only be recognized to genus level (*Adineta* and *Macrotrachela*) were identified from a total of 73 specimens. The species *Habrotrocha lata* was the most abundant of the specimens (51%) followed by *Adineta steineri* (13.7%), *Macrotrachela habita* (8.2%), *Macrotrachela* sp. (6.8%) , *Adineta* sp. (2.7%) and *Habrotrocha maculata* (1.4%). No rotifer eggs were found within the study samples.

3.2.1.4 Oribatid Mites - Fourteen oribatid genera and 1 specimen that could only be identified to the family Oripodoides were represented within the 169 specimens collected from the June and August ecological survey (Appendix 5). The dominant genera included *Fucozetes* (42.5%), *Mycobates* (21%), *Oppiella* (12.5%) *Limnozetes* (8.3%) and *Sellnickochthonius* (6.5%). The remaining 9 genera each had low abundances and were all represented by as few as 1 specimen each: *Cultroribula* (1.8%), *Nothrus* (1.8%), *Camisia* (1.2%), *Xenillus* (1.2%) *Brachychonius* (0.6%), *Epidamaeus* (0.6%), *Rhysotritia* (0.6%) *Trhypochthonius* (0.6%) and *Trimalaconothrus* (0.6%). In addition to the oribatids, mites from other suborders were also occasionally found: Endostigmata (3 specimens) and Prostigmata (3 specimens). To allow for quantitative analysis of the oribatid mites all of the genera were grouped into a single category: the oribatid mites.

3.2.1.5 Collembolans

One collembolan genera and 2 groups that could only be identified as far as family were identified from 46 specimens collected in June and August, 2002. The 2 families Poduroidea (13%) and Isotomidae (9%) were each represented by only a few specimens while the genus *Folsomia* (61%) dominated the collembolan specimen set. There were also 8 poorly preserved specimens which could not be identified.

3.2.2 Analysis of 4 Environmental Variables on Bryofaunal Distributions

The June and August 2002 ecological survey of the bdelloid rotifers and collembolans identified far too few specimens to be useful in quantitative analysis. Thus, the bdelloid and collembolan specimens identified during this sampling period were useful only in broadening the species list established from the preliminary findings of October 2001.

3.2.2.1 Nematodes - Nematodes were by far the most abundant of the meiofaunal groups and had the most robust dataset of all the bryofauna (i.e. larger specimen sets and sample sizes allowed for more accurate analysis). To maintain the quantitative nature and integrity of the dataset and to insure that the ecological trends were properly explained, the nematode dataset was first analysed and discussed separately from that of the other bryofauna. Non-Metric Multidimensional Scaling (NMS) was conducted for each town separately to determine any distributional effects that season, elevation and horizon have on nematode populations. There was too much interaction of conflicting variables when the analysis was run on the 3 towns together. The R-squared values for significance of each axis as well as selected graphical output of the NMS analysis detailing the relationship of each town's dataset to the 3 environmental variables are given below.

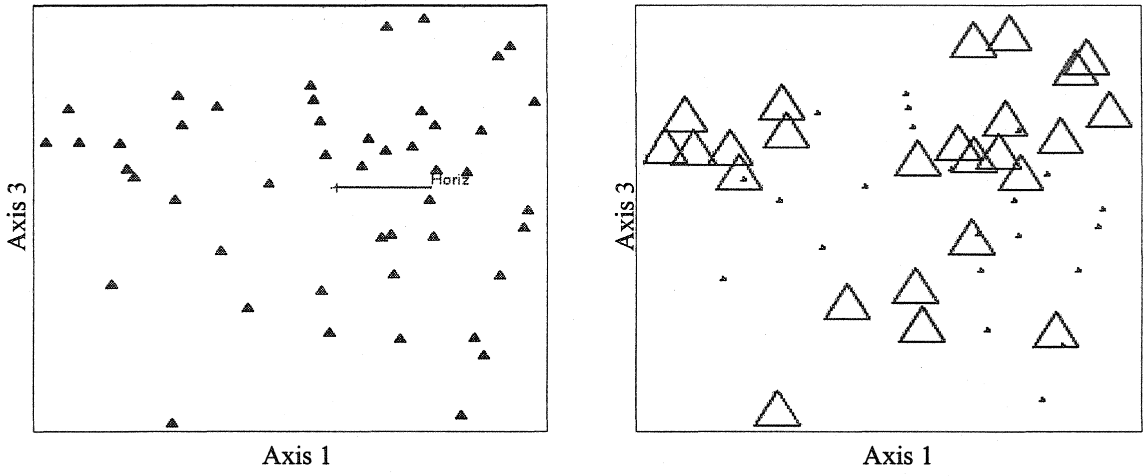
R-squared Values - The R-squared values for the nematode dataset are given in Table 3.8, which indicate the amount of variability explained by each axis. The 2 axes that explain the greatest amount of variation are represented graphically in Figures 3.1, 3.2 and 3.3. The r-squared values represent the coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space (Increment and cumulative r-squared were adjusted for any lack of orthogonality of axes)(McCune and Mefford, 1999).

Main Matrix and Overlays of 3 Environmental Gradients (Season, Elevation and Horizon) - Figures 3.1, 3.2 and 3.3 are selected graphical results of the NMS analysis showing the correlation of seasonality, elevation and horizon depth with nematode distribution for each town. Figures 3.1(a), 3.2(a) and 3.3(a) are main matrix plots of the study sites with respect to the 2 axes that explain the largest amount of variation in the dataset (largest r-squared values). Bi-plot (joint plot) lines originating from the centroid of each graph show the relationship between the environmental variables and ordination scores. The angle and length of the line indicate the direction and strength of the relationship. The longer the bi-plot line, the stronger the relationship of the environmental gradient is to the dataset.

Figures 3.1(b)(c)(d), 3.2(b)(c)(d) and 3.3(b)(c)(d) are overlays of the environmental gradients on the main matrices for each town. Overlays of season,

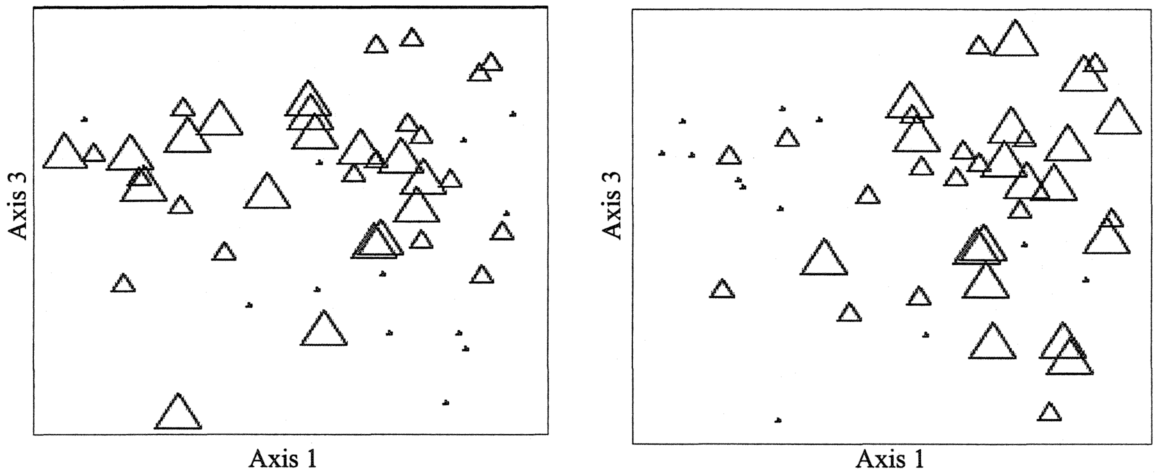
Table 3.8. R-squared values for the 3 axes that explain the greatest amount of variability in the nematode dataset (June and August, 2002).

Nain		
	R-squared Values	
Axis	**Increment**	**Cumulative**
1	.255	.255
2	.147	.402
3	.263	.665
Hopedale		
	R-squared Values	
Axis	**Increment**	**Cumulative**
1	.353	.353
2	.429	.782
3	.027	.809
Makkovik		
	R-squared Values	
Axis	**Increment**	**Cumulative**
1	.169	.169
2	.182	.351
3	.166	.517



(a) Main Matrix (Cumulative r-squared: 0.518). Triangles represent the sample sites. Bi-plot line represents moss horizon.

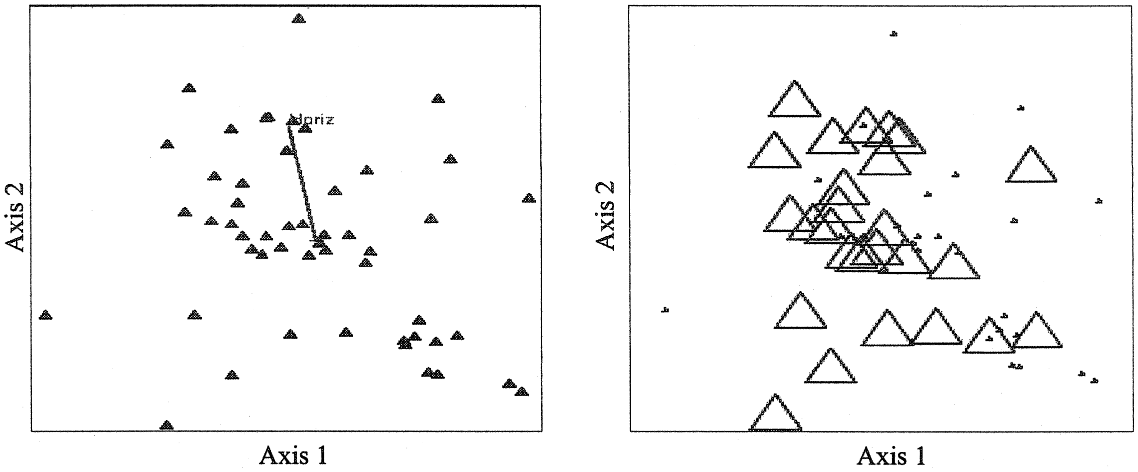
(b) Overlay of Seasonality Matrix on Main Matrix (Axis 1: r=-0.149; Axis 3: r=0.264). Small triangles represent spring season, large triangles represent summer season.



(c) Overlay of Elevation Matrix on Main Matrix (Axis 1: r=-0.308; Axis 3: r=0.254). Small, medium and large triangles represent the low, medium and high elevations, respectively.

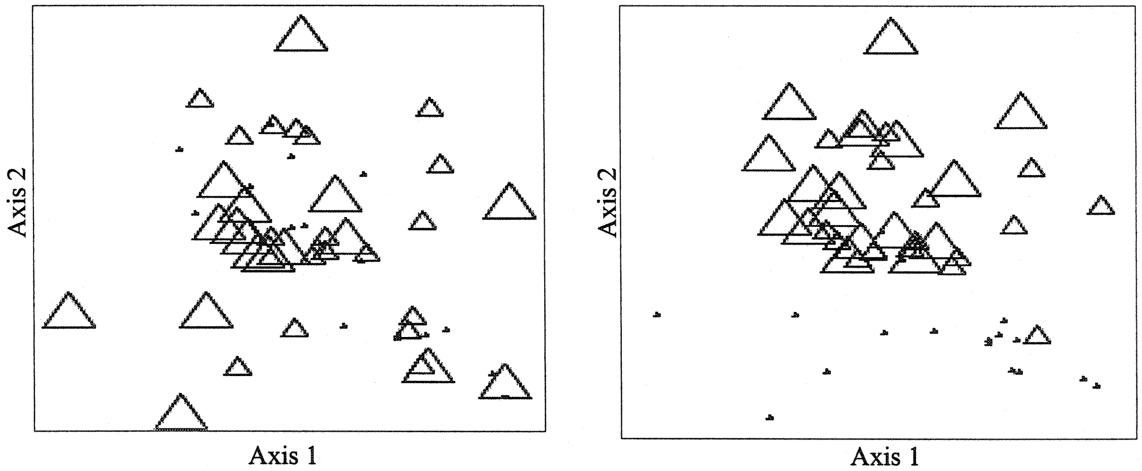
(d) Overlay of Horizon Matrix on Main Matrix (Axis 1: r=0.599; Axis 3: r=0.047). Small, medium and large triangles represent the A, B and C-moss horizons, respectively.

Figure 3.1. The effects of seasonality, elevation and horizon depth on nematode distribution in Nain, Labrador (June and August, 2002).



(a) Main Matrix (Cumulative r-squared: 0.782). Triangles represent the sample sites. Bi-plot line represents horizon.

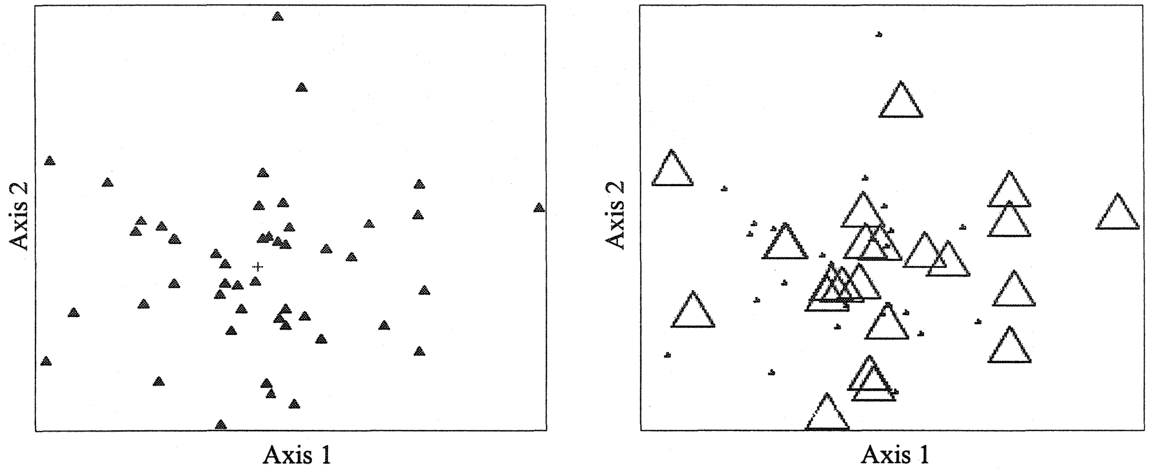
(b) Overlay of Seasonality Matrix on Main Matrix (Axis 1: r=-0.420; Axis 2: r=0.105). Small triangles represent spring season, large triangles represent summer season.



(c) Overlay of Elevation Matrix on Main Matrix (Axis 1: r=-0.206; Axis 2: r=-0.006). Small, medium and large triangles represent the low, medium and high elevations, respectively.

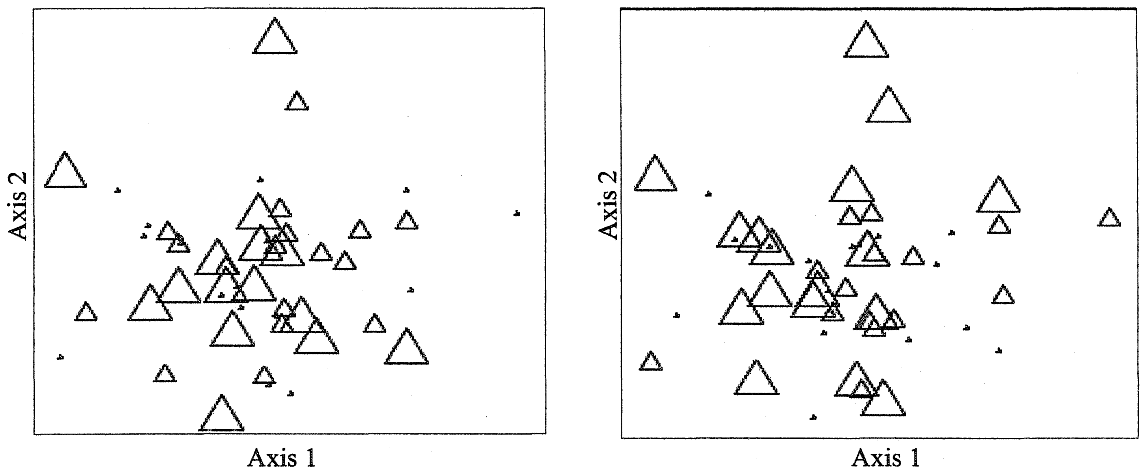
(d) Overlay of Horizon Matrix on Main Matrix (Axis 1: r=-0.291; Axis 2: r=0.746). Small, medium and large triangles represent the A, B and C-moss horizons, respectively.

Figure 3.2. The effects of seasonality, elevation and horizon depth on nematode distribution in Hopedale, Labrador (June and August, 2002).



(a) Main Matrix (Cumulative r-squared: 0.351). Triangles represent the sample sites.

(b) Overlay of Seasonality Matrix on Main Matrix (Axis 1: r=0.226; Axis 2: r=0.000). Small triangles represent spring season, large triangles represent summer season.



(c) Overlay of Elevation Matrix on Main Matrix (Axis 1: r=-0.041; Axis 2: r=0.009). Small, medium and large triangles represent the low, medium and high elevations, respectively.

(d) Overlay of Horizon Matrix on Main Matrix (Axis 1: r=-0.122; Axis 2: r=0.173). Small, medium and large triangles represent the A, B and C-moss horizons, respectively.

Figure 3.3. The effects of seasonality, elevation and horizon depth on nematode distribution in Makkovik, Labrador (June and August, 2002).

elevation and horizon are given for each town. The Pearson values (r) are provided below the figures to indicate the strength of each environmental gradient to the axes of the main matrix.

Species and Corresponding Pearson Values (r) - Table 3.9 gives the Pearson coefficients (r) which show the degree to which each species accounts for the variability represented by the 2 most significant axes. Highly negative or positive Pearson values (max +/- 1) indicate those species that are found at the ends of the gradient/axis to which they correspond and are those species that account for the greatest amount of variability of the particular axis/gradient. Pearson values closer to zero indicate those species that do not contribute greatly to the variation of an axis/gradient and may indicate that the gradient being measured has little affect upon the species' distribution or that too few specimens of that species were available. For example, the nematodes that explained the greatest amount of variation in the dataset were *Aphelenchoides* (Nain, axis 1), *Prismatolaimus* (Nain, axis 3), *Eudorylaimus* (Hopedale, axis 1), *Plectus* (Hopedale, axis 2), *Achromadora* (Makkovik, axis 1) and *Monhystera* 1 (Makkovik, axis 2).

Latitudinal Trends in Nematode Distribution - Quantitative analysis did not reveal any significant trends between nematode species and latitude of sample sites. This does not mean that latitudinal trends did not exist for nematode distribution; it may have been that there was too much interrelation between the environmental variables (i.e. the grouping/independent variables are not mutually exclusive). Instead, Table 3.10 shows total species richness and abundance within each town (elevations and horizons grouped together) during both 2002 sampling seasons to investigate trends that may indicate a latitudinal relationship.

Table 3.9. Nematode genera and corresponding Pearson values (r) for axes accounting for most variability in each study town in northern, coastal Labrador (June and August, 2002).

	Nain		Hopedale		Makkovik	
Genus	Axis 1	Axis 3	Axis 1	Axis 2	Axis 1	Axis 2
Achromadora	0.096	0.264	0.310	-0.241	0.556	0.252
Acrobeloides	-0.175	-0.097				
Aphelenchoides	-0.697	0.266	-0.263	-0.391	0.252	-0.153
Bunonema	-0.136	0.192	0.286	-0.229	0.320	0.125
Daptonema			0.310	-0.262		
Eudorylaimus	0.275	0.284	0.731	-0.243	0.313	-0.182
Euteratocephalus	0.214	0.289	0.415	-0.276	0.329	-0.204
Hemicycliophora					-0.251	-0.109
Labronema	0.000	-0.163	0.203	0.107	0.294	0.069
Monhystera 1	-0.067	0.195	0.440	-0.455	0.384	-0.296
Monhystera 2			0.018	-0.236	0.522	0.185
Mononchus	0.253	-0.093	-0.069	0.078	0.193	-0.083
Ogma			-0.178	0.209	-0.141	0.172
Plectus	-0.584	0.273	0.540	-0.556	0.527	0.081
Prismatolaimus	0.306	0.507	0.220	-0.109	0.291	-0.119
Teratocephalus	0.143	0.137	-0.048	-0.218	0.132	0.012
Tylencholaimus	0.111	0.165	-0.195	-0.392	0.219	0.072
Tylenchus 1			0.124	-0.160	-0.051	-0.096
Tylenchus 2	0.147	0.432	0.139	-0.124	0.175	0.240
Wilsonema	0.239	0.336	0.020	-0.006	0.100	-0.075
Zeldia	0.175	0.149	0.196	-0.147		

Table 3.10. Nematode genera richness and abundance relative to latitude for 3 towns in northern, coastal Labrador (June and August, 2002).

	June – 2002			August - 2002		
Genus	Nain	Hopedale	Makkovik	Nain	Hopedale	Makkovik
Achromadora	22	50	43	53	132	123
Acrobeloides	51					
Aphelenchoides	78	13		314	371	31
Bunonema	13	10		31		3
Daptonema		17				
Eudorylaimus	95	241	72	93	47	40
Euteratocephalus	2	48	14	8	45	15
Hemicycliophora			8			
Labronema	13	3	3	5		5
Monhystera 1	27	255	58	16	57	39
Monhystera 2			3		13	17
Mononchus		5	1	6		4
Ogma			2		2	8
Plectus	151	1331	57	238	513	213
Prismatolaimus	72	75	9	309	18	14
Teratocephalus	20	21	6	53	53	12
Tylencholaimus			2	37	4	9
Tylenchus 1		1	12			
Tylenchus 2	34	16	1	210	3	1
Wilsonema		14	2	25	8	1
Zeldia				2	2	
Total Abundance	578	2100	293	1441	1268	535
Total Species	12	15	16	15	14	16

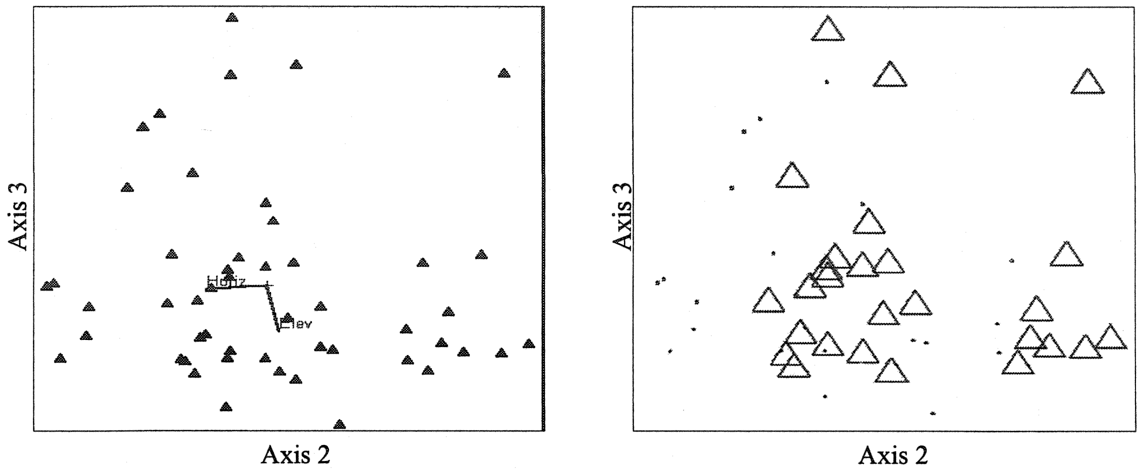
3.2.2.2 Tardigrades and Oribatid Mites - There were far fewer tardigrade and mite specimens than nematodes within the samples. To analyse these groups on their own would have done little to determine the ecological trends associated with their distribution, as low specimen representation would often result in empty variables. Thus, the tardigrades and oribatids were merged with the nematodes so that the highly quantitative weight of the nematode data would provide the structure needed to explain the ecological trends of the less abundant tardigrade and oribatid fauna. However, while strengthening the tardigrade and oribatid data the trends of the nematode dataset may have been slightly "diluted". For this reason the nematodes were analysed separately in the preceding section.

Non-Metric Multidimensional Scaling (NMS) was conducted for each town separately to determine any distributional effects that season, elevation and horizon have on tardigrade and oribatid populations. There was too much interaction of conflicting variables when analysis was run on the 3 towns together. The R-squared values for significance of each axis as well as selected graphical output of the NMS analysis detailing the relationship of each town's dataset to the 3 environmental variables are given below.

R-squared Values - The R-squared values for the entire bryofaunal dataset are given in Table 3.11, which indicate the amount of variability explained by each axis. The 2 axes that explain the greatest amount of variation are represented graphically in Figures 3.4, 3.5 and 3.6. The r-squared values represent the coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional

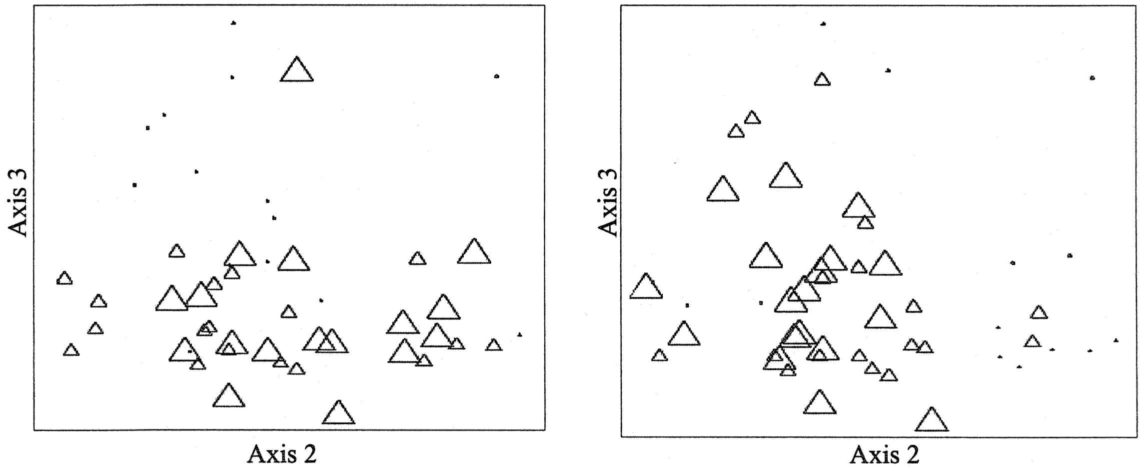
Table 3.11. R-squared values for the 3 axes that explain the greatest amount of variability in the bryofaunal dataset (June and August, 2002).

Nain		
	R-squared Values	
Axis	**Increment**	**Cumulative**
1	.190	.190
2	.208	.398
3	.226	.625
Hopedale		
	R-squared Values	
Axis	**Increment**	**Cumulative**
1	.241	.241
2	.309	.550
3	.282	.832
Makkovik		
	R-squared Values	
Axis	**Increment**	**Cumulative**
1	.139	.139
2	.197	.336
3	.207	.543



(a) Main Matrix (Cumulative r-squared: 0.434). Triangles represent the sample sites. Bi-plot lines represent horizon (axis 2) and elevation (axis 3).

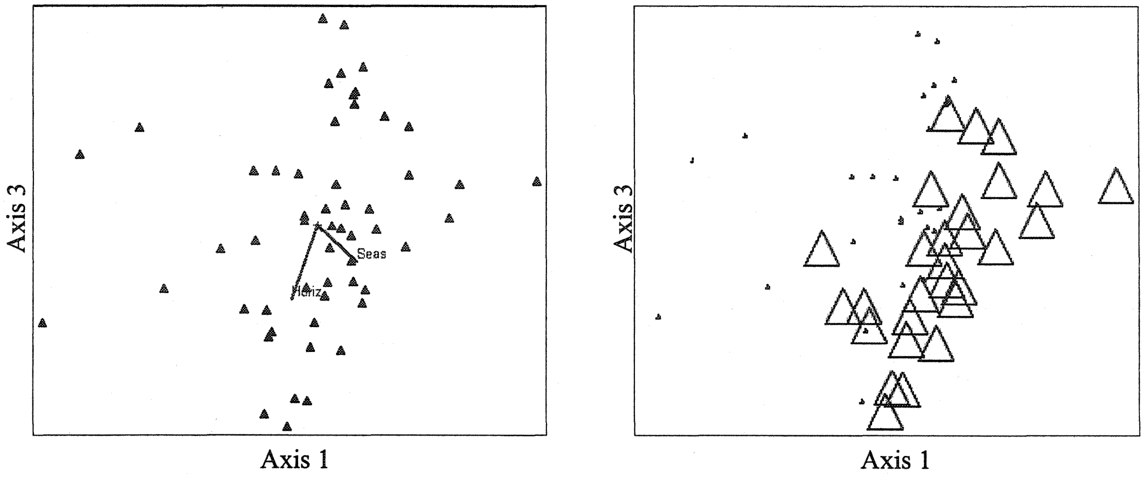
(b) Overlay of Seasonality Matrix on Main Matrix (Axis 2: r=0.384; Axis 3: r=0.062). Small triangles represent spring season, large triangles represent summer season.



(c) Overlay of Elevation Matrix on Main Matrix (Axis 2: r=0.212; Axis 3: r=-0.477). Small, medium and large triangles represent the low, medium and high elevations, respectively.

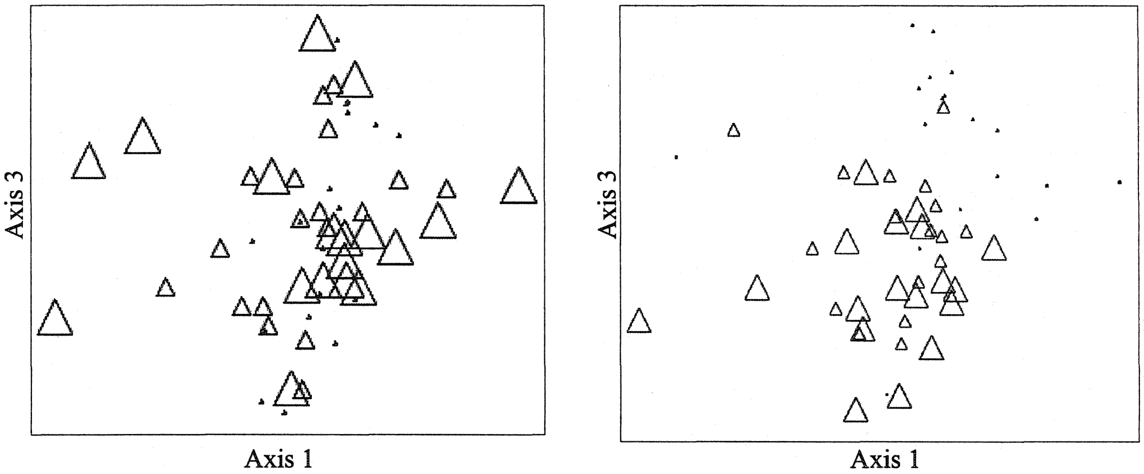
(d) Overlay of Horizon Matrix on Main Matrix (Axis 2: r=-0.476; Axis 3: r=-0.142). Small, medium and large triangles represent the A, B and C-moss horizons, respectively.

Figure 3.4. The effects of seasonality, elevation and horizon depth on bryofaunal distribution in Nain, Labrador (June and August, 2002).



(a) Main Matrix (Cumulative r-squared: 0.523). Triangles represent the sample sites. Bi-plot lines represent season (axis 1) and horizon (axis 3).

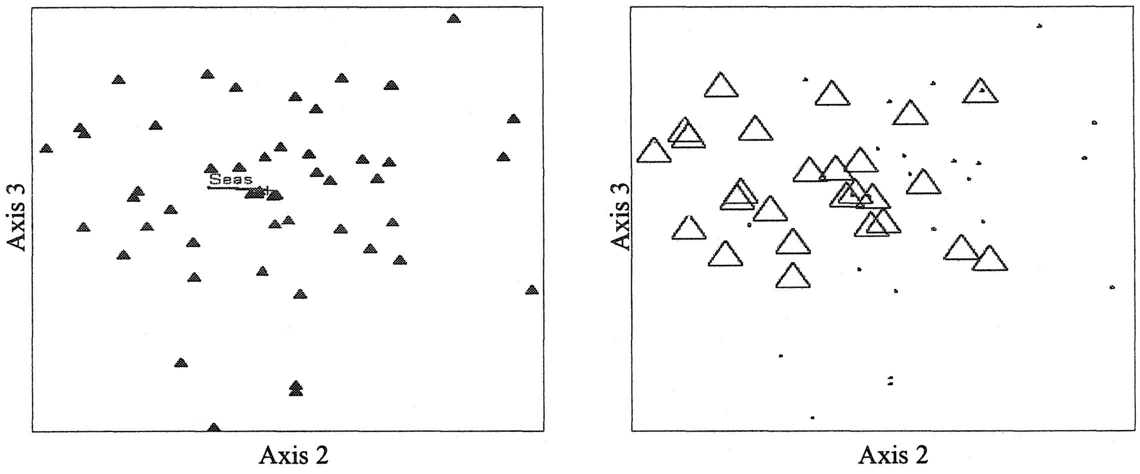
(b) Overlay of Seasonality Matrix on Main Matrix (Axis 1: r=0.402; Axis 3: r=-0.383). Small triangles represent spring season, large triangles represent summer season.



(c) Overlay of Elevation Matrix on Main Matrix (Axis 1: r=-0.069; Axis 3: r=0.024). Small, medium and large triangles represent the low, medium and high elevations, respectively.

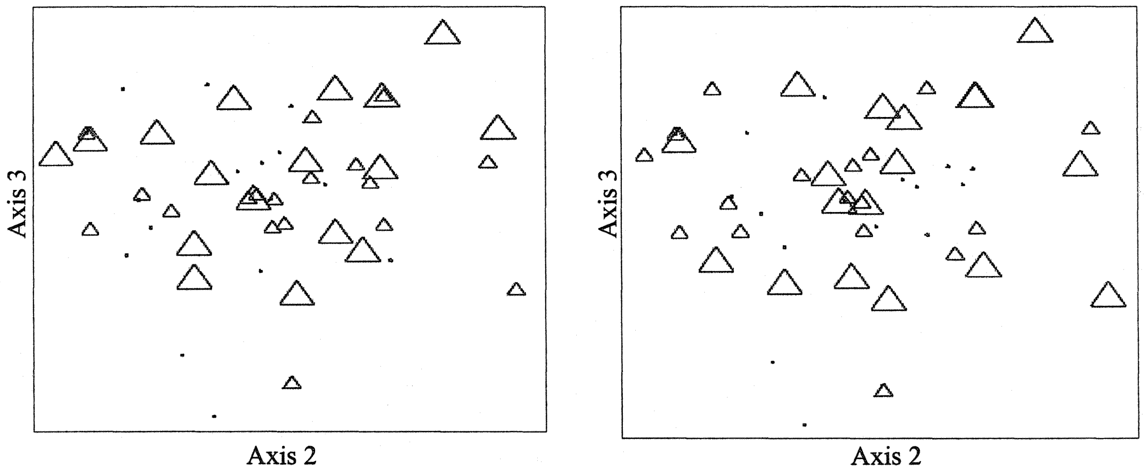
(d) Overlay of Horizon Matrix on Main Matrix (Axis 1: r=-0.319; Axis 3: r=-0.547). Small, medium and large triangles represent the A, B and C-moss horizons, respectively.

Figure 3.5. The effects of seasonality, elevation and horizon depth on bryofaunal distribution in Hopedale, Labrador (June and August, 2002).



(a) Main Matrix (Cumulative r-squared: 0.404). Triangles represent the sample sites. Bi-plot line represents season.

(b) Overlay of Seasonality Matrix on Main Matrix (Axis 2: r=-0.449; Axis 3: r=0.117). Small triangles represent spring season, large triangles represent summer season.



(c) Overlay of Elevation Matrix on Main Matrix (Axis 2: r=0.193; Axis 3: r=0.237). Small, medium and large triangles represent the low, medium and high elevations, respectively.

(d) Overlay of Horizon Matrix on Main Matrix (Axis 2: r=0.192; Axis 3: r=0.201). Small, medium and large triangles represent the A, B and C-moss horizons, respectively.

Figure 3.6. The effects of seasonality, elevation and horizon depth on bryofaunal distribution in Makkovik, Labrador (June and August, 2002).

space (Increment and cumulative r-squared were adjusted for any lack of orthogonality of axes)(McCune and Mefford, 1999).

Main Matrix and Overlays of Environmental Gradients (Season, Elevation and Horizon) - Figures 3.4, 3.5 and 3.6 are selected graphical results of the NMS analysis showing the correlation of seasonality, elevation and horizon depth with tardigrade and oribatid distribution for each town. Figures 3.4(a), 3.5(a) and 3.6(a) are main matrix plots of the study sites with respect to the 2 axes that explain the largest amount of variation in the dataset (largest r-squared values). Bi-plot (joint plot) lines originating from the centroid of each graph show the relationship between the environmental variables and ordination scores. The angle and length of the line indicate the direction and strength of the relationship. The longer the bi-plot line, the stronger the relationship of the environmental gradient to the dataset.

Figures 3.4(b)(c)(d), 3.5(b)(c)(d) and 3.6(b)(c)(d) are overlays of the environmental gradients on the main matrices for each town. Overlays of season, elevation and horizon are given for each town. The Pearson values (r) are provided below the figures to indicate the strength of each environmental gradient to the axes of the main matrix.

Species and Corresponding Pearson Values (r) - Table 3.12 gives the Pearson coefficients (r) which show the degree to which each species accounts for the variability represented by the 2 most significant axes (see section 3.2.2.1 for more information on Pearson Values). For example, the tardigrades that explained the greatest amount of variation in the dataset were *M. hufelandi* (Nain, axis 2 and 3; Hopedale, axis 3), *M. echinogenitus* (Hopedale, axis 1; Makkovik, axis 2) and *D. recamieri* (Makkovik, axis 3).

Table 3.12. Tardigrade species and oribatid mite genera with corresponding Pearson values (r) for axes accounting for the most variability in each study town in northern, coastal Labrador (June and August, 2002).

	Nain		Hopedale		Makkovik	
Species	Axis 2	Axis 3	Axis 1	Axis 3	Axis 2	Axis 3
D. nodulosum	-0.034	0.044				
D. pingue			0.192	0.245	-0.212	-0.007
D. ramazzotti	-0.096	-0.172	0.053	0.051		
D. recamieri					0.161	-0.116
D. scoticum			0.084	-0.027	-0.261	-0.096
Echiniscus sp.			-0.071	0.077		
H. convergens	-0.096	-0.113			0.059	0.030
M. echinogenitus			0.260	0.222	-0.351	-0.044
M. harmsworthi	0.047	-0.107	0.007	-0.089	-0.114	0.054
M. hufelandi	-0.163	0.465	0.134	0.426	0.207	0.022
Mesocrista spitzbergense	-0.008	-0.144	0.062	0.170	-0.226	-0.062
Minibiotus intermedius	-0.034	0.044	0.153	0.220		
Oribatid Mites	-0.242	0.094	0.094	0.160	-0.336	0.109

Latitudinal Trends in Tardigrade and Oribatid Mite Distribution – As was the case with the nematodes, quantitative analysis did not reveal any significant trends between tardigrade and oribatid species and latitude of sample sites. Instead, Table 3.13 shows total species richness and abundance within each town during both 2002 sampling seasons to investigate trends that may indicate a latitudinal relationship.

3.3 Species Lists – Canadian Distributions and Trophic Habits

3.3.1 Nematodes

CHROMADORIDA
Cyantholaimidae
Achromadora Cobb, 1913

- Members of the genus *Achromadora* have been found in fresh water and moist soils and are thought to feed upon algae and diatoms (Goodey, 1951). Desiccation tolerance is unknown for this group. *Achromadora* has been recorded for Canada within British Columbia (Panesar *et al.*, 2000) and Newfoundland (Cuthbert, 1990).

ARAEOLAIMIDA
Plectidae
Plectus Bastian, 1865

- *Plectus* is known to be a widespread genus inhabiting soil and freshwater systems as well as mosses and lichens (Goodey, 1951; Nicholas, 1975). *Plectus* has been recorded for Canada within British Columbia (Panesar *et al.*, 2000) and Newfoundland (Cuthbert, 1990). This genus is well adapted to tolerating desiccation and is thought to feed upon bacteria and small organic particles (Goodey, 1951; Bassus, 1962).

Wilsonema Cobb, 1913

- Little is known regarding the members of this genus. All the species tend to be relatively small in size and typically found within the soil although some specimens have also been identified from lichens (Goodey, 1963). *Wilsonema* has been recorded for Canada within British Columbia (Panesar *et al.*, 2000) and Newfoundland (Cuthbert, 1990). Feeding habits are unknown for this group (Goodey, 1951).

Teratocephalidae
Euteratocephalus Andrassy, 1958

- Members of the genus *Euteratocephalus* occur in both freshwater and soil (Goodey, 1951). *Euteratocephalus* has been recorded for Canada within Newfoundland (Cuthbert, 1990). Goodey (1963) indicates that this genus

Table 3.13. Tardigrade species and oribatid mite genera richness and abundance relative to latitude in 3 towns of northern, coastal Labrador (June and August, 2002).

	June – 2002			August - 2002		
Tardigrade Species	Nain	Hopedale	Makkovik	Nain	Hopedale	Makkovik
D. nodulosum				4		
D. pingue					20	4
D. scoticum			1		2	7
D. ramazzotti	1			1	2	
D. recameri						2
Echiniscus sp.		4				
H. convergens			1	2		
M. echinogenitus		4			28	17
M. hufelandii	26	11	3	24	9	
M. harmsworthi	6	5		1	8	4
Mesocrista spitzbergense				5	1	1
Minibiotus intermedius				1	2	
Total Abundance	**33**	**24**	**5**	**38**	**72**	**35**
Total Species	**3**	**4**	**3**	**7**	**8**	**6**
Oribatid Mite Genera	Nain	Hopedale	Makkovik	Nain	Hopedale	Makkovik
Brachychthonius		1				
Camisia			2			
Cultroribula		1	1			
Epidamaeus				2		
Fucozetes	2	23	8	2	20	17
Limnozetes		6			3	5
Mycobates		5	1		18	11
Nothrus		2				1
Oppiella	10			9	1	1
Rhysotritia						1
Sellnickochthonius	2		1	3		5
Thrypochthonius					1	
Trimalaconothrus						1
Xenillus		1			1	
Total Abundance	**14**	**39**	**13**	**16**	**44**	**42**
Total Genera	**3**	**7**	**5**	**4**	**6**	**8**

is fairly uncommon and little has been determined regarding its feeding habits.

Teratocephalus de Man, 1876

- Members of the genus *Teratocephalus* occur in both freshwater and soil (Goodey, 1951).). *Teratocephalus* has been recorded for Canada within British Columbia (Panesar *et al.*, 2000). Goodey (1963) indicates that this genus is fairly uncommon and little has been determined regarding its feeding habits, however Overgaard-Nielsen (1948) states that the species *Teratocephalus terrestris* is a bacterial feeder.

MONHYSTERIDA

Monhysteridae

Monhystera Bastian, 1865

- Members of the genus *Monhystera* have been recorded from freshwater and soil environments (Goodey, 1951). *Monhystera* has been recorded for Canada within British Columbia (Panesar *et al.*, 2000). Species within this genus may feed upon vegetation (Goodey, 1963) and bacteria (Bassus, 1962) Anhydrobiotic ability has not been determined. Two unidentified species of *Monhystera* were found in this study.

Xylalidae

Daptonema Cobb, 1920

- Members of this genus are typically defined as free-living, marine nematodes (Platt and Warwick, 1988). No further information is available for this genus regarding habitat, distribution and trophic habits.

Steineria Micoletzky, 1922

- Members of this genus are typically defined as free-living, marine nematodes (Platt and Warwick, 1988). No further information is available for this genus regarding habitat, distribution and trophic habits.

ENOPLIDA

Prismatolaimidae

Prismatolaimus de Man, 1880

- *Prismatolaimus* has been recorded from freshwater and damp soils (Goodey, 1951). *Prismatolaimus* has been recorded for Canada within British Columbia (Panesar *et al.*, 2000) and Newfoundland (Cuthbert, 1990). Because *Prismatolaimus* species tend to be found in moist environments its desiccation tolerance is probably lower than others such as *Plectus* (Hyman, 1951). Feeding habits for this genus are unknown.

DORYLAIMIDA

Dorylaimidae

Eudorylaimus Andrassy, 1959

- Species of *Eudorylaimus* have been collected from a wide range of habitats and are believed to be relatively cosmopolitan (Goodey, 1963). *Eudorylaimus* has been recorded for Canada within Newfoundland (Cuthbert, 1990). Some species have been observed feeding on mite eggs, algae, protozoans and fungi (Goodey, 1963). Anhydrobiotic ability of this group has not been determined.

Labronema Thorne, 1939

- The genus *Labronema* has been collected from mosses and soil surrounding plant roots (Goodey, 1951). *Labronema* has been recorded for Canada within British Columbia (Panesar *et al.*, 2000). Many species are predaceous on other nematodes while others feed upon algae and mosses (Goodey, 1951). Little is known about the desiccation tolerance of this genus, however its close relative *Dorylaimus* is thought to have a low desiccation tolerance (Overgaard-Neilsen, 1948).

Tylencholaimus de Man, 1876

- Members of the genus *Tylencholaimus* inhabit *Sphagnum* sp. and other mosses or soil around the roots of plants (Goodey, 1963). *Tylencholaimus* has been recorded for Canada within British Columbia (Panesar *et al.*, 2000) and Newfoundland (Cuthbert, 1990). Feeding habits are unknown.

MONONCHIDA

Mononchidae

Mononchus Bastian, 1865

- The genus *Mononchus* contains carnivorous species found in soil, moss and freshwater environments (Goodey, 1951; Hyman, 1951; Bassus, 1962). *Mononchus* has been recorded for Canada in British Columbia (Panesar *et al.*, 2000) and Newfoundland (Cuthbert, 1990). The feeding habits of this genus include protozoans, nematodes, rotifers, tardigrades and small oligochaetes. Hyman (1951) listed *Mononchus* as one of the genera characteristic of desiccation-prone moss environments.

Prionchulus (Cobb, 1916) Wu & Hoeppli, 1929

- Like the genus *Mononchus*, *Prionchulus* contains carnivorous species found in soil, moss and freshwater environments (Goodey, 1951; Hyman, 1951; Bassus, 1962). *Prionchulus* has been recorded for Canada in British Columbia (Panesar *et al.*, 2000) and Newfoundland (Cuthbert, 1990). The feeding habits of this genus include protozoans, nematodes, rotifers, tardigrades and small oligochaetes. It is unknown if this genus also shares the high desiccation tolerance of *Mononchus*.

TYLENCHIDA

Aphelenchoididae

Aphelenchoides Fischer, 1894

- Members of the genus *Aphelenchoides* are very widespread and occur in a variety of habitats including soil, litter and mosses and many species are known to be plant and insect parasites (Goodey, 1963). *Aphelenchoides* has been recorded for Canada in British Columbia (Panesar *et al.*, 2000) and Newfoundland (Cuthbert, 1990). Some free-living and saprophagous forms feed upon fungal hyphae while others prey upon other nematodes (Goodey, 1963; Bassus, 1962). The anhydrobiotic ability of

Aphelenchoides is unknown, however the close relative *Aphelenchus* is listed as characteristic of mosses prone to desiccation (Hyman, 1951).

Neotylenchidae

Ogma Southern, 1914

- *Ogma* (syn. *Criconema*) has been obtained from soil, leaf litter, sphagnum moss and often around the roots of plants. *Ogma* has been recorded for Canada within Newfoundland (Cuthbert, 1990). It is thought that members of this genus are primarily external parasites of plant roots (Goodey, 1963). Desiccation tolerance is unknown for this group.

Tylenchidae

Tylenchus Bastian, 1965

- Species occurring within the genus *Tylenchus* are widespread and abundant in both high and low elevations (Goodey, 1951). They have been regularly collected from soils and some have been found in mosses. *Tylenchus* has been recorded for Canada in British Columbia (Panesar *et al.*, 2000) and Newfoundland (Cuthbert, 1990). The feeding habits of *Tylenchus* are largely unknown but it has been determined that some feed on fungus, plant roots and mosses (Goodey, 1951; Bassus, 1962). Some studies on members within this genus have shown a very high tolerance of desiccation (Goodey, 1951). Two species of *Tylenchus* were found in this study.

Hemicycliophoroidea

Hemicycliophora de Man, 1921

- The genus *Hemicycliophora* is typically found in soils especially surrounding the roots of plants. *Hemicycliophora* has been recorded for Canada within Newfoundland (Cuthbert, 1990).Feeding habits are largely unknown (Goodey, 1963), however in a few cases it has been show that they are ectoparasites on plants (Meyl, 1955; Goodey, 1963; Cooper and Van Gundy, 1970).

RHABDITIDA

Cephalobidae

Acrobeloides (Cobb, 1924) Thorne, 1937

- The genus *Acrobeloides* is found mainly in soil but has also been found in moss (Goodey, 1951; Zullini and Peretti, 1986). *Acrobeloides* has been recorded for Canada within British Columbia (Panesar *et al.*, 2000) and Newfoundland (Cuthbert, 1990). Members of this genus are closely associated with and probably feed upon plant roots and decaying plant tissues (Goodey, 1963).

Zeldia Thorne, 1937

- The genus *Zeldia* is typically found within soils or decaying plant tissues. There is no record of *Zeldia* species for Canada. Members of this genus are saprophagous or microbivorous in feeding habit (Goodey, 1963).

Bunonematidae

Bunonema Jagerskiold, 1905

- The genus *Bunonema* has been frequently recorded within sphagnum and other mosses as well as rotting wood and other organic matter (Goodey, 1963). *Bunonema* has been recorded for Canada in British Columbia (Panesar *et al.*, 2000) and Newfoundland (Cuthbert, 1990). It is assumed that members within this genus feed upon fungal hyphae or bacteria (Sachs, 1949; Goodey, 1963). Anhydrobiotic abilities of this genus are unknown.

Rhabditidae

Rhabditis Dujardin, 1845

- Members of the genera *Rhabditis* feed upon bacteria and occur wherever this food source is plentiful (Goodey, 1963). Species from this group have been found in soils and mosses (Goodey, 1951). *Rhabditis* has been recorded for Canada in British Columbia (Panesar *et al.*, 2000).

Panagrolaimidae

Panagrolaimus Fuchs, 1930

- The members of the genus *Panagrolaimus* are typically saprophages and are found in soils, litter and decaying or partially decaying vegetable matter. Some species are also associated with the dauer larvae of beetles which often aid in the dissemination of the nematodes (Goodey, 1963). This genus is very widespread and at least 1 species (*Panagrolaimus rigidus*) is cosmopolitan in its distribution (Meyl, 1953). *Panagrolaimus* has been recorded for Canada in British Columbia (Panesar *et al.*, 2000).

3.3.2 Tardigrades

Heterotardigrade Species

ECHINISCOIDEA

Echiniscidae

Echiniscus wendti Richters, 1903

- This species is said to have a cosmopolitan geographic distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). *Echiscus wendti* has been recorded for Canada in British Columbia (Murray, 1910; Kathman and Dastych, 1990) and Newfoundland (Bateman and Collins, 2001).

Proechiniscus hanneae Petersen, 1951

- This species has been described as being distributed primarily within Greenland (McInnes, 1994). However, findings have also been recorded for Canada in Newfoundland (Bateman and Collins, 2001).

Eutardigrade Species

PARACHELA

Macrobiotidae

Macrobiotus echinogenitus Richters, 1904

- This species is described as having a cosmopolitan distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been recorded for Canada in British Columbia (Murray, 1910; Kathman, 1990), Ontario (Murray, 1910), and New Brunswick (Argue, 1971,1972, 1974).

Macrobiotus harmsworthi Murray, 1907

- This species is described as having a cosmopolitan distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). *M. harmsworthi* has been recorded for Canada in British Columbia (Kathman, 1990), The Northwest Territories (Van Rompu *et al.,* 1991), Ontario (Murray, 1906), NewBrunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001). *Macrobiotus harmsworthi* is a known predator of rotifers, nematodes and other tardigrades (Kinchin, 1994).

Macrobiotus c.f. *hufelandi* Shultze, 1833

- This species has been described as having a cosmopolitan distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been recorded for Canada in British Columbia (Richters, 1908; Murray, 1910; Kathman, 1990), Alberta (Murray, 1910), Ontario (Murray, 1910), Quebec (Iharos, 1973), New Brunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001). *Macrobiotus hufelandi* is a known predator of rotifers, nematodes and other tardigrades (Kinchin, 1994).

Minibiotus intermedius Plate, 1888

- This species is described as having a cosmopolitan distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been recorded for Canada in British Columbia (Kathman, 1990), Ontario (Murray, 1910), New Brunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001).

Calohypsibiidae

Calohypsibius ornatus Richters,1900

- This species is described as having a widespread distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been recorded for Canada in British Columbia (Kathman, 1990) and Newfoundland (Bateman and Collins, 2001).

Hypsibiidae

Hypsibius convergens Urbanowicz, 1925

- This species is described as having a cosmopolitan distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been recorded for Canada in British Columbia (Kathman, 1990), The Northwest Territories (Van Rompu *et al.*, 1991 and 1992), New Brunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001).

Hypsibius dujardini Doyere, 1840

- This species is described as having a cosmopolitan distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been recorded for Canada in the Northwest Territories (Van Rompu *et al.*, 1991, 1992), New

Brunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001).

Hypsibius microps Thulin, 1928

- This species is described as having a widespread distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been previously recorded for Canada only once, in Newfoundland (Bateman and Collins, 2001).

Diphascon nodulosum Ramazzotti, 1957

- This species has been described as having a distribution limited to North and Central America (McInnes, 1994). It has been recorded for Canada in British Columbia (Kathman, 1990), New Brunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001).

Diphascon pingue Marcus, 1936

- This species is described as having a cosmopolitan distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been recorded for Canada in British Columbia (Kathman, 1990), New Brunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001).

Diphascon ramazzottii Robotti, 1970

- This species has been described as having a distribution limited only to Europe (McInnes, 1994). It has only been previously recorded for Canada by 1 specimen in Newfoundland (Bateman and Collins, 2001).

Diphascon recamieri Richters, 1911

- This species is described as having a widespread distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been recorded for Canada in British Columbia (Kathman, 1990) and the Northwest Territories (Van Rompu *et al.*, 1992).

Diphascon scoticum Murray, 1905

- This species is described as having a cosmopolitan distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been recorded for Canada in British Columbia (Murray, 1910; Kathman, 1990), Alberta (Murray, 1910), New Brunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001).

Platicrista angustata Murray, 1905

- This species is described as having a widespread distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been recorded for Canada in New Brunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001).

Mesocrista spitzbergense Richters, 1903

- This species is described as having a distribution limited to Europe, Africa and North America (McInnes, 1994). It has been recorded for Canada in British Columbia (Kathman, 1990), New Brunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001).

APOCHELA

Milnesiidae

Milnesium tardigradum Doyere, 1840

- This species is described as having a cosmopolitan distribution (Ramazzotti and Maucci, 1983; McInnes, 1994). It has been recorded for Canada in British Columbia (Richters, 1908; Kathman, 1990), Ontario (Murray, 1910), Quebec (Iharos, 1973), New Brunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001). *Milnesium tardigradum* is a known predator of rotifers, nematodes and other tardigrades (Kinchin, 1994).

3.3.3 Bdelloid Rotifers

No specific trophic habits are known for these bdelloids.

BDELLOIDEA

Habrotrochidae

Habrotrocha lata lata Bryce, 1892
- This species has been recorded for Canada only from Newfoundland (Bateman, 1975).

Habrotrocha maculata Murray, 1911
- This species has been recorded for Canada only from Ontario (Murray, 1911).

Philodinidae

Macrotrachela aculata Murray, 1911
- This species has not previously been recorded within Canada.

Macrotrachela habita Bryce, 1894
- This species has been recorded for Canada only from Newfoundland (Bateman, 1975).

Macrotrachela multispinosa Thompson, 1892
- This species has been recorded for Canada only from Newfoundland (Bateman, 1975).

Macrotrachela plicata hirundinella Murray, 1909
- This species has been recorded for Canada only from Newfoundland (Bateman, 1975).

Macrotrachela punctata Murray, 1911
- This species has not previously been recorded within Canada.

Adinetidae

Adineta gracilis Janson, 1893
- This species has been recorded for Canada in British Columbia, the Rocky Mountains and Ontario by Murray (1911) and Newfoundland by Bateman (1975).

Adineta steineri Bartos, 1951
- This species has been recorded for North America only from Newfoundland (Bateman, 1975).

Adineta vaga Bryce, 1893
- This species has been recorded in Canada for British Columbia (Murray, 1911) and Ontario (Murray, 1911; Nogrady, 1989).

3.3.4 Oribatid Mites

No specific trophic habits are known for these oribatid mites other than they are likely bryophagous, bactivorous or fungivorous (Gerson, 1969; Kinchin, 1990).

BRACHYPYLINA

Astegistidae

Cultroribula Berlese, 1908

- This genus has been recorded for Canada in the Northwest Territories (Hammer, 1952; Behan, 1978), Yukon Territory (Behan, 1978), Quebec (Marshall, 1968; Smith, 1978), Nova Scotia (Behan-Pelletier, 1987) and Newfoundland (Dwyer *et al.*, 1998)

Ceratozetidae

Fuscozetes Sellnick, 1928

- This genus has been recorded for Canada in the Northwest Territories (Hammer, 1952; Behan, 1978), Yukon Territory (Behan, 1978), Manitoba (Oswald and Minty, 1970), Ontario (Jacot, 1935), Quebec (Marshall, 1968) and Newfoundland (Behan-Pelletier, 1985).

Damaeidae

Epidamaeus Bulanova-Zachvatkina, 1957

- This genus has been recorded for Canada in British Columbia (Behan-Pelletier and Norton, 1985), Alberta (Powell and Skaley, 1975), the Northwest Territories (Hammer, 1952; Behan, 1978), Yukon Territory (Behan, 1978; Bulanova-Zachvatkina, 1979), Manitoba (Oswald and Minty, 1971), Ontario (Banks, 1909; Norton, 1979), Quebec (Behan-Pelletier and Norton, 1983), New Brunswick (Pielou and Verma, 1968), Nova Scotia (Behan-Pelletier, 1987) and Newfoundland (Behan, 1978; Dwyer *et al.*, 1998).

Limnozetidae

Limnozetes Hull, 1916

- This genus has been recorded for Canada in the Northwest Territories (Behan, 1978), Yukon Territory (Behan, 1978), Manitoba (Hammer, 1952) and Nova Scotia (Behan-Pelletier, 1987).

Mycobatidae

Mycobates Hull, 1916

- This genus has been recorded for Canada in the Northwest Territories (Hammer, 1952; Behan, 1978), Yukon Territory (Behan, 1978) Manitoba (Hammer, 1952), Quebec (Behan, 1978), Nova Scotia (Behan-Pelletier, 1987) and Newfoundland (Behan, 1978; Dwyer *et al.*, 1998).

Oppiidae

Opiella Jacot, 1937

- This genus has been recorded for Canada in Alberta (Hammer, 1952), the North West Territories (Hammer, 1952), Yukon Territory (Behan, 1978), Manitoba (Hammer, 1952) Quebec (Marshall, 1968), Nova Scotia (Behan-Pelletier, 1987) and Newfoundland (Behan, 1978; Dwyer *et al.*, 1998).

Xenillidae

Xenillus Robineau-Desvoidy, 1839

- One unidentified group of this genera has been recorded for Canada in Manitoba (Oswald and Minty, 1970).

ENARTHRONOTA

Brachychthoniidae

Brachychthonius Berlese, 1910

- This genus has been recorded for Canada in British Columbia (Marshall, 1979), The Northwest Territories (Behan, 1978), Ontario (Marshall, 1972) and Quebec (Marshall, 1968; Smith, 1978).

Sellnickochthonius Krivoluckij, 1964

- This genus has been recorded for Canada in Alberta (Hammer, 1952), the Northwest Territories (Hammer, 1952; Behan, 1978), Quebec (Reeves and Marshall, 1971) and Nova Scotia (Behan-Pelletier, 1987).

DESMONOMATA

Camisiidae

Camisia von Heyden, 1826

- This genus has been recorded for Canada in Alberta (Hammer, 1952; Powell and Skaley, 1975), the Northwest Territories (Hammer, 1952; Behan, 1978), Yukon Territory (Behan, 1978), Manitoba (Hammer, 1952), Quebec (Behan, 1978), New Brunswick (Pielou and Verma, 1968), Nova Scotia (Behan-Pelletier, 1987) and Newfoundland (Behan, 1978; Dwyer *et al.*, 1998).

Malaconothridae

Trimalaconothrus Berlese, 1916

- This genus has been recorded for Canada in the Northwest Territories (Hammer, 1952; Behan, 1978), Manitoba (Conroy, 1974), Quebec (Marshall, 1968), Nova Scotia (Behan-Pelletier, 1987) and Newfoundland (Behan, 1978).

Nothridae

Nothrus C.L. Koch, 1835

- This genus has been recorded for Canada in the Northwest Territories (Hammer, 1952; Behan, 1978), Yukon Territory (Behan, 1978), Manitoba (Hammer, 1952), Ontario (Marshall, 1972; Freitag and Ryder, 1973), Quebec (Smith, 1978; Forest *et al.*, 1982), Nova Scotia (Behan-Pelletier, 1987) and Newfoundland (Behan, 1978; Dwyer *et al.*, 1998).

Trhypochthoniidae

Trhypochthonius Berlese, 1904

- This genus has been recorded for Canada in British Columbia (Marshall, 1979), the Northwest territories (Hammer, 1952), Yukon Territory (Behan, 1978), Manitoba (Hammer, 1952; Oswald and Minty, 1970), Quebec (Marshall, 1968; Behan, 1978) and Nova Scotia (Behan-Pelletier, 1987).

MIXONOMATA
Euphthiracaridae

Rhysotritia Markel and Meyer, 1959

- This genus has been recorded for Canada in the Northwest Territories (Hammer, 1952), Manitoba (Hammer, 1952; Oswald and Minty, 1970) Quebec (Behan, 1978), Nova Scotia (Behan-Pelletier, 1987) and Newfoundland (Behan, 1978; Dwyer *et al.*, 1998).

3.3.5 Collembolans

COLLEMBOLA
Isotomidae

Folsomia Willem, 1902

- This genus has been recorded for Canada in the Northwest Territories (Toda and Tanno, 1983). No specific trophic habits are known for the members within this genus other than they likely feed upon moss, algae, fungal hyphae, bacteria or decaying plant matter (Petersen and Luxton, 1982; Lartey *et al.*, 1989; Kinchin, 1990; Varga *et al.*, 2002).

Chapter 4

Discussion

4.1 Species Identified and Abundances Relative to 2001 and 2002 Studies.

Thirteen of the 23 nematode genera identified were common to both the 2001 and 2002 study years. The genera *Plectus, Eudorylaimus* and *Prismatolaimus* dominated the specimens of both studies. Ten of the 18 tardigrade species identified were common to both years and *M. hufelandi* always dominated in abundance. *Diphascon ramazzottii* was also highly abundant but only in the 2001 study while *M. echinogenitus, D. pingue* and *M. harmsworthi* were only abundant in the 2002 study. All 3 of the bdelloid rotifer genera were common between the 2001 and 2002 collections. The genus *Macrotrachela* was the most abundant of the genera followed by *Habrotrocha* and *Adineta*. In addition to the oribatid mites identified from the 2001 study, the 2002 study recorded 10 further genera. A large proportion of tardigrade eggs, belonging to the species *M. echinogenitus* was found in August of 2002. The genera that dominated the mite specimens were *Fuscozetes*, *Mycobates*, *Oppiella*, *Limnozetes* and *Sellnickochthonius*. Finally, 2 collembolan families were identified during the study, Poduroidea and Isotomidae. The genus *Folsomia* (family Isotomidae) dominated the collembolan specimen set throughout both years.

A probable explanation for the high degree of species and abundance variation between study years is that the moss collected in 2001 was often from a more variable environment. For example, the 2001 samples were often of varying sizes taken from very wet moss mats of different species as compared to the less saturated moss cushions of 1 species collected during the 2002 studies.

4.2 Environmental Parameters

The effects of elevation, horizon depth, seasonality and latitude on bryofaunal distributions are discussed in the following section. However, before environmental parameters are considered the following must be noted.

First, the nematodes and mites were only identified to the genus level which may have slightly limited the accuracy of the analysis and the application of specific distributional trends for these animals. For example, in cases where a particularly abundant genus may be represented by large numbers of species, for example *Plectus* and *Aphelenchoides* which may represented by as many as 11 species each (Hanel, 1994, 1996; Ruess, 1995; Ruess and Funke, 1995), vastly different effects of environmental variables such as elevation or moss depth may have been masked when studied only at the genus level.

Second, many of the trends discussed in the study of variable environments on bryofaunal distributions relied on the data acquired from only 2 quantitative samplings. Although some very strong trends were found, it is important to acknowledge that these findings are quite preliminary and require further study to be verified.

Third, the rotifers and collembolans were left out of the analysis as were the oribatid mites from the 2001 study because far too few specimens were collected of each to be useful in assessing environmental trends on distribution. The relatively low abundance of these groups within the samples may have been a result of the sampling methods. For example, larger moss samples may have been required to procure greater numbers of the larger bryofauna (mites and collembolans) as densities of the larger organisms cannot reach that of the smaller meiofaunal groups in moss samples of the same size. The bdelloid rotifers were a difficult group to work with in the laboratory as identification is largely based on features only visible in living specimens (Bateman, 1970). Therefore, delays between collection and identification alone may have caused high mortality and relatively low representation of bdelloids within the samples.

4.2.1 Elevation

It was often the case that elevation and horizon depth produced the most significant effects on faunal distribution in Nain but were not as strong in Hopedale or Makkovik. This was likely due to the much greater total height of the sample hill and the greater distances between successive sampling altitudes (Figure 2.3).

4.2.1.1 Nematodes – No elevational relationship existed for total nematode abundance and species richness in Nain and Hopedale during the preliminary investigation (October 2001). In Nain, however, 4 genera typical of each elevation did show some preliminary altitudinal trends. *Plectus* and *Panagrolaimus*, the 2 most abundant genera within the Nain samples, showed a net decrease in abundance with increased elevation while *Eudorylaimus*, the third most abundant genus, and *Aphelenchoides* showed a net increase in numbers with increased elevation (Table 3.1). In Hopedale, the most abundant genera (*Plectus, Monhystera, Eudorylaimus* and *Panagrolaimus*) showed no significant distribution patterns with elevation. *Eudorylaimus* numbers were greatest in the highest altitude but did not show a steady increase from low to high elevation. *Prismatolaimus* exhibited the only significant elevational relationship as it was abundant only within the low elevation (Table 3.1).

Some preliminary altitudinal trends were found in Makkovik. The greatest abundance of nematodes within Makkovik was found in the low and high elevations with the lowest elevation yielding the greatest genera richness. There was no significant relationship between any of the genera and elevation, except that *Plectus* and *Eudorylaimus,* the most abundant genera in the Makkovik samples, were found to be least numerous in the mid elevation (Table 3.1).

When the findings of each of the 3 northern towns were merged with respect to elevation a trend of decreasing genera richness with increasing altitude was evident. Table 3.2 showed that the low elevation yielded a total of 15 nematode genera, where the mid elevation yielded 10 genera and the high elevation produced 9 genera. Table 3.2 also suggests preliminary findings as to the optimal altitudinal habitats for each genus, which range from preference for low, medium or high altitudes and those that are cosmopolitan throughout all 3 elevations.

The quantitative study (June and August, 2002) of nematode communities with relation to an elevational gradient did not reveal any significant trends within the 2 towns of Hopedale and Makkovik. The Pearson values (r) for the relevant axes were quite small and a relatively low amount of variability in the dataset was explained by elevation in these towns. The nematode genera do not seem to be limited by the altitudinal gradients presented within these 2 towns.

In Nain however, nematode distribution showed a significant degree of variability explained by elevation. In this case, the axis that explained the most elevation linked variability was also the axis that corresponded to moss horizon. Both elevation and moss horizon were represented by fairly high Pearson values on the same axis and were thus mutually inclusive. One end of the gradient represented high elevation and upper moss horizons while the other extreme represented low elevations and deeper moss horizons (C-layer). This relationship was somewhat intuitive because species capable of inhabiting exposed, high elevations should also tend to exhibit higher desiccation tolerances while those species found in less exposed, low elevations would tend to be less tolerant of desiccation. Thus, the first axis in Figure 3.1 represented a desiccation tolerance gradient with those highly tolerant species (high elevation and moss horizon) occurring on the left end and those less tolerant species (low elevation and moss horizon) occurring on the right end.

Understanding the elevation/desiccation tolerance gradient being represented by axis 1 in Figure 3.1 allowed the specific genus relations to this gradient to be determined by examining the individual Pearson values (r) in Table 3.9. The major contributors to the variation of the axis, or those genera that are found at the extremes, were *Aphelenchoides, Plectus, Prismatolaimus* and *Eudorylaimus*. Of these genera *Aphelenchoides* and *Plectus* were the 2 that were most abundant at the high elevation/high horizon end of the gradient and were the genera that were most adapted to desiccation (as deemed by this study). This supports Hyman's (1951) findings that listed *Plectus* as characteristic of environmental extremes but negates the preliminary (October 2001) findings for this species which indicated a decreased abundance with increasing elevation. Conversely, *Prismatolaimus* and *Eudorylaimus* were the 2 genera that were most abundant at the low elevation/low horizon end of the gradient and were the genera that were least adapted to desiccation (as deemed by this study). The preliminary (October 2001) study also found *Prismatolaimus* to be abundant only within the low elevations, this supports the hypothesis that this species exhibits a generally low tolerance to desiccation. Powers *et al.* (1998) found *Eudorylaimus* to dominate relatively low elevations of ~180m and below in the Antarctic, which supports the 2002 quantitative study but contradicts the preliminary (October 2001) findings. Therefore it is highly likely that *Eudorylaimus* spp. are relatively intolerant of frequent desiccation which is characteristic of higher altitudes. The remaining species had relatively low Pearson values for this gradient and thus fall somewhere between the 2 extremes in their ability to withstand desiccation.

4.2.1.2 Tardigrades - The preliminary elevational surveys of the northern, coastal towns of Nain, Hopedale and Makkovik revealed varying trends. Nain showed a directly proportional relationship between elevation and species diversity having only 2 species in the low, 5 in the mid and 8 in the upper altitude (Table 3.3). *Diphascon ramazzottii* was highly abundant in the low site (71 specimens) and not nearly as abundant in the 2 higher sites. *Macrobiotus hufelandi* showed relatively high representation throughout the differing altitudes. As in Nain, the 2 highest elevations in Hopedale showed the greatest species diversity. *Diphascon ramazzottii* was not as abundant in Hopedale as it was in the lower elevations of Nain but instead showed a limited representation throughout the elevations. Makkovik produced fewer tardigrade species than both Nain and Hopedale. An inversely proportional relationship of species diversity and elevation was the trend for Makkovik as the greatest number of species was found in the lowest elevation (Table 3.3). *Minibiotus intermedius* was the dominating tardigrade and was found only within the low elevation. *Diphascon ramazzottii* had an even further reduced abundance within Makkovik but, similar to Nain and Hopedale, was only found in the lower altitudes.

When the findings for each of the 3 northern towns were merged a trend of increased species diversity with increased elevation was evident. The low elevation yielded a total of 7 species, where the mid elevation yielded 9 species and the high elevation produced 13 species (Table 3.4). Additionally, *D. ramazzottii* was found in greatest abundance in the lower elevations below 25m. *Minibiotus intermedius* showed similar predominance within elevations below 25m. This seemed to suggest that *D. ramazzottii* and *M. intermedius* were best suited to habitats at lower elevations. *Macrobiotus hufelandi* was found to be represented nearly evenly throughout the 3 elevations of each community.

These preliminary results suggested strong links between tardigrade distribution and elevation. However, these findings were preliminary and based largely on inconsistent sampling methods. Additionally, elevational trends found within the preliminary (October 2001) study were based upon extremely small representative groups (only 5 of the tardigrade species within the dataset were represented by more than 10 specimens). Without larger specimen groups and more samples it was difficult to determine if these were actually ecological distribution differences related to elevation. A much higher degree of significance was given to the quantitative findings of the June and August, 2002 study.

The quantitative analysis of elevational effects on tardigrade communities did not find any significant relationship within Makkovik and Hopedale (likely due to the smaller differences in successive elevations, see section 4.2.1). However, a fairly strong relationship was found regarding elevation and bryofaunal distribution within Nain. Axis 3 of Figure 3.4 indicated an elevational gradient beginning with high altitude at the bottom of the axis and moving to low altitude at the top of the axis. The r-squared value for axis 3 was the largest of the 3 main axes and thus it was the elevational gradient that explained the greatest amount of variability within the bryofaunal dataset of Nain.

The species of tardigrade that contributed most to the variation of the elevational gradient (highly positive or negative Pearson values in Table 3.12) were *Mesocrista spitzbergensis, M. harmsworthi, M. hufelandi* and *D. ramazzottii*. Of these species *M. hufelandi* had the largest Pearson value (0.465), was represented by many specimens and was typically found only in the lower elevations. The species *Mesocrista spitzbergense, M. harmsworthi* and *D. ramazzottii* were typically found in the upper elevations but because they were less abundant they have relatively low Pearson values. The remainder of the tardigrade species found in Nain were represented by too few specimens to be useful in inferring elevational relationships. *Macrobiotus hufelandi* was found to be restricted to lower elevations while *Mesocrista spitzbergensis, M. harmsworthi* and *D. ramazzottii* were typical of higher elevations in the absence of *M. hufelandi*. The occurrence of *M. harmsworthi* in the higher elevations and *M. hufelandi* in the lower elevations was directly supported by the findings of Dastych (1980) in Poland and Wright (1990) in Britain. This elevational trend likely existed because the 3 high altitude species were better adapted to the harsh environment characteristic of higher altitudes, than was *M. hufelandi*, which was described by Wright (1990) as being a hygrophilic species incapable of frequent desiccation. Both, Dastych's (1980) and Wright's (1990) studies were conducted in parts of the world which exhibited similar seasonal climate trends to those of Labrador, thus strengthening the distributional trends attributed to these tardigrades by this study.

The quantitative findings of this study revealed some similarities to the preliminary study of 2001. For both studies *M. hufelandi* was found to have fairly high representation within the lower elevations, a trend confirmed by Wright (1990) in Britain, and *Mesocrista spitzbergensis* was only found in the highest elevations. However, the largest population of *D. ramazzottii* (83 specimens) was found in the lowest elevation in Nain (October 2001) which contradicts the findings of the 2002 study that suggested a distribution limited to upper elevations. Therefore, the relationship shared between elevation and *D. ramazzottii* populations requires further investigation. Other discrepancies that existed between the preliminary and quantitative findings are relatively small and greater significance was placed on the findings from the quantitative analysis.

4.2.1.3 Oribatid Mites - The quantitative analysis of elevational effects on the entire bryofaunal group did not find any significant relationship within Makkovik and Hopedale (likely due to the small differences in successive elevations, see section 4.2.1). However, in Nain where elevation played a significant role in explaining the variability in the bryofaunal dataset, the oribatid mite group had a Pearson value very close to zero and was distributed fairly evenly across the elevational gradient. Therefore, general oribatid abundence was not greatly influenced by changing elevation. These finding support the conclusions of Seyd *et al.* (1996) in the mountains of Snowdonia, Britain who found that in the absence of highly invasive environmental factors (e.g. glaciation) small changes in elevation did not seem to have great effect on oribatid populations. However, since oribatid abundance throughout the elevations was relatively low, further investigation with larger samples may find that a distinct elevational pattern does exist for the bryophilous mites.

4.2.2 Moss Horizon/ Desiccation Tolerance

The quantitative ecological study of 2002 was the first to determine the relationship of moss depth/horizon to the associated nematode, tardigrade and oribatid mite communities for Labrador as well as for Canada as a whole. Moss horizon was the environmental variable that accounted for the greatest amount of variability in the datasets. With the exception of Makkovik, nematode, tardigrade and oribatid mite distributions within each site at each town were directly related to the vertical horizons within the moss sample. The different moss horizons (A,B and C) were directly correlated with variable amounts of moisture and thus the distribution of the bryofauna throughout the moss horizons is likely linked to a gradient of desiccation tolerance.

4.2.2.1 Nematodes - Axis 1 of Figure 3.1 and axis 2 of Figure 3.2 were those axes that were strongly correlated with moss horizon/desiccation tolerance in Nain and Hopedale (respectively). As indicated by the r-squared values for axes 1 and 2 of Nain and Hopedale respectively a relatively large amount of the variability in the data set was explained by the desiccation tolerance gradient. In Hopedale and Nain a characteristic nematode community was determined to exist in the drier, upper horizons (A-B) that was distinctly different from the nematode genera typical of the lower, moister horizons (B-C). Thus, the communities occurring at either end of this axis represented extremes in their abilities to tolerate desiccation (low to high tolerance). Because the B-horizon is transitional between the drier A-horizon and the relatively wet C-horizon, it is understandable that there is a degree of overlap in the B-horizon along the moss horizon/desiccation gradient.

With an understanding of the gradient represented by axis 1 and 2 in Figures 3.1 and 3.2 respectively, specific abilities of the nematode genera to tolerate desiccation are determined by examining the individual Pearson values (r) in Table 3.9. In Nain, the genera that contributed the most to the variation of the axis/gradient were *Aphelenchoides, Eudorylaimus, Plectus* and *Prismatolaimus*. In Hopedale, the genera *Aphelenchoides, Euteratocephalus, Monhystera* 1, *Plectus* and *Tylencholaimus* contributed the most to explaining the axis/gradient. In both Hopedale and Nain the genera *Plectus* and *Aphelenchoides* were typical of the dryer A-horizon and were seldom found in the lower C-horizon. This is directly supported by the findings of Overgaard-Neilsen (1948), who described *Aphelenchoides* and *Plectus* as the 2 genera most typical of the upper moss horizons, and Hyman (1951) who found *Plectus* to dominate in environments most prone to desiccation. In Hopedale, the genera *Euteratocephalus, Monhystera* 1 and *Tylencholaimus* also had relatively large Pearson values for this axis and were also typically found in the uppermost horizons. The high degree of correlation of these genera with the upper, dryer moss horizons indicated a high degree of desiccation tolerance.

More nematode genera were typical of the upper moss horizons for Hopedale than for Nain. As discussed in the section dealing with elevational effects on nematode distribution, desiccation tolerance is often directly correlated with elevation as well as with moss horizon. It is probable that Hopedale had more genera in upper moss horizons than Nain because elevation was not playing as great of a role in the variation explained by the axis/gradient. Thus, the sample hill in Hopedale, being much smaller than that of Nain was less affected by elevational interaction and more genera were likely capable of inhabiting the upper moss horizons. In Nain, *Eudorylaimus* and *Prismatolaimus* and in Hopedale, *Labronema* and *Ogma* were the genera typical of the lower horizons and it is believed that these genera exhibit a low degree of desiccation tolerance compared with the genera correlated with the upper most moss horizons. The predominance of members of the Dorylaimidae found in the lower moss horizons, where desiccation was less frequent, was also noted by Overgaard-Neilsen (1948).

4.2.2.2 Tardigrades and Oribatid Mites - Axis 2 of Figure 3.4 and axis 3 of Figure 3.5 are those axes that were strongly correlated with moss horizon/desiccation tolerance in Nain and Hopedale (respectively). As indicated by the r-squared values for axes 1 and 2 of Nain and Hopedale respectively a relatively large amount of the variability in the data set was explained by the axes representative of desiccation tolerance. Hopedale and Nain revealed a characteristic bryofaunal community in the drier, upper horizons (A-B) that was distinctly different from that existing in the lower, moister horizons (B-C). Thus, the communities occurring at either end of this axis represent extremes in their abilities to tolerate desiccation (low to high tolerance). Again, the B-horizon being transitional between the drier A-horizon and the relatively wet C-horizon is likely to show a varying degree of overlap along the moss horizon/desiccation gradient.

Although the tardigrade species were represented by relatively few specimens and had Pearson values of low magnitude (Table 3.12), the following depth related trends were determined. In Nain, all of the tardigrades species had distributions restricted to the lower moss horizons. *Macrobiotus hufelandi, D. ramazzottii* and *H. convergens* contributed the most to the variation, explained by the depth/desiccation axis, and were typical of the lower moss horizons. Hallas (1978) would classify these species as less specialized bryophilous species based on their occurrence in the lower moss horizons. In Hopedale, the tardigrades accounted for a large amount of the variation caused by moss horizon. The species *D. pingue, M. echinogenitus, M. hufelandi* and *Minibiotus intermedius* were those with highly positive Pearson values and were typical only of the upper most moss horizon and would also be classified by Hallas (1978) as being the most specialized bryofauna. *Diphascon ramazzottii,* and *M. harmsworthi* were the tardigrade species that had Pearson values of very low magnitude and were fairly evenly distributed throughout the moss horizons. The species *D. scoticum, Echiniscus sp.* and *Mesocrista spitzbergense* were represented by too few specimens to have ecological trends inferred about them.

The desiccation/horizon findings of Nain and Hopedale seemed to be in direct contrast. A majority of the tardigrades of Nain were restricted to the lower moss horizons, while the majority of species in Hopedale were either found in the upper moss horizons or exhibited cosmopolitan distributions throughout. A probable explanation for this is the greater total height of the sample hill in Nain and the greater distances between successive sampling altitudes (See section 4.2.1). Because environmental conditions tend to be more extreme at higher rather than lower altitudes, the effects of desiccation on the moss horizons in the upper elevations were probably more pronounced in the moss samples of Nain than those of Hopedale. Thus, elevation not being independent of desiccation tolerance was also playing a minor role in explaining this gradient.

A desiccation tolerance gradient was evident for the tardigrades within Hopedale and Nain but no one species studied was more capable of tolerating desiccation than another. Rather, the tardigrades as a group inhabited the parts of the moss that were most suitable to their moisture requirements. In Nain, where higher altitudes subjected the mosses to a harsher environment, the tardigrades were not found in the upper horizons, while the lower less harsh sample elevations in Hopedale allowed the occupation of tardigrades within the most productive and exposed A-horizon.

Similar trends were found for the oribatid mite group. In Nain, the oribatid distributions were limited to the lower parts of the moss (B, C-Horizons), while in Hopedale oribatids had a relatively uniform distribution throughout the moss horizons. As was the case with the tardigrades, it is probable that variability of oribatids in moss horizons was being slightly affected by the harsher environmental extremes of higher sample altitudes in Nain. The oribatid mites in this study were directly confined to the moss horizons that met their requirements for moisture. In the lower elevations where the upper moss horizons were subjected to less harsh environmental extremes the oribatids were able to occupy variable moss depths. However, at higher altitudes where the upper moss horizons were more often subjected to desiccation as well as other climatic extremes, the oribatids were restricted to the lower more stable moss horizons. These findings are the first ever recorded relating oribatid mite distribution to moss depth.

4.2.3 Seasonality

The effect of seasonality on nematode, tardigrade and oribatid mite distributions was investigated during spring (June 2002) and summer (August 2002). The genera with highly negative Pearson values were found most/only during the summer sampling. The genera with Pearson values close to 0 were those genera that were constant throughout both seasons. The genera with highly positive Pearson values were found most/only during the spring sampling. Seasonality was found to be significantly variable for the nematode dataset only in Hopedale, but was significantly variable in both Hopedale and Makkovik for the pooled bryofaunal dataset.

4.2.3.1 Nematodes – Nematode genera that were most abundant during the spring season and had highly positive Pearson values (Table 3.9) were *Eudorylaimus, Euteratocephalus, Daptonema, Achromadora, Monhystera* 1 and *Plectus*. Few genera had greater representation in the summer than in the spring as indicated by the relatively low negative Pearson values. The genera that did exhibit greater summer abundance were *Aphelenchoides, Tylencholaimus* and *Ogma*. The genus *Plectus* was represented by a very large number of specimens in the spring and far fewer specimens in the summer. *Plectus'* large representation and distinct differences in abundance between the 2 seasons accounted for a very large portion of the variability in the axis. The genera having significant seasonal differences in abundance (*Aphelenchoides, Tylencholaimus* and *Ogma*) were represented by far fewer specimens and, thus, the seasonal trends were dwarfed by the effects of *Plectus* and other highly abundant genera. Therefore, even though the Pearson values for the genera more abundant in the summer were not relatively large they were still significant in the explanation of the seasonality gradient. Genera that had more even representation throughout the sampling seasons and Pearson values closer to 0 were *Monhystera* 2, *Mononchus, Teratocephalus* and *Wilsonema.*

Generally, the results show that the abundance and richness of nematode genus was not constant throughout the 2 sample seasons. A majority of genera had higher abundance in the early reproductive season rather than late, which suggested that these genera were more adapted to non-consistent and often harsh spring weather. Yeates

(1972), Popovici (1980), Banage (1966) and Bassus (1962) each found similar patterns of peaks in nematode abundance in early spring. It was determined that *Plectus* and *Monhystera* 1 were highly correlated with the upper, desiccation prone moss horizons. The abundance of these genera has now also been strongly correlated with an earlier, harsher growing season. These findings suggested that these genera are generally adapted to harsh environmental conditions.

Sampling the fall and winter seasons in Labrador is difficult as fall is variable in length from year to year and harsh winters make accessing the sites difficult. However, sampling from these remaining seasons and repeating the entire procedure over several years would further clarify the seasonal relationship shared with nematode richness and abundance. The towns of Nain and Makkovik did not show significant season related patterns with regard to nematode distributions. This supports the opinions of Franz (1942), Neilsen (1949) and Cuthbert (1990) who found that seasonal patterns of nematode distribution and abundance were difficult to evaluate and that any such trends were often disputable.

4.2.3.2 Tardigrades and Oribatid Mites – Only a few of the tardigrade species had abundances that were high enough to identify significant seasonal trends. The species *D. ramazzottii, D. recamieri, Echiniscus sp., H. convergens, Mesocrista spitzbergense* and *Minibiotus intermedius* were represented by very few specimens in the dataset and must be studied further with regard to seasonal abundance. However, in both Hopedale and Makkovik *M. echinogenitus, D. pingue* and *D. scoticum* were represented by a relatively large number of specimens and occurred predominantly in the summer samples. It is probable that these 3 species were most reproductively active during the late spring to summer, a trend, which was enforced in this study by the discovery of a large number of *M. echinogenitus* eggs in the summer samples and none in the spring samples. *Macrobiotus harmsworthi* was also represented by many specimens but had a relatively even seasonal abundance. This likely suggests that members of this species exhibited relatively constant reproductive rates throughout the 2 sample seasons.

The seasonal analysis for *M. hufelandi* revealed seemingly conflicting trends since it was most abundant in the spring samples of Makkovik and in the summer samples of Hopedale. However, Kinchin (1985) found peaks in the abundance of *M. hufelandi* in England during the spring *and* the autumn, which might be argued to support the findings of this study when the similarity between the Labrador coast's summer and England's autumn is considered. The predominance of tardigrade eggs from the species *M. echinogenitus* made it difficult to apply seasonal reproductive trends to the other species. Generally, this study revealed that some tardigrade species differed in seasonal abundance while others were more constant throughout the spring and summer sampling seasons. The seasonal relationships of tardigrades have not been well investigated (Kinchin, 1994), therefore, these findings add important contributions to the existing body of knowledge. However, the small number of other studies relating tardigrade populations to seasonality makes it difficult to assign any generalizations to the trends found during this study. Further investigations are required before generalizations can be made with respect to seasonal effects of tardigrade populations.

Although the oribatid mites were represented by relatively low abundances they were found to have an even spring and summer abundance within Nain and Hopedale, while in Makkovik the mites exhibited summer numbers of nearly 4 times the spring (42 to 13 specimens). A higher summer abundance of oribatids was also found by Mitchell (1976) in the Canadian Rocky Mountains. The oribatids were not largely represented within the samples of this study and it is unknown whether these results were reflective of actual seasonal differences of mite abundances in Makkovik.

4.2.4 Latitude

Non-metric multidimensional analysis of latitude did not show any significant differences between the various bryofauna of the 3. This was likely because there was a high degree of interaction and possible overshadowing of the latitudinal gradient by the other environmental variables measured. Also, not a large enough latitudinal gradient may have been represented between the study communities. There was also no direct latitudinal based evidence for variability in nematode, tardigrade and oribatid species richness. Because latitudinal trends discussed were based on generalizations made during only 2 sample periods, results should be further studied to insure validity.

4.2.4.1 Nematodes - Table 3.10 showed that total nematode abundance was consistently lowest for both seasons in Makkovik (lowest latitude), while abundance more than doubled from June to August in Nain (greatest latitude) and was halved from June to August in Hopedale (middle latitude). The richness of genera among latitudes was generally quite even, however, a slight trend of decreasing genera richness with increasing latitude was observed (Table 3.10). Makkovik was represented by slightly more genera in both seasons than both Nain and Hopedale.

Genera that showed fairly even representation throughout the latitudes were *Achromadora, Eudorylaimus, Euteratocephalus, Labronema, Monhystera* 1, *Mononchus, Plectus, Prismatolaimus, Teratocephalus* and *Tylencholaimus.* Genera that were more typical of the lower latitudes were *Hemicycliophora, Monhystera* 2, *Ogma* and *Tylenchus* 1. Finally, the genera that had greatest representation in the upper latitudes were *Acrobeloides, Aphelenchoides, Bunonema* and *Tylenchus* 2. None of these apparent trends were statistically significant so further investigation is required before any firm conclusions can be inferred regarding the latitudinal relationship between nematode abundance and richness. As indicated by Nicholas (1975), free-living nematode populations are quite widespread and may not be governed by factors such as latitude.

4.2.4.2 Tardigrades and Oribatid Mites - Although statistical analysis did not indicate significant importance of a latitudinal gradient in the dataset for tardigrades and oribatid mites, some latitudinal trends were suggested in Table 3.13. *Macrobiotus hufelandi* was the only tardigrade to show abundance patterns consistent with a latitudinal gradient. The abundance of this species greatly increased as the latitude of the study sites increased. Also, within the October 2001 survey, *D. ramazzottii* dominated the specimens in Nain, had fewer numbers in Hopedale and even fewer in Makkovik. *Diphascon ramazzottii* also showed the same trend of decreased numbers in lower latitudes within the June and August samples, but was represented by far fewer specimens. Thus, it is possible that both *M. hufelandi* and *D. ramazzottii* showed a degree of preference for higher latitudes which would support the findings of Nelson (1975, 1991) in Tennessee and North Carolina that showed tardigrade abundance increased with increasing latitude. The latitudinal trends for the remaining species were quite minor and variable between seasons; however, both the tardigrades and oribatids had the highest abundances in Hopedale (Table 3.13).

Thus, with the exception of *M. hufelandi* and *D. ramazzottii* that showed consistently high abundance within only the upper latitudes, the distributions of tardigrades and oribatid mites did not show any significant relationship to latitude. Olszanowski and Niedbala (2000) also found that oribatid mite populations did not seem to be limited to latitudinal ranges in the Slonsk Nature Reserve, Poland.

4.3 Canadian Distributions of Identified Specimens

4.3.1 Nematodes

All of the nematode genera identified within this study were new records for Labrador, Canada. Additionally, this was the first Canadian study to examine bryophilous nematodes, thus, each of the 17 genera were significant national findings from which a bryophilous nematode species list for Canada has been established However, all but 1 of the 17 genera identified within this study has been identified in studies on Canadian soils (Appendix 1). The genera *Achromadora, Plectus, Wilsonema, Prismatolaimus, Tylencholaimus, Mononchus, Prionchulus, Aphelenchoides, Tylenchus, Acrobeloides* and *Bunonema* have been previously found in British Columbia (Panesar *et al.*, 2000, 2001) and Newfoundland (Cuthbert, 1990). *Teratocephalus*, *Monhystera, Labronema, Rhabditis* and *Panagrolaimus* have only been recorded for Canada within British Columbia (Panesar *et al.*, 2000, 2001) and are new records for Atlantic Canada. The remaining genera, *Euteratocephalus, Eudorylaimus, Ogma* and *Hemicycliophora* have been previously found only in Newfoundland (Cuthbert, 1990). The 1 genus found in this study that has not been previously recorded for Canada in soils or mosses was *Zeldia*.

There was a high degree of similarity between the moss nematofauna of Labrador, Canada and the nematodes discovered in soil studies conducted by Panesar *et al.* (2000, 2001) in British Columbia and Cuthbert (1990) in Newfoundland. This similarity may also exist for many other parts of Canada but until now these were the only 2 Canadian investigations to extensively survey terrestrial nematode communities. It is therefore difficult to make generalizations as to the nematodes that exhibit cosmopolitan, widespread or even limited ranges of distribution in Canada.

There were also 5 nematode genera found in Labrador and British Columbia (Vancouver Island) but not from the island of Newfoundland which seems odd given that British Columbia lies much further away from Labrador than does Newfoundland. This implied that for some unknown reason the 5 genera were better suited to survival in British Columbia and Labrador than to Newfoundland. It may have been that the insular nature of Newfoundland prevented the spread of some nematodes from parts of mainland Canada. However, in all likelihood the discrepancies between Newfoundland and Labrador nematode genera were more a result of sampling methods than of differential habitat preference. It is probable that the genera common to both British Columbia and Labrador would also be found in Newfoundland but have simply not yet been discovered due to the very few studies which have been conducted on the island.

Similarly, the nematodes found in both Newfoundland and Labrador but not in British Columbia may have resulted from differential adaptation to significantly variable environments between the east and west coasts of Canada or simply that too few studies have been conducted on the soil and moss nematodes to make generalizations regarding national distribution patterns.

4.3.2 Tardigrades

Of the 18 tardigrade species identified 10 have been described as having cosmopolitan distributions (Ramazzotti and Maucci, 1983; McInnes, 1994): *E. wendti*, *M. echinogenitus*, *M. harmsworthi*, *M. hufelandi, Minibiotus intermedius*, *H. convergens*, *H. dujardini*, *D. scoticum*, *D. pingue* and *Milnesium tardigradum*; and 4 with widespread distributions (Ramazzotti and Maucci, 1983; McInnes, 1994): *P. angustata*, *C. ornatus, H. microps* and *D. recamieri*. Although these species have been described as having widespread to cosmopolitan distributions many have not been routinely encountered in Canada and as such are important national findings (Appendix 2). *Echiniscus wendti* and *C. ornatus* have only been recorded previously in Canada within parts of British Columbia (Kathman, 1990) and Newfoundland (Bateman and Collins, 2001). *Platycrista angustata* has been recorded in parts of New Brunswick (Argue, 1971, 1972, 1974) and Newfoundland (Bateman and Collins, 2001) and *H. microps* has only been recorded previously within Canada from Newfoundland (Bateman and Collins, 2001), which made this finding in Labrador a new record for mainland Canada. The species *D. nodulosum* and *Mesocrista spitzbergensis* do not have cosmopolitan or widespread distribution patterns but have been found throughout Canada.

The final 2 species *Proechiniscus hanneae* and *D. ramazzottii* have small ranges of distribution and were new findings for mainland Canada. *Proechiniscus hanneae* has been found only in Greenland (McInnes, 1994) and recently in parts of Newfoundland (Bateman and Collins, 2001); however, its discovery in Labrador was not especially surprising because Labrador, being situated somewhat between both Greenland and that Newfoundland likely shares many species common to both. Bateman and Collins (2001) suggest a wind related mode of dispersal for species Newfoundland has in common with Greenland, it may be similarly speculated that Greenland species, including *Proechiniscus hanneae* were dispersed to parts of Labrador by the same process. *Diphascon ramazzottii* has a range of dispersal that includes only parts of Europe (France, Italy and Russia). Collins and Bateman (2001) found 1 specimen of *D. ramazzottii* in Newfoundland but were unable to repeat this finding. It should be noted that *D. ramazzottii* was 1 of the 2 species that dominated the tardigrade specimens of the 2001 samples (21% of 440 specimens) which was an unusual finding as this species has only previously been documented for Canada by 1 specimen in insular Newfoundland. The largest Labrador population of *D. ramazzottii* existed in Nain at low elevations (~30m).

4.3.3 Bdelloid Rotifers

Studies on Canadian bdelloid rotifers are extremely limited (See section 1.1.1). Therefore, however qualitative these preliminary findings add appreciably to the knowledge of Canadian bdelloids. The species *Adineta gracilis* has been previously recorded the most within Canadian studies from British Columbia to Newfoundland (Murray, 1911; Bateman, 1975), and is likely a widespread species for Canada. *Adineta vaga* and *H. maculata* have only been recorded within central and western Canada thus making these findings new records for eastern Canada and implying a widespread to cosmopolitan national distribution for these species. Conversely, the species *H. lata lata*, *Adineta steineri, M. plicata hirundinela, M. multispinosa* and *M. habita* have all been recorded in Canada only within insular Newfoundland (Bateman, 1975), which made these Labrador findings new records for mainland Canada. Finally, *M. punctata* and *M. aculata* were 2 species found in Labrador that were new records for Canada. Ricci (1987) found the bdelloid genera *Habrotrocha* and *Macrotrachela* to be the 2 most widespread of the moss rotifers but these genera, to date, have a much smaller range of distribution in Canada (Murray, 1911; Bateman, 1975). More studies are required to determine if any actual trends in Canadian rotifer distribution exist.

4.3.4 Oribatid Mites and Collembolans

All of the oribatid and collembolan genera identified in this study have been previously recorded within Canada but were new records for Labrador. The oribatid genera *Epidamaeus, Camisia, Nothrus, Fuscozetes, Mycobates, Opiella* and *Trhypochthoniidae* are represented in most of the Canadian studies on moss, soil and litter oribatids and are likely widespread throughout the country. Six of the remaining mite genera (*Cultroribula, Rhysotritia, Trimalaconothrus, Brachythonius, Sellnickochthonius* and *Limnozetes*) have also been identified within a number of Canadian studies but are more limited in their degree of representation throughout the country than the widespread genera. Of these 13 widespread mite genera, *Brachythonius* has been found in British Columbia (Marshall, 1979), the Northwest Territories (Behan, 1978), Ontario (Marshall, 1972) and Quebec (Marshall, 1968; Smith, 1978) but is a new record for eastern Canada. The last oribatid genus *Xenillus* has only previously been recorded in soils of Manitoba (Oswald and Minty, 1970) and was also a new record for eastern Canada. Finally, the collembolan genus *Folsomia* has been recorded previously in Canada only in Tuktoyaktuk, Northwest Territories and may have a distribution limited to northern environments. However, this hypothesis needs to be further investigated before validity can be determined.

4.4 Biotic Interactions

Although direct observations regarding the interaction of the moss bryofauna were not conducted, it was possible to identify the species that were most positively correlated with one another and speculate possible biotic reasons for these relationships. The 2 dominant bryofaunal communities that were typical of low elevation/deeper moss horizons and high elevation/upper moss horizons are discussed below.

The bryofauna that were most positively correlated with low elevation and low horizon depth (B-C horizons) were the nematodes *Eudorylaimus, Prismatolaimus, Labronema* and the tardigrade *M. hufelandi*. Members of the genus *Eudorylaimus* are known to feed upon algae, protozoans and fungi (Goodey, 1963), *Labronema* may feed on other nematodes or algae and mosses (Goodey, 1951), while the feeding habits for *Prismatolaimus* are unknown. The tardigrade *M. hufelandi* feeds upon nematodes, rotifers and other tardigrades (Kinchin, 1994). These bryofauna are likely to have an interconnected trophic structure, as they exist most commonly together in large numbers. It is probable that the predatory *Labronema* and *M. hufelandi* feed upon the smaller *Prismatolaimus* species as well as larval *Eudorylaimus* and *Labronema* species. Additionally, *M. hufelandi* may also feed upon other members of its own species.

The bryofauna typical of the higher elevations and upper moss horizons were the nematodes *Plectus* and *Aphelenchoides* and the tardigrade *M. harmsworthi*. *Plectus* is thought to feed upon bacteria and small organic particles (Goodey, 1951; Bassus, 1962) while in addition to the majority of the plant parasitic members of the genus *Aphelenchoides* some also feed upon fungal hyphae or other nematodes (Goodey, 1963; Bassus, 1962). The tardigrade *M. harmsworthi* feeds upon nematodes, rotifers and other tardigrades. Therefore, the trophic relations within this exposed environment can be speculated with a relatively high degree of confidence, as there is such low species richness. It is highly likely that within this community *M. harmsworthi* feeds on *Plectus*, *Aphelenchoides* and other members of its own species. It is also probable that many of the members within the genus *Aphelenchoides* are plant parasitic on bryophytes as well as vascular plants that grow in and around the mosses.

These speculative findings are based only on highly correlated communities and are presented to exemplify possible biotic interactions and detail methods by which to evaluate such biotic relationships when direct observations cannot be made. Further research into other bryofaunal communities and direct observations of trophic habits are required to confidently understand the biotic relationships of these organisms.

4.5 Assessment of Bryofaunal Systems as Biological Indicators

Mosses have been previously evaluated as useful bioindication systems (Goodman *et al.*, 1975). More recently, Steiner (1995a, b) found the bryofauna to be highly suitable bioindicating systems, specifically of airborne pollutants. Although this study predominantly recorded the baseline ecological trends of the moss faunal communities of Labrador it also produced information regarding the use of these systems as monitors of environmental stress. Certain species and genera were described on the basis of their ability to tolerate varying forms of environmental stress. Certain genera and species were found to be more adapted to varying extremes. For example, the nematode genera *Plectus* and *Aphelenchoides* and the tardigrade species *D. pingue, M. echinogenitus* and *Minibiotus intermedius* were found to be most tolerant to desiccation and were most commonly found in the upper moss regions (Horizon A), while the nematode genera

Eudorylaimus and *Prismatolaimus*, the tardigrade species *D. ramazzottii* and *M. harmsworthi* and the oribatid mite group were less tolerant to desiccation and were typically found in the lower moss regions (Horizon C). Additionally, in certain cases a distinct community of organisms was described for each moss depth. Each of these findings contributes to the essential understanding of how these communities can be used as effective bioindicators.

The tendency for stress tolerant bryofaunal to inhabit the upper moss horizons may be of key importance when using the moss invertebrates to monitor environmental disturbances. For example, when trying to determine the effects of air-borne pollutants on bryofaunal communities one might benefit from focussing on the bryofaunal community inhabiting the upper most moss horizon (A) as this is the portion of the moss that is most likely to be exposed to such pollutants. If the moss cushion was considered as a whole there would likely be less tendency to find pronounced pollutant related trends because the bryofaunal communities of the lower moss horizons, which are less affected by the air-borne pollutants, would have a diluting effect on the pollutant-related trends of the upper moss communities. In this regard, Steiner's (1995b) study on the effects of air pollution on moss meiofauna may have produced results of even greater significance if he had instead looked at the bryofaunal changes throughout the moss horizons and paid specific attention to the A-horizon communtiy.

4.6 Conclusion

With the exception of the bdelloid rotifers and collembolans which occurred in too few numbers, this study determined that the bryofauna do exhibit quantitative reactions to various environmental gradients. Future studies on the bryophilous collembolans and mites would benefit by collecting larger moss samples than those collected in this study as the relative sizes of these bryofauna prevent them from reaching densities as high as the smaller meiofauna in small moss cores. Similarly, it was determined that when studying bdelloid rotifers every effort must be made to extract and identify the specimens while alive as prolonged storage in moist samples can lead to high mortality.

Moss horizon/desiccation tolerance was found to be the environmental variable that explained the greatest amount of variability in the bryofaunal datasets. The moss fauna that exhibited the highest tolerance to desiccation were the nematode genera *Plectus* and *Aphelenchoides* and the tardigrade species *D. pingue, M. echinogenitus* and *Minibiotus intermedius.* The bryofauna that seemed the least tolerant of desiccation and were typically found in the lower moss horizons were the nematode genera *Eudorylaimus* and *Prismatolaimus*, the tardigrade species *D. ramazzottii* and *M. hufelandi* and the oribatid mite group. The moss fauna that were typical of higher elevations were the nematode genera *Plectus* and *Aphelenchoides* and the tardigrade species *M. harmsworthi*, while those typical of lower elevations were the nematodes *Prismatolaimus, Eudorylaimus* and the tardigrade species *M. hufelandi* and *Mesocrista spitzbergense.* The oribatid mite group did not show significant altitude related distribution patterns but did have a much greater abundance in the summer collection than in the spring. Most nematode genera and tardigrade species showed even seasonal representation or peaks in summer abundance. The tardigrade *M. echinogenitus* had a much greater abundance of adult specimens and eggs in the late summer which likely suggests a summer/fall reproductive period for this species. No overall latitudinal trends were evident from the analysis of the bryofaunal dataset, although, certain bryofauna showed distribution patterns which may have been partially reflective of a latitudinal gradient.

In future uses of the bryofaunal biological indication system to monitor air pollution, the communities typical of the upper moss horizons should be given a high degree of attention and be separated from the rest of the moss cushion upon collection as they are the animals that are highly resistant to variable environments and are most likely to encounter airborne pollutants.

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Appendix 1. Genera recorded by Canadian studies on soil and litter nematodes (including Labrador genera).

Order	**Family**	**Genus**	**Area Found**
CHROMADORIDA	Cyantholaimidae	*Achromadora*	BC (P,M&B), NL (C), **L (B)**
		Ethmolaimus	BC (P,M&B)
	Chromadoridae	*Punctodora*	BC (P,M&B)
ARAEOLAIMIDA	Bastianiidae	*Bastiania*	BC (P,M&B)
	Plectidae	*Chronogaster*	BC (P,M&B)
		Plectus	BC (P,M&B), NL (C), **L (B)**
		Wilsonema	BC (P,M&B), NL (C), **L (B)**
	Teratocephalidae	*Euteratocephalus*	NL (C), **L (B)**
		Teratocephalus	BC (P,M&B), **L (B)**
	Diplopeltidae	*Cylindrolaimus*	BC (P,M&B)
MONHYSTERIDA	Monhysteridae	*Monhystera*	BC (P,M&B), **L (B)**
		Eumonhystera	NL (C)
		Monhysterella	BC (P,M&B)
	Xylalidae	*Daptonema*	**L (B)**
		Steineria	**L (B)**
ENOPLIDA	Ironidae	*Cryptonchus*	BC (P,M&B)
	Prismatolaimidae	*Prismatolaimus*	BC (P,M&B), NL (C), **L (B)**
	Tripylidae	*Tripyla*	BC (P,M&B)
DORYLAIMIDA	Alaimidae	*Alaimus*	BC (P,M&B), NL (C)
	Aporcelaimidae	*Aporcelaimus*	BC (P,M&B)
		Aporcelaimellus	BC (P,M&B), NL (C)
		Thonus elegans	NL (C)
	Diptherophoridae	*Diptherophora*	NL (C)
	Dorylaimidae	*Discolaimus*	BC (P,M&B)
		Dorylaimus	BC (P,M&B)
		Eudorylaimus	BC (P,M&B), NL (C), **L (B)**
		Mesodorylaimus	NL (C)
		Prodorylaimus	NL (C)
		Labronema	BC (P,M&B), **L (B)**
		Pungentus	BC (P,M&B)
		Tylencholaimus	BC (P,M&B), NL (C), **L (B)**

	Longidoridae	*Xiphinema*	BC (P,M&B), ON (A,S &VS)
	Leptonchidae	*Leptonchus*	BC (P,M&B)
		Tylencholaimellus	BC (P,M&B)
	Nygolaimidae	*Nygolaimus*	BC (P,M&B)
		Paravulvulus	NL (C)
MONONCHIDA	Mononchidae	*Clarkus*	BC (P,M&B)
		Iotonchus	BC (P,M&B)
		Miconchus	BC (P,M&B)
		Mononchus	BC (P,M&B), NL (C), **L (B)**
		Mylonchulus	BC (P,M&B), NL (C)
		Prionchulus	BC (P,M&B), NL (C), **L (B)**
TYLENCHIDA	Aphelenchidae	*Aphelenchus*	BC (P,M&B)
	Aphelenchoididae	*Aphelenchoides*	BC (P,M&B), NL (C), **L (B)**
	Criconematidae	*Criconema*	BC (P,M&B)
		Criconemoides	ON (L&M), Q (B,D&F)
		Neocrossonema	NL (C)
		Paratylenchus	Q (B,D&F)
	Neotylenchidae	*Deladenus*	NL (C)
		Nothocriconemella	NL (C)
		Ogma	NL (C), **L (B)**
		Seriespinula	NL (C)
	Anguinidae	*Ditylenchus*	BC (P,M&B), NL (C)
	Tylenchidae	*Psilenchus*	BC (P,M&B)
		Tylenchus	BC (P,M&B), NL (C), **L (B)**
		Tylenchorhynchus	ON (L&M), PEI (E&K)
		Coslenchus	NL (C)
		Malenchus	NL (C)
	Pratylenchidae	*Pratylenchus*	ON (L&M), Q (B,D&F), PEI (E&K), NL (C)
		Hirschmanniella	NL (C)
	Heteroderidae	*Heterodera*	ON (L&M)
		Meloidogyne	ON (L&M), Q (B,D&F)

	Hemicycliophoroidea	*Hemicycliophora*	NL (C), **L (B)**
	Hoplolaimidae	*Helicotylenchus*	Q (B,D&F)
		Rotylenchus	ON (L&M)
RHABDITIDA	Cephalobidae	*Acrobeles*	BC (P,M&B)
		Acrobeloides	BC (P,M&B), NL (C), **L (B)**
		Cephalobus	BC (P,M&B), NL (C)
		Eucephalobus	NL (C)
		Chiloplacus	BC (P,M&B)
		Zeldia	**L (B)**
	Bunonematidae	*Bunonema*	BC (P,M&B), NL (C), **L (B)**
	Diplogasteridae	*Micoletzky*	NL (C)
	Rhabditidae	*Protorhabditis*	BC (P,M&B)
		Rhabditis	BC (P,M&B), **L (B)**
	Panagrolaimidae	*Panagrolaimus*	BC (P,M&B), **L (B)**
	Steinernematidae	*Steinernema*	BC (H,F&W)

Location:
BC = British Columbia
L **= Labrador**
NL = Newfoundland and Labrador
ON = Ontario
PEI = Prince Edward Island
Q = Province of Quebec

Recorded from:
B = Boeckner (current study)
B,D&F = Bélair *et al.*, 2001
C = Cuthbert, 1990
E&K = Edwards and Kimpinski, 1997
H,F&W = Hayes *et al.*, 1999
L&M = Little and Maun, 1997
P,M&B = Panesar *et al.*, 2000

Appendix 2. Species recorded by Canadian studies on the terrestrial tardigrades (including Labrador genera, adapted with permission from Bateman and Collins, 2001).

Heterotardigrada Species	**Area Found**	**Distribution Pattern** According to RAMAZZOTTI and MAUCCI 1983, and MCINNES 1994
Bryochoerus intermedius (Murray,1910)	BC (M)	rare
Bryodelphax parvulus Thulin, 1928	BC (M)	widespread?
Echiniscus bisetosus Heinis,1908	BC (M)	
E. canadensis Murray, 1910	BC (M)	holarctic, widespread
E. horningi Schuster & Grigarick, 1971	BC (K&D)	N.Amer.
E. maucci Ramazzotti, 1956	NB (A),BC (K&D)	N.Amer.
E. merokensis Richters, 1904	NF (B&C), NWT (W&K)	widespread
E. oihonnae Richters, 1903	BC (M)	widespread
E. quadrispinosis Richters, 1902	BC (K&D)	cosmopolitan
E. reymondi Marcus, 1928	BC (M-named by MARCUS)	Can-BC
E. spiniger Richters, 1904	NB (A)	widespread
E. sylvanus Murray, 1910	ON (M)	Can-ON
E. wendti Richters, 1903	NF (B&C), BC (M, K&D), **L (B)**	cosmopolitan
Hypechiniscus gladiator (Murray, 1905)	NB (A), BC (R, K&D)	widespread
Proechiniscus hanneae (Petersen, 1951)	NF (B&C), **L (B)**	Grnlnd
Pseudechiniscus alberti Dastych, 1987	YU (D)	N.Amer.-Yukon
P.goedeni Grigarick, Mihelcic, & Schuster, 1964	BC (K&D)	cosmopolitan
P. suillus (Ehrenberg, 1853)	NB (A),BC (K&D), NWT (W&K,VR[2])	cosmopolitan
Testechiniscus laterculus (Schuster, Grigarick, & Toftnei,1980)	BC (K&D)	Can-BC
T. spinuloides (Murray, 1907)	NB (A)	Eur, N.Amer.
T. spitzbergensis (Scourfield, 1897)	NWT(W&K,VR[1],[2])	holarctic

Eutardigrada Species	**Area Found**	**Distribution Pattern**
Dactylobiotus ambiguus (Murray, 1907)	NB (A)	cosmopolitan
D. *dispar* (Murray, 1907)	NWT (VR)	cosmopolitan
Macrobiotus areolatus Murray, 1907	NB (A), ON (M), SK (P), BC (M,K), RM (M)	cosmopolitan
M. bondavilli Manicardi, 1989	YU (MA)	Can. - Yukon
M. crenulatus Richters, 1904 (=*M.dentatus* Binda, 1974)	BC (K)	Eur. N.Amer.
M. echinogenitus Richters, 1904	NB (A), ON (M), BC (M,K), **L (B)**	cosmopolitan
M. furciger Murray, 1906	NB (A)	widespread
M. harmsworthi Murray, 1907	NF (B&C), NB (A), ON (M), BC (K), NWT (VR[1]) , **L (B)**	cosmopolitan
M. cf. *hufelandi* Shultze, 1833	NF (B&C), NB (A), Q (I), ON (M), BC (R,M,K), RM(M), **L (B)**	cosmopolitan
M. montanus Murray, 1910	NF (B&C), NB (A)	
M. occidentalis Murray, 1910	BC (M)	cosmopolitan
M. richtersi Murray, 1911	NB (A), Q (I), BC (K)	cosmopolitan
M. tenuis Binda & Pilato, 1972	SA(P)	Eur, N. Amer.

M. tonollii Ramazzotti, 1956	NB (A)	Eur, N. Amer.
M. virgatus Murray, 1910	ON (M), BC (M)	Eur, N.Amer. Aust.
M. willardi Pilato, 1977	SA (P)	Eur, N.Amer.
Minibiotus intermedius (Plate, 1888)	NF (B&C), NB (A), ON (M), BC (K), **L (B)**	cosmopolitan
M. lazzaroi Maucci, 1986	BC (K)	Eur, N.Amer.
Murrayon dianeae (Kristensen, 1982)	NF (B&C), NWT, (VR^{1,2})	Grnlnd, NWT
M. hibernicus (Murray, 1911)	NB (A), BC (K)	Eur, N.Amer.
M. pullari (Murray, 1907)	NB (A)	widespread
Microhypsibius (Thulin, 1928) *sp.*	NF (B&C)	Europe,Greenland, Japan
Pseudodiphascon arrowsmithi Kathman & Nelson, 1989	BC (K)	
Amphibolus smreczynskii (Weglarska, 1970)	NWT (W)	Eur, Can-NWT
A. weglarskae (Dastych, 1972)	BC (K), NWT (VR^{2})	Eur, N.Amer.
*Calohypsibius ornatus** (Richters,1900)	NF (B&C), BC (K), **L (B)**	widespread
Hypsibius arcticus Murray, 1907	WC (M), BC (M), ON (M)	cosmopolitan
H. convergens (Urbanowicz, 1925)	NF (B&C), NB (A), BC (K), NWT (VR^{1},^{2}), **L (B)**	cosmopolitan
H. dujardini (Doyere, 1840)	NF (B&C), NB (A), NWT (VR^{1},^{2}), **L (B)**	cosmopolitan
H. microps Thulin, 1928	NF (B&C), **L (B)**	widespread
H. pallidus Thulin, 1911	NF (B&C), NB (A), Q (I)	cosmopolitan
Isohypsibius bertolanii Manicardi, 1989	YU (MA)	Can,-Yukon
I. canadensis (Murray, 1910)	BC (M), NWT (VR^{2}), RM (M)	Asia, N,Amer.
I. granulifer (Thulin, 1928)	NWT (VR^{1},^{2})	cosmopolitan
I. lunulatus (Iharos, 1966)	NF (B&C), BC (K), YU (MA)	widespread
I. papillifer (Murray, 1905)	NWT (VR^{1},^{2})	cosmopolitan
I. papillifer bulbosus (Marcus, 1928)	NWT (VR^{1},^{2})	cosmopolitan?
I. prosostomus (Thulin 1928)	NF (B&C)	widespread
I. sattleri (Richters, 1902) (=*I. bakonyensis* (Iharos, 1964))	NF (B&C), NB (A), BC (M,K), RM (M)	cosmopolitan
I. schaudinni (Richters, 1909)	NF (B&C), Q (I), NWT (VR^{2})	widespread, cosmopolitan
I. tetradactyloides (Richters, 1907)	NWT (VR^{1},^{2})	cosmopolitan
I. tuberculatus (Plate,1888)	NB (A),BC (M)	widespread
I. woodsae Kathman, 1989	BC (K)	Can-BC
Ramazzottius baumanni (Ramazzotti, 1962)	BC (K)	NZ, Amer.
R. oberhauseri (Doyere, 1840)	NB (A), Q (I), BC (M,K)	cosmopolitan
R. sp	NF (B&C)	
Diphascon (Adropion) belgicae (Richters, 1911)	NB (A), BC (K)	widespread
D(A.) modestum Binda, Pilato & Dastych, 1984	BC (K)	Eur, Can.-BC
D(A.) prorsirostre Thulin, 1928	NF (B&C), NB (A), BC (K)	widespread
D.(A.) scoticum Murray, 1905	NF (B&C), NB (A), RM (M), BC (M,K), **L (B)**	cosmopolitan
D.(Diphascon) alpinum Murray, 1906	ON (M), RM (M)	cosmopolitan
D.(D.) bullatum Murray, 1905	NB (A)	widespread
D.(D.) burti Nelson, 1991	NB (A- named by N)	Can-NB
D.(D.) chilenense Plate, 1888	RM (M)	cosmopolitan
D.(D.) iltisi (Schuster &	BC (K)	Eur, N.Amer., Asia

Grigarick, 1965)		
D.(D.) nodulosum (Ramazzotti, 1957)	NF (B&C), NB (A), BC (K), **L (B)**	NZ, N.&C.Amer.
D.(D.) oculatum vancouverense (Thulin, 1907)	BC (M)	Eur, N.Amer.
D.(D.) pingue (Marcus, 1936) (including *brunsvicensis)* Argue, 1972)	NF (B&C),NB (A), BC (K), **L (B)**	cosmopolitan
D.(D.) ramazzottii Robotti, 1970	NF (B&C), **L (B)**	Europe
D.(D.) recamieri Richters, 1911	BC (K), NWT (VR^2), **L (B)**	widespread
D.(D.) rugosum (Bartos, 1935)	NB (A)	Eur., Can -NB
D.(D.) tenue Thulin, 1928	Q (I)	Eur, Can-Q
D. *behanae* Dastych, 1987	YU (D)	Eur, Can-Yukon
Hebesuncus conjungens (Thulin, 1911)	NF (B&C)	widespread
Itaquascon pawlowskii Weglarska, 1973	BC (K)	Eur, N.& C.Amer.
Mesocrista spitzbergense (Richters, 1903)	NF (B&C), NB (A), BC (K), **L (B)**	Eur, Afr, NA
Platicrista angustata (Murray, 1905)	NF (B&C), NB (A), **L (B)**	widespread
P. cheleusis Kathman, 1990	BC (K)	Can-BC
Milnesium tardigradum Doyere, 1840	NF (B&C), NB (A), BC (R, K) Q (I), ON (M), **L (B)**	cosmopolitan

Location:

BC = British Columbia
L = Labrador
NB = New Brunswick
NL = Newfoundland and Labrador
NWT = Northwest Territories
ON = Ontario
PEI = Prince Edward Island
Q = Province of Quebec
RM = Rocky Mountains
SA = Saskatchewan
WC = West Coast

Recorded from:

A = Argue (1971, 1972, 1974)
B = Boeckner (current study)
B&C = Bateman and Collins (2001)
D = Dastych (1987)
I = Iharos (1973)
K = Kathman (1990)
K&D = Kathman and Dastych (1990)
MA = Manicardi (1989)
M = Murray (1910)
N = Nelson (1991)
P = Pilato (1977)
R = Richters (1908)
VR^1 = Van Rompu *et al.* (1991)
VR^2 = Van Rompu *et al.* (1992)
W = Wegalarska (1970)
W&K = Wegalarska and Kuc (1980)

Appendix 3. Nematode raw data (June and August, 2002).

Site	Town	Season	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	U	V	W	Y	Totals
NA1A1	Nain	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NA1B1	Nain	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NA1C1	Nain	Jun-02	2	1	1	7	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	15
NA1A2	Nain	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NA1B2	Nain	Jun-02	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
NA1C2	Nain	Jun-02	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
NA1A3	Nain	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NA1B3	Nain	Jun-02	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
NA1C3	Nain	Jun-02	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	4
NA2A1	Nain	Jun-02	1	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
NA2B1	Nain	Jun-02	10	5	0	0	0	1	0	0	0	2	0	0	4	0	0	0	0	0	2	0	0	0	0	24
NA2C1	Nain	Jun-02	0	5	0	0	0	11	0	0	0	0	0	0	4	0	0	0	0	0	2	0	0	0	0	22
NA2A2	Nain	Jun-02	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	34
NA2B2	Nain	Jun-02	2	13	0	0	0	7	0	0	0	1	0	0	10	0	0	0	0	0	8	3	0	0	0	44
NA2C2	Nain	Jun-02	0	4	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
NA2A3	Nain	Jun-02	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	7
NA2B3	Nain	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7
NA2C3	Nain	Jun-02	4	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	31
NA3A1	Nain	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NA3B1	Nain	Jun-02	30	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	34
NA3C1	Nain	Jun-02	3	0	0	0	0	10	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	15
NA3A2	Nain	Jun-02	44	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	2	73
NA3B2	Nain	Jun-02	1	9	1	0	0	2	0	0	0	7	0	0	0	0	0	0	0	0	0	0	1	0	6	27
NA3C2	Nain	Jun-02	5	6	0	0	0	1	0	0	0	0	0	0	16	0	0	0	0	0	0	3	0	0	8	39
NA3A3	Nain	Jun-02	0	6	25	4	0	9	0	0	1	0	0	0	0	0	0	0	0	0	0	0	32	0	1	78
NA3B3	Nain	Jun-02	39	19	0	0	0	7	0	0	0	2	0	0	0	16	0	0	0	0	0	0	2	0	1	86
NA3C3	Nain	Jun-02	10	3	0	0	0	0	0	0	1	0	0	0	0	6	0	0	0	0	0	1	0	0	0	21
HA1A1	Hope	Jun-02	65	0	27	0	0	6	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	102
HA1B1	Hope	Jun-02	17	11	5	0	0	2	0	0	4	1	0	0	0	5	0	0	0	0	0	3	0	0	0	48
HA1C1	Hope	Jun-02	13	1	2	0	0	6	0	0	1	1	0	0	1	0	0	0	0	0	0	2	0	0	0	27
HA1A2	Hope	Jun-02	80	0	32	0	0	7	0	0	11	0	0	0	0	4	0	0	0	0	0	2	0	0	0	136
HA1B2	Hope	Jun-02	3	2		0	0	2	0	0	0	0	0	0	0	2	0	0	1	0	0	1	0	0	0	11
HA1C2	Hope	Jun-02	4	4	3	0	0	8	0	0	2	0	0	0	0	2	0	0	0	0	0	1	0	0	0	24
HA1A3	Hope	Jun-02	205	0	101	0	0	11	0	0	3	0	0	0	0	10	0	0	0	0	0	4	0	0	0	334
HA1B3	Hope	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HA1C3	Hope	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HA2A1	Hope	Jun-02	52	1	38	0	0	16	1	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	116
HA2B1	Hope	Jun-02	10	0	2	0	0	32	0	0	0	0	0	0	5	8	0	0	1	0	0	0	0	0	0	58
HA2C1	Hope	Jun-02	25	5	0	0	0	5	0	0	0	0	0	0	0	2	0	0	0	3	0	0	0	0	0	40
HA2A2	Hope	Jun-02	116	2	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	2	0	0	11	0	0	154
HA2B2	Hope	Jun-02	17	3	0	0	0	10	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	34
HA2C2	Hope	Jun-02	14	5	2	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	26
HA2A3	Hope	Jun-02	77	3	2	0	0	14	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	100
HA2B3	Hope	Jun-02	18	8	6	0	0	16	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52

Site	Town	Season	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	U	V	W	Y	Totals
HA2C3	Hope	Jun-02	1	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
HA3A1	Hope	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
HA3B1	Hope	Jun-02	0	2	3	2	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32
HA3C1	Hope	Jun-02	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
HA3A2	Hope	Jun-02	126	1	14	0	0	6	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	149
HA3B2	Hope	Jun-02	14	2	2	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	22
HA3C2	Hope	Jun-02	7	3	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	13
HA3A3	Hope	Jun-02	448	10	15	0	0	25	0	0	20	4	0	0	0	6	0	0	0	10	4	0	1	0	0	543
HA3B3	Hope	Jun-02	7	7	0	0	0	2	0	0	2	9	0	0	0	8	0	0	0	0	0	0	0	0	0	35
HA3C3	Hope	Jun-02	12	5	1	0	0	13	13	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	48
MA1A1	Makk	Jun-02	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
MA1B1	Makk	Jun-02	10	1	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	20
MA1C1	Makk	Jun-02	0	0	4	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
MA1A2	Makk	Jun-02	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
MA1B2	Makk	Jun-02	4	1	1	0	0	3	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	13
MA1C2	Makk	Jun-02	2	1	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	8
MA1A3	Makk	Jun-02	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3
MA1B3	Makk	Jun-02	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	4
MA1C3	Makk	Jun-02	0	1	0	1	0	0	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	6
MA2A1	Makk	Jun-02	2	0	3	0	0	7	0	0	1	1	0	0	0	6	0	0	0	0	0	0	0	0	0	20
MA2B1	Makk	Jun-02	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
MA2C1	Makk	Jun-02	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	2	0	0	0	0	0	0	0	5
MA2A2	Makk	Jun-02	4	0	21	0	0	3	0	0	7	0	0	4	0	3	0	0	1	0	0	1	0	0	0	44
MA2B2	Makk	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MA2C2	Makk	Jun-02	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3
MA2A3	Makk	Jun-02	1	1	1	0	0	13	0	0	0	0	0	0	0	4	12	0	0	0	0	0	0	0	0	32
MA2B3	Makk	Jun-02	4	1	0	0	0	6	0	0	0	1	0	0	0	6	3	0	0	0	0	3	0	0	0	24
MA2C3	Makk	Jun-02	0	1	8	0	0	3	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	15
MA3A1	Makk	Jun-02	1	0	3	0	0	8	0	0	0	0	0	0		1	0	0	0	0	0	2	0	0	0	15
MA3B1	Makk	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MA3C1	Makk	Jun-02	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
MA3A2	Makk	Jun-02	4	0	2	0	0	6	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	15
MA3B2	Makk	Jun-02	0	0	4	0	0	5	0	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	13
MA3C2	Makk	Jun-02	1	0	3	0	0	1	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	9
MA3A3	Makk	Jun-02	11	0	5	0	0	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
MA3B3	Makk	Jun-02	0	0	0	0	0	3	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	7
MA3C3	Makk	Jun-02	3	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	7
NA1A1	Nain	Aug-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	10
NA1B1	Nain	Aug-02	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	1	5	0	0	11
NA1C1	Nain	Aug-02	0	16	3	0	0	2	0	0	3	1	0	0	0	24	0	2	2	0	0	1	0	1	0	55
NA1A2	Nain	Aug-02	48	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	4	59	0	0	113
NA1B2	Nain	Aug-02	12	6	0	0	0	2	0	0	1	3	0	0	0	15	0	0	0	0	0	0	3	0	0	42
NA1C2	Nain	Aug-02	2	19	0	0	0	6	0	0	0	11	0	0	0	0	0	15	1	0	0	0	0	0	0	54
NA1A3	Nain	Aug-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
NA1B3	Nain	Aug-02	4	0	0	4	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	11
NA1C3	Nain	Aug-02	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	6
NA2A1	Nain	Aug-02	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	44	0	0	78

Site	Town	Season	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	U	V	W	Y	Totals
NA2B1	Nain	Aug-02	0	49	0	0	0	3	10	0	0	0	0	0	11	0	0	2	0	0	1	1	0	0	0	77
NA2C1	Nain	Aug-02	1	51	0	0	0	3	0	0	0	1	0	0	19	0	0	1	0	0	0	0	0	0	0	76
NA2A2	Nain	Aug-02	15	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	19	0	0	36
NA2B2	Nain	Aug-02	3	0	0	0	0	6	0	0	0	2	0	0	17	0	0	0	0	0	0	0	0	0	0	28
NA2C2	Nain	Aug-02	2	10	3	0	0	17	3	0	1	1	0	0	17	0	0	0	0	0	0	3	0	0	0	57
NA2A3	Nain	Aug-02	9	1	1	0	0	2	0	0	0	0	0	0	11	0	0	0	0	0	9	4	67	0	0	104
NA2B3	Nain	Aug-02	1	18	3	0	0	10	5	0	0	0	0	0	98	1	1	1	0	0	1	1	3	0	0	143
NA2C3	Nain	Aug-02	3	115	1	0	0	10	0	0	1	2	0	0	25	0	1	0	0	0	0	1	1	0	0	160
NA3A1	Nain	Aug-02	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
NA3B1	Nain	Aug-02	5	5	3	0	0	8	3	0	0	0	0	0	5	0	0	4	0	0	0	0	0	1	0	34
NA3C1	Nain	Aug-02	4	14	1	0	0	4	0	0	0	2	0	0	3	1	0	0	0	0	0	0	0	0	0	29
NA3A2	Nain	Aug-02	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	68	0	0	73
NA3B2	Nain	Aug-02	37	0	0	1	0	1	0	0	0	13	0	0	0	6	0	0	0	0	18	4	26	0	0	106
NA3C2	Nain	Aug-02	2	5	0	0	0	8	4	0	2	7	0	0	3	1	0	0	0	0	1	4	0	0	0	37
NA3A3	Nain	Aug-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
NA3B3	Nain	Aug-02	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	2	15	0	0	73
NA3C3	Nain	Aug-02	2	0	0	0	0	7	0	0	0	9	0	0	0	0	0	3	0	0	0	0	2	0	0	23
HA1A1	Hope	Aug-02	16	0	1	0	0	3	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	24
HA1B1	Hope	Aug-02	4	0	2	0	1	1	0	0	1	2	0	0	0	5	0	0	0	0	0	1	0	0	0	17
HA1C1	Hope	Aug-02	5	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	8
HA1A1	Hope	Aug-02	48	0	7	0	0	0	0	0	5	1	0	0	0	2	0	0	0	0	0	4	5	0	0	72
HA1B2	Hope	Aug-02	107	2	5	0	0	9	1	3	2	10	0	0	0	26	0	0	0	0	0	0	0	2	0	167
HA1C2	Hope	Aug-02	9	1	0	0	0	1	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	15
HA1A3	Hope	Aug-02	73	0	18	0	0	3	0	0	5	1	0	0	0	15	0	1	0	0	0	0	7	0	0	123
HA1B3	Hope	Aug-02	33	4	1	0	0	8	2	1	1	5	0	0	0	10	0	0	0	0	0	1	0	0	0	66
HA1C3	Hope	Aug-02	10	1	0	0	0	0	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	16
HA2A1	Hope	Aug-02	32	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1	12	0	0	50
HA2B1	Hope	Aug-02	4	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
HA2C1	Hope	Aug-02	3	1	0	0	0	4	0	1	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	14
HA2A2	Hope	Aug-02	23	0	0	0	0	1	0	0	1	0	0	0	0	10	0	0	0	0	0	0	0	0	0	35
HA2B2	Hope	Aug-02	4	0	0	0	0	1	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	9
HA2C2	Hope	Aug-02	1	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	4
HA2A3	Hope	Aug-02	22	2	8	0	0	0	0	3	1	2	0	0	0	6	0	1	0	0	0	2	84	0	0	131
HA2B3	Hope	Aug-02	2	0	0	0	0	7	0	2	11	0	0	0	0	10	0	0	0	0	0	1	0	0	0	33
HA2C3	Hope	Aug-02	3	0	0	0	0	2	0	0	1	1	0	0	0	2	0	0	0	0	0	0	0	0	0	9
HA3A1	Hope	Aug-02	17	1	0	0	0	1	0	0	0	8	0	0	0	2	0	1	0	0	0	0	39	0	0	69
HA3B1	Hope	Aug-02	20	2	2	0	0	1	0	0	0	2	0	0	0	4	0	0	0	0	0	0	0	0	0	31
HA3C1	Hope	Aug-02	9	1	2	0	0	1	0	0	4	0	0	0	0	4	0	0	0	0	0	0	20	0	0	41
HA3A2	Hope	Aug-02	19	0	8	0	0	0	0	2	0	6	0	0	0	3	0	1	0	0	0	0	204	0	0	243
HA3B2	Hope	Aug-02	16	1	1	0	0	0	1	0	1	6	0	0	1	9	0	0	0	0	0	0	0	0	0	36
HA3C2	Hope	Aug-02	8	0	1	0	0	0	0	0	6	0	0	0	1	3	0	0	0	0	0	0	0	0	0	19
HA3A3	Hope	Aug-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HA3B3	Hope	Aug-02	13	0	0	0	0	1	0	0	0	3	0	0	1	3	0	0	0	0	0	0	0	0	0	21
HA3C3	Hope	Aug-02	12	0	0	0	0	0	1	1	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	18
MA1A1	Makk	Aug-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MA1B1	Makk	Aug-02	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
MA1C1	Makk	Aug-02	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4

Site	Town	Season	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	U	V	W	Y	Totals
MA1A2	Makk	Aug-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MA1B2	Makk	Aug-02	103	1	0	0	0	1	0	7	0	2	0	0	0	7	0	0	0	0	2	3	1	0	0	127
MA1C2	Makk	Aug-02	5	0	3	4	0	0	1	7		0	0	0	1	0	12	3	0	0	0	0	0	0	0	36
MA1A3	Makk	Aug-02	3	0	4	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	11
MA1B3	Makk	Aug-02	9	1	4	0	0	10	0	2	4	0	0	0	0	24	0	0	0	0	0	1	0	0	0	55
MA1C3	Makk	Aug-02	4	2	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	12
MA2A1	Makk	Aug-02	15	0	2	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	21
MA2B1	Makk	Aug-02	8	1	0	0	0	0	0	0	0	0	0	0	0	37	0	2	1	0	0	0	0	0	0	49
MA2C1	Makk	Aug-02	5	1	1	0	0	2	0	0	0	0	0	0	0	6	0	1	0	0	0	0	0	0	0	16
MA2A2	Makk	Aug-02	3	1	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	7
MA2B2	Makk	Aug-02	10	2	2	0	0	2	0	1	0	2	0	0	0	15	0	0	0	0	0	0	0	0	0	34
MA2C2	Makk	Aug-02	1	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	9
MA2A3	Makk	Aug-02	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
MA2B3	Makk	Aug-02	16	0	0	0	0	1	0	0	0	6	0	0	0	0	0	1	1	0	0	0	0	0	0	25
MA2C3	Makk	Aug-02	0	2	1	0	0	2	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	8
MA3A1	Makk	Aug-02	14	3	11	1	0	5	0	0	2	0	0	0	0	2	0	0	0	0	0	0	30	0	0	68
MA3B1	Makk	Aug-02	4	0	5	0	0	1	0	0	2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	14
MA3C1	Makk	Aug-02	0	0	1	0	1	3	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	8
MA3A2	Makk	Aug-02	5	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	8
MA3B2	Makk	Aug-02	4	0	1	0	5	1	0	0	1	1	0	0	0	2	3	0	0	0	0	0	0	0	0	18
MA3C2	Makk	Aug-02	1	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4
MA3A3	Makk	Aug-02	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
MA3B3	Makk	Aug-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MA3C3	Makk	Aug-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals			2503	497	452	29	12	588	50	33	132	165	8	13	265	389	34	52	16	17	57	96	807	4	51	6270

Site	**Translation**
NA1A1	Nain, Hill Side A, Low Elevation, Horizon A, Sample 1
MA2C1	Makkovik, Side A, Mid Elevation, Horizon C, Sample 1

Code	**Taxa**	**Code**	**Taxa**	**Code**	**Taxa**
A	*Plectus*	I	*Euteratocephalus*	Q	*Mononchus sphagnii*
B	*Prismatolaimus*	J	*Teratocephalus*	R	*Daptonema*
C	*Monhystera 1*	K	*Hemicycliophora*	S	*Bunonema*
D	*Labronema*	L	*Tylenchus 1*	U	Unknown
E	*Ogma*	M	*Tylenchus 2*	V	*Aphelenchoides*
F	*Eudorylaimus*	N	*Achromadora*	W	*Zeldia*
G	*Wilsonema*	O	*Achromadora larvae*	Y	*Acrobeloides*
H	*Monhystera 2*	P	*Tylencholaimus*		

Appendix 4. Tardigrade raw data (June and August, 2002).

Site	Town	Season	*D. nod*	*D. pin*	*D. sco*	*D.* sp.	*D. ram*	*D. rec*	*E.* sp.	*H. con*	*M. ech*	*M. huf*	*M. har*	*M.* sp.	*M. spi*	*M. int*	Egg *M. ech*	Unidetified	Not Found	Totals
NA1A1	Nain	Jun. 02																		0
NA1B1	Nain	Jun. 02										3								3
NA1C1	Nain	Jun. 02										6								6
NA1A2	Nain	Jun. 02																		0
NA1B2	Nain	Jun. 02										2								2
NA1C2	Nain	Jun. 02										9								9
NA1A3	Nain	Jun. 02																		0
NA1B3	Nain	Jun. 02										2						1		3
NA1C3	Nain	Jun. 02																1		1
NA2A1	Nain	Jun. 02																		0
NA2B1	Nain	Jun. 02																	6	6
NA2C1	Nain	Jun. 02										2								2
NA2A2	Nain	Jun. 02																		0
NA2B2	Nain	Jun. 02					1													1
NA2C2	Nain	Jun. 02																	1	1
NA2A3	Nain	Jun. 02																		0
NA2B3	Nain	Jun. 02																	2	2
NA2C3	Nain	Jun. 02										1								1
NA3A1	Nain	Jun. 02																		0
NA3B1	Nain	Jun. 02																		0
NA3C1	Nain	Jun. 02																		0
NA3A2	Nain	Jun. 02																		0
NA3B2	Nain	Jun. 02											1						1	2
NA3C2	Nain	Jun. 02																		0
NA3A3	Nain	Jun. 02																		0
NA3B3	Nain	Jun. 02										1	5							6
NA3C3	Nain	Jun. 02																		0
HA1A1	Hope	Jun. 02																		0
HA1B1	Hope	Jun. 02																		0
HA1C1	Hope	Jun. 02																		0
HA1A2	Hope	Jun. 02										1								1
HA1B2	Hope	Jun. 02											1							1
HA1C2	Hope	Jun. 02																		0
HA1A3	Hope	Jun. 02									1	3							2	6
HA1B3	Hope	Jun. 02																		0
HA1C3	Hope	Jun. 02																		0
HA2A1	Hope	Jun. 02										3								3
HA2B1	Hope	Jun. 02											1							1
HA2C1	Hope	Jun. 02																	1	1
HA2A2	Hope	Jun. 02										1							1	2
HA2B2	Hope	Jun. 02										1	1							2
HA2C2	Hope	Jun. 02																		0
HA2A3	Hope	Jun. 02									1									1

Site	Town	Season	*D. nod*	*D. pin*	*D. sco*	*D.* sp.	*D. ram*	*D. rec*	*E*. sp.	*H. con*	*M. ech*	*M. huf*	*M. har*	*M* . sp.	*M. spi*	*M. int*	Egg *M. ech*	Unidetified	Not Found	Totals
HA2B3	Hope	Jun. 02										1	2							3
HA2C3	Hope	Jun. 02										1								1
HA3A1	Hope	Jun. 02																		0
HA3B1	Hope	Jun. 02																		0
HA3C1	Hope	Jun. 02																		0
HA3A2	Hope	Jun. 02																		0
HA3B2	Hope	Jun. 02																		0
HA3C2	Hope	Jun. 02																		0
HA3A3	Hope	Jun. 02									1								1	2
HA3B3	Hope	Jun. 02									1									1
HA3C3	Hope	Jun. 02							4											4
MA1A1	Makk	Jun. 02																		0
MA1B1	Makk	Jun. 02																		0
MA1C1	Makk	Jun. 02																		0
MA1A2	Makk	Jun. 02																		0
MA1B2	Makk	Jun. 02																		0
MA1C2	Makk	Jun. 02			1															1
MA1A3	Makk	Jun. 02																		0
MA1B3	Makk	Jun. 02																		0
MA1C3	Makk	Jun. 02																		0
MA2A1	Makk	Jun. 02																	1	1
MA2B1	Makk	Jun. 02																		0
MA2C1	Makk	Jun. 02																		0
MA2A2	Makk	Jun. 02								1									1	2
MA2B2	Makk	Jun. 02																		0
MA2C2	Makk	Jun. 02																		0
MA2A3	Makk	Jun. 02										1		1						2
MA2B3	Makk	Jun. 02																		0
MA2C3	Makk	Jun. 02																		0
MA3A1	Makk	Jun. 02										1		1						2
MA3B1	Makk	Jun. 02																	1	1
MA3C1	Makk	Jun. 02																		0
MA3A2	Makk	Jun. 02										1								1
MA3B2	Makk	Jun. 02																		0
MA3C2	Makk	Jun. 02																		0
MA3A3	Makk	Jun. 02																		0
MA3B3	Makk	Jun. 02																		0
MA3C3	Makk	Jun. 02																		0
NA1A1	Nain	Aug. 02										1								1
NA1B1	Nain	Aug. 02																		0
NA1C1	Nain	Aug. 02										1								1
NA1A2	Nain	Aug. 02																	1	1
NA1B2	Nain	Aug. 02										1								1
NA1C2	Nain	Aug. 02								2									1	3
NA1A3	Nain	Aug. 02																		0
NA1B3	Nain	Aug. 02										2								2
NA1C3	Nain	Aug. 02										2							1	3

Site	Town	Season	*D. nod*	*D. pin*	*D. sco*	*D. sp.*	*D. ram*	*D. rec*	*E. sp.*	*H. con*	*M. ech*	*M. huf*	*M. har*	*M. sp.*	*M. spi*	*M. int*	Egg *M. ech*	Unidetified	Not Found	Totals
NA2A1	Nain	Aug. 02																		0
NA2B1	Nain	Aug. 02					1													1
NA2C1	Nain	Aug. 02										1								1
NA2A2	Nain	Aug. 02																		0
NA2B2	Nain	Aug. 02										1							3	4
NA2C2	Nain	Aug. 02										2								2
NA2A3	Nain	Aug. 02																		0
NA2B3	Nain	Aug. 02																		0
NA2C3	Nain	Aug. 02										2			1					3
NA3A1	Nain	Aug. 02																		0
NA3B1	Nain	Aug. 02													3					3
NA3C1	Nain	Aug. 02													1					1
NA3A2	Nain	Aug. 02										3								3
NA3B2	Nain	Aug. 02										1							1	2
NA3C2	Nain	Aug. 02	4									5	1			1				11
NA3A3	Nain	Aug. 02										2								2
NA3B3	Nain	Aug. 02																		0
NA3C3	Nain	Aug. 02																		0
HA1A1	Hope	Aug. 02																		0
HA1B1	Hope	Aug. 02																		0
HA1C1	Hope	Aug. 02																		0
HA1A2	Hope	Aug. 02																		0
HA1B2	Hope	Aug. 02																		0
HA1C2	Hope	Aug. 02																		0
HA1A3	Hope	Aug. 02																		0
HA1B3	Hope	Aug. 02																		0
HA1C3	Hope	Aug. 02																		0
HA2A1	Hope	Aug. 02																		0
HA2B1	Hope	Aug. 02																		0
HA2C1	Hope	Aug. 02																		0
HA2A2	Hope	Aug. 02																		0
HA2B2	Hope	Aug. 02																		0
HA2C2	Hope	Aug. 02																		0
HA2A3	Hope	Aug. 02																		0
HA2B3	Hope	Aug. 02																		0
HA2C3	Hope	Aug. 02																		0
HA3A1	Hope	Aug. 02																		0
HA3B1	Hope	Aug. 02																		0
HA3C1	Hope	Aug. 02																		0
HA3A2	Hope	Aug. 02																		0
HA3B2	Hope	Aug. 02																		0
HA3C2	Hope	Aug. 02										1								1
HA3A3	Hope	Aug. 02									1									1
HA3B3	Hope	Aug. 02																		0
HA3C3	Hope	Aug. 02											3							3
MA1A1	Makk	Aug. 02																		0
MA1B1	Makk	Aug. 02																		0

Site	Town	Season	*D. nod*	*D. pin*	*D. sco*	*D.* sp.	*D. ram*	*D. rec*	*E*. sp.	*H. con*	*M. ech*	*M. huf*	*M. har*	*M*. sp.	*M. spi*	*M. int*	Egg *M. ech*	Unidetified	Not Found	Totals
MA1C1	Makk	Aug. 02											1							1
MA1A2	Makk	Aug. 02																		0
MA1B2	Makk	Aug. 02			4	1														5
MA1C2	Makk	Aug. 02											1							1
MA1A3	Makk	Aug. 02																		0
MA1B3	Makk	Aug. 02																		0
MA1C3	Makk	Aug. 02						2											1	3
MA2A1	Makk	Aug. 02																		0
MA2B1	Makk	Aug. 02																		0
MA2C1	Makk	Aug. 02																		0
MA2A2	Makk	Aug. 02																		0
MA2B2	Makk	Aug. 02																		0
MA2C2	Makk	Aug. 02																		0
MA2A3	Makk	Aug. 02		1		1					3								1	6
MA2B3	Makk	Aug. 02		2	2						8				1		2		1	16
MA2C3	Makk	Aug. 02		1									1						3	5
MA3A1	Makk	Aug. 02									2									2
MA3B1	Makk	Aug. 02											1				1			2
MA3C1	Makk	Aug. 02															1			1
MA3A2	Makk	Aug. 02									2								1	3
MA3B2	Makk	Aug. 02															2			2
MA3C2	Makk	Aug. 02			1												3			4
MA3A3	Makk	Aug. 02																		0
MA3B3	Makk	Aug. 02									2						2			4
MA3C3	Makk	Aug. 02																		0
Totals			4	4	8	2	2	2	4	3	22	65	19	2	6	1	11	2	32	189

Site	**Translation**
NA1A1	Nain, Hill Side A, Low Elevation, Horizon A, Sample 1
MA2C1	Makkovik, Side A, Mid Elevation, Horizon C, Sample 1

Code	**Translation**	**Code**	**Translation**
D. nod	*Diphascon nodulossum*	*M. har*	*Macrobiotus harmsworthi*
D. pin	*Diphascon pingue*	*M*. sp.	*Macrobiotus* species
D. sco	*Diphascon scoticum*	*M. spi*	*Mesocrista spitzbergense*
D. sp.	*Diphascon* species	*M. int*	*Minibiotus intermedius*
D. ram	*Diphascon ramazzottii*	Egg *M. ech*	*Macrobiotus echinogenitus* egg
D. rec	*Diphascon recamieri*		
E. sp.	*Echiniscus* species		
H. con	*Hypsibius convergens*		
M. ech	*Macrobiotus echinogenitus*		
M. huf	*Macrobiotus hufelandi*		

Appendix 5. Oribatid mite raw data (June and August, 2002).

Site	Town	Seas	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Totals
NA1A1	Nain	Jun. 02																0
NA1B1	Nain	Jun. 02									2	1		1				4
NA1A2	Nain	Jun. 02																0
NA1C2	Nain	Jun. 02									3							3
NA1C3	Nain	Jun. 02									3			1				4
NA1C3	Nain	Jun. 02																0
NA2B1	Nain	Jun. 02																0
NA2C2	Nain	Jun. 02									1							1
NA2B3	Nain	Jun. 02									1							1
NA3A1	Nain	Jun. 02																0
NA3B1	Nain	Jun. 02					1											1
NA3B3	Nain	Jun. 02					1											1
HA1A2	Hope	Jun. 02						1										1
HA1B2	Hope	Jun. 02					1											1
HA1C3	Hope	Jun. 02							1									1
HA2A1	Hope	Jun. 02							1									1
HA2C1	Hope	Jun. 02							1									1
HA2A2	Hope	Jun. 02					3											3
HA2B2	Hope	Jun. 02					1		1									2
HA2A3	Hope	Jun. 02					6			1								7
HA2B3	Hope	Jun. 02					9			1								10
HA2C3	Hope	Jun. 02	1															1
HA3A3	Hope	Jun. 02					2	5	1								1	9
HA3B3	Hope	Jun. 02			1		1											2
MA1B1	Makk	Jun. 02		1														1
MA1C1	Makk	Jun. 02					1											1
MA1B2	Makk	Jun. 02					3							1				4
MA1C2	Makk	Jun. 02					1											1
MA1B3	Makk	Jun. 02			1													1
MA1C3	Makk	Jun. 02		1			2											3
MA2B2	Makk	Jun. 02							1									1
MA2A3	Makk	Jun. 02					1											1
MA3B3	Makk	Jun. 02																0
NA1B1	Nain	Aug. 02									3			3				6
NA1C2	Nain	Aug. 02									1							1
NA1C3	Nain	Aug. 02																0
NA2C2	Nain	Aug. 02				1					2							3
NA3A1	Nain	Aug. 02					2											2
NA3B3	Nain	Aug. 02									3							3
HA1A1	Hope	Aug. 02					4											4
HA1B1	Hope	Aug. 02			1			1			1							3
HA1A2	Hope	Aug. 02						1	1									2
HA1B2	Hope	Aug. 02					5		1									6
HA1C2	Hope	Aug. 02							1									1
HA1A3	Hope	Aug. 02							2									2
HA1B3	Hope	Aug. 02					3											3
HA1C3	Hope	Aug. 02					2											2
HA2A1	Hope	Aug. 02															1	1
HA2C1	Hope	Aug. 02					1											1
HA2A2	Hope	Aug. 02																0
HA2B2	Hope	Aug. 02					1		6									7
HA2C2	Hope	Aug. 02					1		2									3
HA2A3	Hope	Aug. 02						1	4									5
HA2B3	Hope	Aug. 02													1			1
HA3B1	Hope	Aug. 02					2											2
HA3A3	Hope	Aug. 02					1											1
HA3C3	Hope	Aug. 02							1									1

Site	Town	Seas	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Totals
MA1A1	Makk	Aug. 02					1											1
MA1B1	Makk	Aug. 02												1				1
MA1C1	Makk	Aug. 02						1					1					2
MA1B2	Makk	Aug. 02					2							2				4
MA1C2	Makk	Aug. 02							1									1
MA1B3	Makk	Aug. 02					1				1			2				4
MA2A1	Makk	Aug. 02					1		1									2
MA2B1	Makk	Aug. 02					5		1									6
MA2C1	Makk	Aug. 02							2									2
MA2A2	Makk	Aug. 02					1											1
MA2B2	Makk	Aug. 02					5											5
MA2C2	Makk	Aug. 02														1		1
MA2A3	Makk	Aug. 02							1									1
MA2B3	Makk	Aug. 02						1										1
MA2C3	Makk	Aug. 02							1									1
MA3A1	Makk	Aug. 02						1										1
MA3B1	Makk	Aug. 02						1	2									3
MA3C2	Makk	Aug. 02					1											1
MA3A3	Makk	Aug. 02						1										1
MA3B3	Makk	Aug. 02							1									1
MA3C3	Makk	Aug. 02							1	1								2
Totals			1	2	3	1	72	14	35	3	21	1	1	11	1	1	2	169

Site	**Translation**
NA1A1	Nain, Hill Side A, Low Elevation, Horizon A, Sample 1
MA2C1	Makkovik, Side A, Mid Elevation, Horizon C, Sample 1

Code	**Taxa**	**Code**	**Taxa**
A	*Brachychthonius*	I	*Oppiella*
B	*Camisia*	J	Oripodoidea
C	*Cultroribula*	K	*Rhysotritia*
D	*Epidamaeus*	L	*Sellnickochthonius*
E	*Fuscozetes*	M	*Trhypochthonius*
F	*Limnozetes*	N	*Trimalaconothrus*
G	*Mycobates*	O	*Xenillus*
H	*Nothrus*		