Effects of simulated climate change on High Arctic soil arthropods at Alexandra Fiord, Nunavut, Canada using open-topped chambers.

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Abstract

The study of Arctic arthropods has been an ongoing project for decades. The relative simplicity of the ecological relationships in comparison to tropical or even temperate regions has made the Arctic an attractive study site. Relative simplicity, however, does not mean simple. The relationships between arthropods and their environment including interactions with plants, vertebrates and other arthropods are very complex and require a great deal of study to make sense of them. One of the main reasons Arctic arthropods have been studied recently, is their unique position to act as environmental indicators in regards to global warming. The increase in global temperature seen by many scientists is predicted to have its first and greatest effects in the global polar regions. Arthropods, being temperature and moisture sensitive, are prime candidates for basing climate change predictive models. The International Tundra Experiment (ITEX) open-topped chamber (OTC) program at Alexandra Fiord, Ellesmere Island, Nunavut, is one such study site where the arthropods are sampled from open field and OTC treatments. The OTCs increase the ambient air and soil temperatures by two to three degrees Celsius. By comparing populations of arthropods found in the two different areas, it is hoped that a model of population change can be created which will serve to indicate a climate shift. The use of arthropods should not convey the impression that the temperature change will be the direct cause of a fluctuation in population. It is possible that alterations in abundance of food sources as a result of increased temperatures will be the cause of population changes, as plants flourish or die back or as one species out-competes another for resources. Alternatively, changes in humidity levels may result in increased rates of desiccation, as occurs in some species of Collembola during periods of low humidity. During the summer of 2000, there was no significant difference found between the populations of OTC and control treatments of the most prevalent soil arthropods in the Arctic, the Collembola and the Acari. A number of possible reasons are given for this. The OTCs were researched and found to be adequate tools for the manipulation of temperature, but effects of other climatic variables could not be determined. The sampling plan used in 2000 was looked at and found to be of good design; however, some modifications are suggested.

Introduction

The Arctic has been the focus over the past couple of decades of many researchers looking to find reliable predictive measures of the effects of global warming. It is predicted, through the use of General Circulation Models (GCMs), that the earth's temperature is going to steadily increase as a result of global warming. The predicted temperature increase is 0.3 ^{0}C per decade for the globe as a whole (Environment Canada 1991), resulting from increases in the carbon dioxide, etc. concentrations in the atmosphere. The Arctic, specifically the area including Ellesmere Island and Alexandra Fiord, the study site, is predicted to have a winter temperature increase of 5 ^{0}C to 7 ^{0}C over the next 100 years and a 1 ^{0}C to 5 ^{0}C increase during the summer (Maxwell 1997). These temperature increases are markedly higher than ones predicted for sub-arctic, temperate and tropical areas (Strathdee *et al.* 1995), and will lead to changes in precipitation patterns, cloud cover, snow melt occurrence and density of snow pack (Callaghan *et al*. 1998). Increases in precipitation in the Arctic are expected to be in the range from 0 to 25%, occurring mostly in the summer and autumn months. Winter and spring months may, on the other hand, experience a decrease in precipitation from what they currently receive. GCMs also predict possible increases in soil moisture (Maxwell 1997). Danks (1992), however, suggests that the predictive value of GCMs for precipitation is limited, as cloud cover patterns and, therefore, subsequent precipitation events are very difficult to model, especially on a regional scale. Regardless of the magnitude of temperature increase, there will be changes to the ecosystems of the Arctic to which the biota must adapt.

The Arctic is poor, in terms of floral and faunal species, in comparison with the temperate and tropical regions of the world; however some areas, such as Alexandra Fiord are much richer, akin to an oasis in the Arctic desert (Danks 1992, Freedman *et al.* 1994, Labine 1994). Comprehensive volumes discussing geology, climate, flora and fauna have been published for Truelove Lowland on Devon Island (Bliss 1977) and Alexandra Fiord on Ellesmere Island (Svoboda and Freedman 1994). The lowland at Alexandra Fiord, which has been studied since 1979, is part of the International Tundra Experiment (ITEX) research program (Freedman *et al.* 1994, Molau 1996). It has a relatively rich diversity of plant life, with 92 species of vascular plants (Ball and Hill 1994), 93 species of mosses and liverworts (Maass *et al.* 1994), and at least 116 species of lichens (Maass and Nams 1994). There are no large mammals present in the lowland, such as muskox (*Ovibos moschatus*) (Henry *et* al. 1994); however some small ones do live there such as the arctic fox (*Alopex lagopus*) and the collared lemming (*Dicrostonyx torquantus groenlandicus*) (Freedman 1994b, Henry *et al*. 1994). The majority of animals present are arthropods and birds. The bird population consists of 27 species which makes the Alexandra Fiord bird diversity lowland unusually rich and abundant for this latitude (Freedman 1994a).

Due to the harshness of the region, there are fewer arthropods present than in areas further south (Birkemoe and Leinaas 2001). It is estimated that there are only 273 families of terrestrial arthropods in the arctic, composed of just over 2000 species which include 112 species of Araneae in 13 families, 349 species of Acari in 98 families, 91 species of Collembola in 11 families and 1547 species of Insecta in 148 families (Danks, 1981). The present day estimations are undoubtedly higher as Danks (1981) points out that the estimates for collembolan and acarian species is low. Alexandra Fiord boasts at least 6 families and 36 species of Collembola (Kukal 1994, Fjellberg 1986, Fjellberg 1994) and 5 families of Acari, represented by 6 species (Kukal 1994). Of the Insecta, the moth *Gynaephora groenlandica* is the most prominent species (Morewood and Ring 1998).

The arthropods of the arctic must be adapted to survive long harsh winters and short, cool summers. During the summer, some pollinating insects take advantage of the ‘solar furnaces’ of flowering plants, which, through concentration of incoming solar radiation, can increase air temperatures by 10^0C over the ambient air temperature (Cooley 1995). Most insects, such as the moth *Gynaephora groenlandica* Wocke (Lepidoptera: Lymantriidae) and the beetle *Hydroporus morio* Aube (Coleoptera: Dytiscidae), as well as Collembola such as *Hypogastrura tullbergi* Schaffer (Collembola: Hypogastruridae) (Addison 1977), utilize a strategy of an extended life cycle, combined with a mechanism of cold-hardiness to survive (Ring RA 1981; Ring RA 1982; O’Doherty and Ring 1987;

Moore and Lee 1991; Danks *et* al. 1994; Morewood and Ring 1998; DeBruyn and Ring 1999; Bocher 2001).

As the arthropods living in the arctic survive close to the limits of life, a rapid change in the temperature could be disastrous. A period of rapid cooling below the freezing level (-5 ^{0}C to -20 ^{0}C) in summer can lead to death as cold hardiness measures may not be in place (Coulson *et al.* 1995). For example, *H. tullbergi* have little or no cold tolerance adaptation present in the post-embryonic stages during the growth season. Birkemoe and Leinaas (2001) surmise that this may occur to allow the collembolan to make the most of the short warm season, which leaves it susceptible to rapid decreases in temperature (Coulson *et al*. 1995). Rapid, sustained increases in temperature can also be detrimental to soil arthropods. Temperature and humidity levels are crucial for arthropods such as Collembola (Hodkinson *et al.* 1996), as water loss increases with increasing temperature and decreasing humidity (Hayward *et al.* 2000). According to Hodkinson *et al.* (1996), Collembola and Acari should have no trouble surviving the temperatures predicted for the arctic in the GCMs, although Collembola are much more susceptible to desiccation than are Acari (Coulson *et al*. 1996, Hodkinson *et al*. 1996, Hayward *et al*. 2000) and may experience more difficulties adapting.

Collembola and Acari, the two most common arthropod taxa in the Arctic, can have very large densities on a global scale. In temperate and tropical regions, Collembola densities may get as to be as large as 200 000 per m^2 to 1 000 000 per m^2 at the extreme, while mite densities are often smaller, ranging up to about 80 000 per m^2. Densities are much lower in the High Arctic, often less than 1000 per m^2 (Hayward *et al*. 2000), but local variation may still be quite significant (Bocher 2001). Both orders are extremely important in the Arctic as decomposers of vegetation (Danks 1981, Brodo 2000, Bocher 2001).

Arthropods, especially mites and springtails, are thought to be good indicators of the effects of temperature increases, such as the ones predicted by GCMs. Birkemoe and Leinaas (2000) state that Collembola are good test subjects because of their free-running lifestyles, as well as their success and the fact that they do not rely upon seasonally occurring resources (plants are always decomposing). Because of this, Acari and Collembola are utilized in studies involving attempts to predict changes caused by global warming (Kennedy 1994, Coulson *et al.* 1996, Hodkinson *et al*. 1996, Birkemoe and Leinaas 2000, Hayward *et al*. 2000, Birkemoe and Leinaas 2001). A number of these studies have been done using climate manipulation devices such as open-topped chambers (OTCs), which artificially increase the ambient air and soil temperatures (and other variables, depending upon design) (Kennedy 1994, Coulson *et al*. 1995, Kennedy 1995, Coulson *et al*. 1996, Hollister and Webber 2000). Through this type of manipulation, it is hoped that the effects of temperature increases on high arctic flora and fauna can be determined.

This paper looks at arthropods collected from the Alexandra Fiord study site, using the ITEX OTCs and attempts to gain an understanding of the effects of the OTCs upon the soil arthropod populations through the comparison of numbers of captured specimens at OTC treatment sites and those captured at adjacent control treatment sites. The two main groups looked at will be the Collembola and the Acari. The OTC itself will be discussed in regards to its validity in temperature-ameliorating experiments. The sample design of the experiment will be looked at and recommendations for future study will be made.

Method

Site Description

The study site was located at Alexandra Fiord on east coast of Ellesmere Island, Nunavut (78^0 53’N, 75^0 55’W). It is a lowland approximately 8 km^2 surrounded by upland polar desert on the east and west, glacial ice on the south and seawater on the north (Muc *et al*. 1994). Three distinct vegetation sites were examined; the willow site situated in the lowland and dominated by *Salix arctic*; the granodiorite site and the dolomite site, both rocky, high level areas on the west edge of the lowland (Muc *et al*. 1994).

Collection Procedure

The study was performed utilizing two treatments, the first using Open Topped Chambers (OTCs) which were designed to increase the ambient air and upper soil temperatures by 2 – 3 ^{0}C and the second, the control treatments, situated in nearby open field areas of similar vegetation type as the corresponding OTCs. The OTCs used were the standard design described in the ITEX Manual as part of the International Tundra Experiment, an on-going polar research effort at several Arctic sites including Alexandra Fiord (Marion 1996).

Two different samples sets were collected; the Willow site data on July 29, 2000 and the Granodiorite and Dolomite site data on July 30, 2000 for a total of 24 samples, 12 from the OTC sites and 12 from the adjacent control sites. Soil cores measuring 5 cm in diameter and 10 cm in length (Ring RA. January 17, 2002. Personal communication), were collected from different OTCs and open-field control sites in three distinct vegetation areas. The same number of samples was taken from each treatment per vegetation site. A total of 16 samples were collected at the willow sites, 4 at the dolomite site and 4 at the granitic site. The soil cores were taken close to the inner edge of the OTC and the matching control core was taken within 2 meters of the OTC core, in the same vegetation regime. Soil cores were weighed and then extraction of the specimens was done at the University of Victoria, Victoria, British Columbia, utilizing a Berlese funnel over the time periods of August 4 to August 14, 2000 for the first sample set and August 14 to August 25, 2000 for the second (Ring RA. January 17, 2002. Pers. comm.). Extracted specimens were stored in 70% ethyl alcohol. Soil cores were further dried and weighed and the final dry mass recorded. Each sample of invertebrates was sorted using a dissecting microscope and a sorting tray. Individuals were then identified to order (except the nematodes), using keys in Borror *et al.* (1981) and Borradaile *et al.* (1961). The Collembola were then further identified to family using the keys of Clayton (1994) and Fjellberg (1985) and pictorial references from Maynard (1951). Collembola were identified using the American nomenclature instead of the European (Addison JA. November 28, 2001. Pers. Comm.)

Data Analysis

The results were analyzed using non-parametric statistical methods. Spearman's rank correlation coefficient (Havilcek and Crain 1988, Burt and Barber1996) was used to look at the relationship between the moisture content of the soil core samples and the number of specimens collected per treatment. The data were then divided into two sections per arthropod group; the first section represented the data for the OTC treatment and the second represented the data for the control treatment. The same tests were run on the Nematoda as were run on the arthropods. A Wilcoxon signed-ranks test (Heath 1995, Burt and Barber 1996) was used to analyze differences in the median of the number of arthropods collected per treatment for each vegetation site. The statistics were all computed using SPSS for Windows 10.0.5 (SPSS Inc. 1999).

Results

The Acari were found to be the most prevalent of the arthropod groups collected, with an overall total of 1023 individuals (Table 1). The Collembola were next in abundance, with 424 individuals. The other arthropod groups all had fewer than 50 individuals, with the adult Diptera only having 2 specimens, one of which was of the family Chironomidae (Diptera), the other unidentified. The larval Diptera were also identified as Chironomidae. The Isotomidae were the most common family of Collembola, with 297 specimens, followed by the Hypogastruridae, Onychiuridae and

Table 1. Total number of individuals collected by invertebrate group and Collembola family.

Group	Number of individuals	Collembola Family	Number of Individuals
Collembola	424	Isotomidae	297
Acari	1023	Hypogastruridae	71
Thysanoptera	45	Onychiuridae	45
Diptera (larvae)	38	Sminthuridae	11
Diptera (adult)	2		
Nematoda	29		

Sminthuridae. Most of the Sminthuridae (10 out of 11) were found at the willow site, control number 5.

The number of individuals captured in both the orders Collembola and Acari were greater in the control treatments than in the OTC treatments (Fig. 1). The Acari were most common in the control treatments with 589 individuals and 434 in the OTC treatments. There were 233 Collembola found in the control treatments and 191 in the OTC treatments. The Thysanoptera, Diptera larvae and the Nematoda all had more individuals collected from the OTC treatments than the control treatments. Of the Collembola, the Isotomidae were the most common, with 166 individuals collected in the control treatments and 131 in the OTC treatments (Fig. 2). The Hypogastruridae was the only family for which more individuals were collected from the control treatments than the OTC treatments.

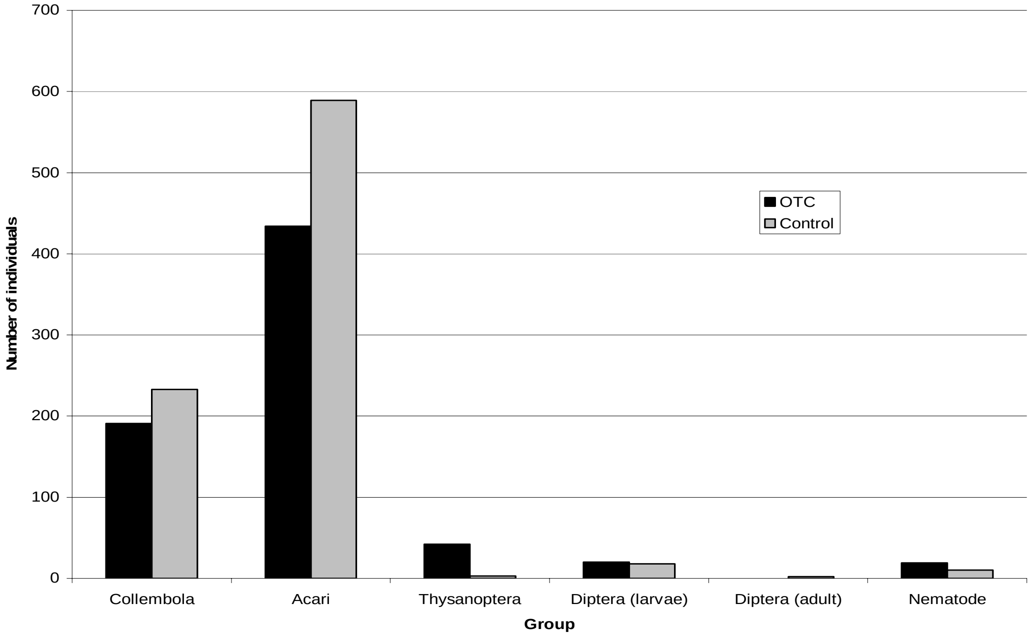

Figure 1. Total number of individuals collected per invertebrate group in OTC and control treatments.

The largest number of Collembola, Acari and Thysanoptera were obtained from the samples extracted beginning on August 4, 2000 (Fig. 3). The Isotomidae and the Hypogastruridae had slightly more individuals collected during the second extraction period (August 14 – August 25, 2000) than the first, but the Onychiuridae and the Sminthuridae had more individuals collected from the first extraction period (August 4 – August 14, 2000) (Fig. 4).

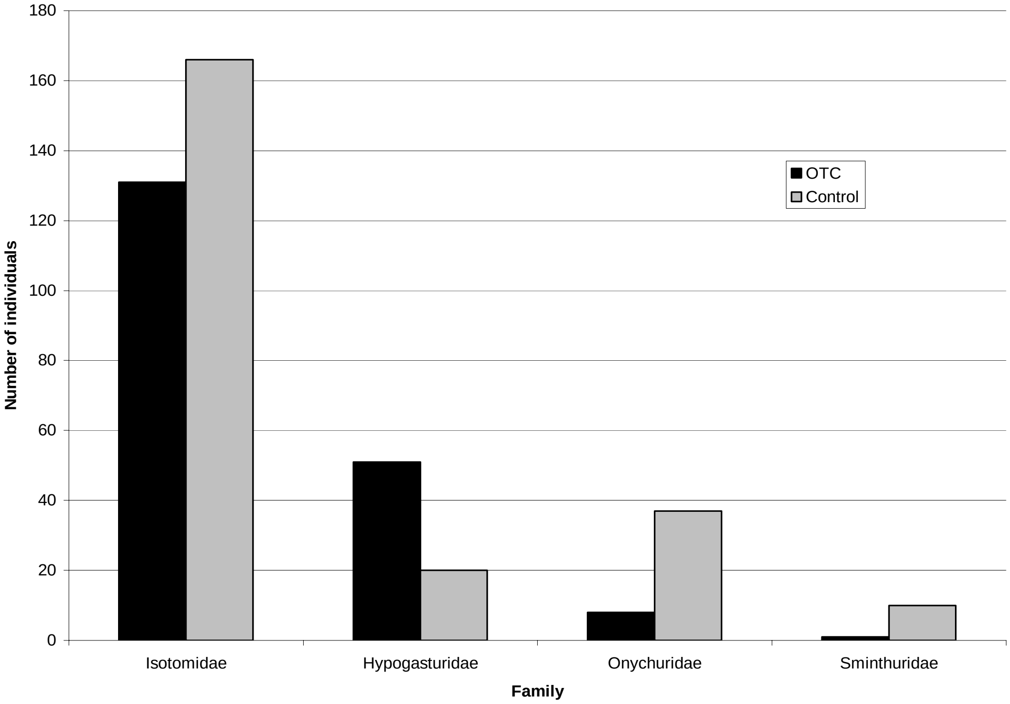

Figure 2. Total number of individuals collected per Collembola family in OTC and control treatments.

The total number of individuals collected at a specific treatment was dominated by the Acari collected at the willow treatments (Fig. 5). The Collembola and Isotomidae followed in size. The number of Acari collected at the willow control site was the largest with 548, followed by 268 mites collected at the willow OTC. The mean number of mites collected in the willow control treatment was 68.5. There were 271 mites captured

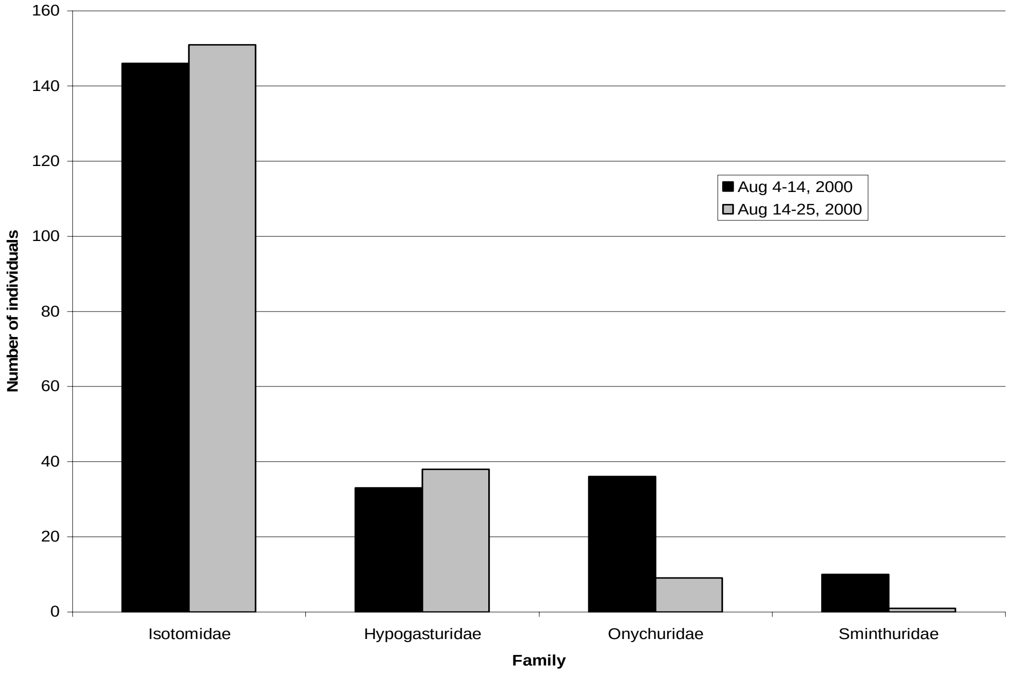

Figure 3. Total number of individuals collected for each invertebrate group per extraction period.

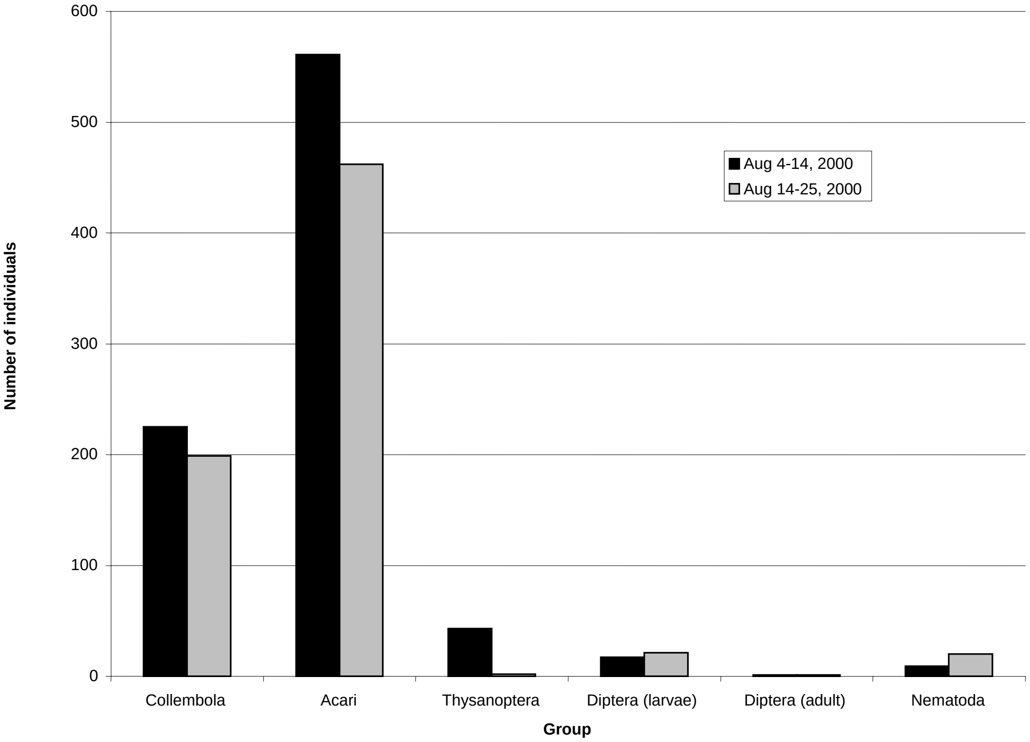

Figure 4. Total number of individuals collected for each Collembola family per extraction period.

at willow control #5, which may be a statistical outlier. Without this outlier, the mean number of mites in the willow control treatments dropped to 39.6. The next highest capture of Acari was 94 individuals from willow control #3. Of the other two vegetation sites, the granodiorite and dolomite, the granodiorite OTC had the higher number of mites collected, with 162 (Fig. 5). The Collembola extracted from the soil core for the willow control had the most individuals with 214. The willow OTC treatment had 140 individuals. The Isotomidae were the dominant collembolan family in terms of individuals collected at the willow treatments. Isotomidae accounted for 75.7% and 90.7% of the total Collembola captured at the willow control and OTC, respectively. Hypogastruridae collected from the granodiorite OTC accounted for 70.1% of all

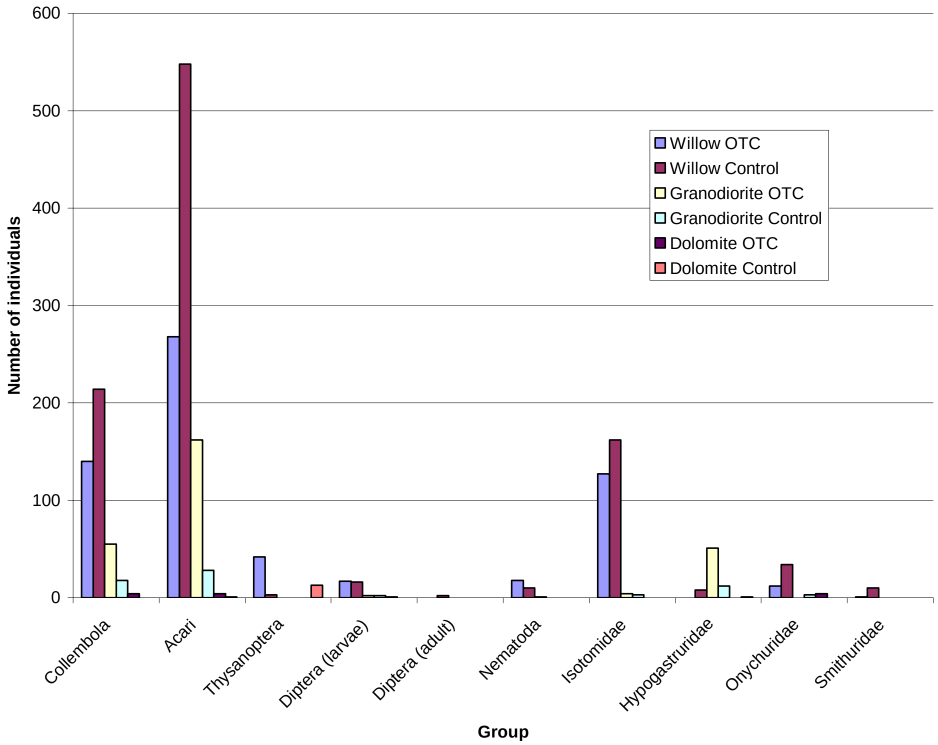

Figure 5. Total number of individuals collected per invertebrate group per treatment at each of three distinct vegetation sites.

Hypogastruridae collected in all treatments. The number of Diptera larvae found in the willow OTC and the willow control were similar (20 in the OTC, 18 in the control). Both of the Diptera adults were extracted from the willow control.

There was no significant correlation found between moisture content of soil cores and the number of individuals found per sample for each arthropod group, except in the adult Diptera (Table 2). The adult Diptera had a very significant weak positive correlation (r_s = 4360, $p_{\alpha = .05}$ = .0166, N = 24). There was no significant correlation between soil moisture content and the number of Collembola individuals extracted per family, except for the Onychiuridae, which had a significant weak positive correlation (r_s = .3751, $p_{\alpha = .05}$ = .0354, N = 24) (Table 3).

Table 2. Correlation of moisture content of soil sample core and number of individuals per invertebrate group using Spearman's rank correlation coefficient.

	Collembola	Acari	Thysanoptera	Diptera (larvae)	Diptera (adult)	Nematoda
r_s	.2982	.2238	.1569	.0345	.4360*	-.1029
Sig. (2-tailed)	.0785	.1465	.2320	.4364	.0166	.3161
N	24	24	24	24	24	24

* Correlation is significant at the .05 level (1-tailed).

Table 3. Correlation of moisture content of soil sample core and number of individuals per Collembola family using Spearman's rank correlation coefficient.

	Isotomidae	Onychiuridae	Hypogastruridae	Sminthuridae
r_s	.1675	.3751*	.2757	.0336
Sig. (2-tailed)	.2170	.0354	.0961	.4381
N	24	24	24	24

* Correlation is significant at the .05 level (1-tailed).

A Wilcoxon signed-ranks test showed no significant difference in median between any of the samples taken for either the arthropod groups or the Collembola families (Tables 4, 5).

Table 4. Determination of difference between the medians of paired OTC and control treatment data for each invertrebrate group using Wilcoxon signed-ranks test.

	Collembola	Acari	Diptera (larvae)	Diptera (adult)	Thysanoptera	Nematoda
Z	-0.7561[a]	0.0000[b]	-0.2108[c]	-1.4142[a]	-0.4472[c]	-0.8409[c]
Asymp. Sig. (2-tailed)	0.4496	1.0000	0.8330	0.1573	0.6547	0.4004
N	12	12	12	12	12	12

a. Based on negative ranks.
b. The sum of negative ranks equals the sum of positive ranks.
c. Based on positive ranks.

Table 5. Determination of difference between the medians of paired OTC and control treatment data for each Collembola family using Wilcoxon signed-ranks test.

	Isotomidae	Onychiuridae	Hypogastruridae	Sminthuridae
Z	-0.6675[a]	-0.9482[a]	-0.5345[c]	-0.4472[a]
Asymp. Sig. (2-tailed)	0.5045	0.3430	0.5930	0.6547
N	12	12	21	12

a. Based on negative ranks.
b. The sum of negative ranks equals the sum of positive ranks.
c. Based on positive ranks.

Table 6. Determination of difference between the medians of samples collected on August 4, 2000 and samples collected on August 14, 2000, for each invertebrate group using Wilcoxon signed-ranks test.

	Collembola	Acari	Thysanoptera	Diptera (larvae)	Diptera (adult)	Nematoda
Z	-0.3560[a]	-0.8240[b]	-0.7071[a]	-0.4165[b]	0.0000[c]	-1.1314[b]
Asymp. Sig. (2-tailed)	0.7218	0.4099	0.4795	0.6771	1.0000	0.2579
N	12	12	12	12	12	12

a. Based on positive ranks.
b. Based on negative ranks.
c. The sum of negative ranks equals the sum of positive ranks

Discussion

The Acari and Collembola were overall the most common arthropods found in both treatments, which was expected (Addison 1977, Danks 1980, Coulson *et al*. 1995, Winchester *et al*. 1999). The lack of significant difference between the samples taken within the OTCs and in the control treatments, however, was not expected. The temperature increase of no more than 3.5 ^{0}C on average over a summer season (Hollister and Webber 2000) has been shown to not be detrimental to soil arthropod populations. Therefore, theoretically, the increase in temperature within the OTCs should cause an increase in the length of the growth season, allowing for faster physiological development and a potential increase in food sources, leading to greater fitness and fecundity and, therefore, a larger population (Kennedy 1994). From the collected data, it can be seen that there is no significant difference between the populations of arthropods within the OTCs and at the control sites. This seems counter-intuitive, as the populations within the OTCs should theoretically be higher than those of the open-field controls.

The low numbers seen for the Collembola and the Acari in the OTC treatments are the result of a limiting factor which is not obvious. Summer temperatures for the year 2000 were not outside the normal for the past 11 years (Henry G. January 14, 2002. Pers. Comm.). This suggests that some other factor, such as lower than average precipitation, brief hot or cold periods, change in vegetation patterns and, therefore, food sources may be the cause of the low populations in the OTCs. Possibly a change in vegetation structure has altered the food resources available, allowing one group of Collembola to out-compete another group, lowering the population (*i.e.* Isotomidae out-competing Hypogastruridae). It is more likely that a decrease in food resources has occurred, affecting all of the species present.

The low populations may also be the result of a trauma from one or two growth seasons previous or from winter mortality. As Coulson *et al*. (1996) observe, soil arthropods are slow to respond to temperature changes due to the buffering capacity of their environment. Collembola and Acari often have life-cycles longer than one year, which may result in changes in their populations lagging behind an increase in temperature (Kennedy 1994, Coulson *et al*. 1996). However, the eleven years that the OTCs have been present should not cause any fluctuation in population, as the arthropods have had a long period to equilibrate with the temperature increases. They may, however, be slow to bounce back from a traumatic temperature increase, summer drought or a particularly harsh winter. Acari are less susceptible to higher temperatures and desiccation than are Collembola, but they seem to have been affected as well. The effects of temperature increases upon soil arthropods are difficult to predict as the habitat in which they live is already harsh and highly variable (Coulson *et al*. 1996).

Moisture deficit may be a more probable mortality factor than high temperatures in the case of Collembola and some species of Acari. Hodkinson *et al*. (1996) have shown that some species of Arctic Collembola (*H. tullbergi*), can tolerate temperatures as high as 35 ^{0}C for short periods of time (< 3 hours) when the humidity was high (R.H. = 100%), but at R.H. = 0%, *H. tullbergi* had 100% mortality before 3 hours at 10^{0}C while *Onychiurus arcticus* Tullberg, had limited survival up to 20^{0}C. The same temperature and humidity tests were run on Arctic Acari. The mites displayed little change in survival rates between the two humidity levels. This result showes that the moisture content of the soil and air needs to be very high for the survival of Collembola and that desiccation is a major factor in mortality, possibly more so than temperature. Collembola and Acari have been found to have low mortality at reasonable Arctic temperatures (Hodkinson *et al.* 1996).

Another possible reason for lower than expected populations is a cooler than normal summer. Callaghan *et al*. (1998) suggest that soil temperatures may be lower than expected in the OTCs as expanding vegetation canopy decreases the amount of solar radiation reaching the soil surface. The decrease in incoming radiation would limit the physiological development of the soil inhabitants, possibly lowering fecundity. However, mortality due to lower than normal temperatures should not be a significant factor (Kennedy 1994).

The lack of correlation between soil moisture and arthropod abundance suggests that the arthropods may be able to tolerate a fairly wide range of moisture levels. There are no data, however, describing the position in the soil column where each individual was at the time of sampling or what the moisture content was at different soil depths. It, therefore, cannot be determined if the invertebrates collected have a wide range of moisture content tolerance. The presumed outlier in the Acari data set of 271 individuals did not affect the results of the Wilcoxon signed ranks test. Both outcomes were the same, with no difference in population seen between the OTC and control treatments. This is due to the nature of this particular non-parametric test (Burt and Barber 1996).

The dominance of Isotomidae in the collected samples may be the result of identification error. Some of the Hypogastruridae may have been identified incorrectly as Onychiuridae, as some species appear very similar (no furcula, white) (Addison JA. November 28, 2001. Pers. Comm.). Three of the samples (Willow Control 7, Dolomite OTC 2 and Dolomite Control 1) were difficult to identify individuals from, as it appeared the ethyl alcohol had been allowed to evaporate from the storage vials, resulting in desiccation of the specimens and subsequent difficulty in identification. The presence of numerous larvae of the family Chironomidae was not surprising, as the chironomids are one of the most abundant Diptera families in the Arctic. Identification of these larvae to species level may reveal a large diversity (Brodo 2000).

A look at the sample design reveals that it is sound, as it is based on the principle of stratified random sampling (Lohr 1999), but problems with computing statistics arise due to the number of samples taken. The low number of samples per treatment (N = 12 for both), is problematic in analysis as many parametric tests rely upon larger samples to establish a semblance of normalcy. The samples were not normally distributed and had to be analyzed using non-parametric methods. A larger number of samples may allow for the use of the more powerful parametric tests such as ANOVA (one-way analysis of variance) (Burt and Barber 1996). The use of only one sample per site creates the additional problem of outliers in the data (Wadely 1967, Burt and Barber 1996). The single sample may fall in an area of extremely rich food resources due to the death of a plant for example, which would lead to large population numbers for some species collected. On the other hand the single sample may land in a denuded region of the sample area which could contain no specimens. The finding of 271 Acari in the Willow Control #5 site may be the result of an outlier of the first type, but it may also be a good representation of the population of mites in the sample sites. It is impossible to tell as only one sample was taken from this site and there is no other data to compare to.

Improvements could be made by increasing the number of OTC and control treatments sampled per vegetation site, for example, take soil cores from 3 OTCs per site instead of one. However, taking more than one core per OTC may be too much for the micro-ecosystem to handle. Including temperature and humidity data with the data from the soil cores would be an excellent practice thereby ensuring that an accurate assessment of invertebrate data would ensue. The numbers of specimens collected could be analyzed for correlation with ambient air, surface and soil temperatures, as well as humidity.

The ITEX OTCs allow for incoming precipitation due to the design, however, they have solid sides which do not allow wind to pass over the vegetation inside the chamber as it normally would (Marion 1996). This effectively decreases wind shear on vegetation within the OTC, which may allow for changes in plant architecture, affecting the arthropod community (Hollister and Webber 2000). These variations in climatic variables may contribute to differences in populations seen within the chambers versus outside. A broad statement saying that temperature is the sole factor involved in the changing the population dynamics may be incorrect. More study could be done in this area, determining the effect of a decrease in wind velocity and subsequent vegetation pruning and the relationship to soil arthropod populations.

Passive greenhouses, such as the OTCs, are used in many studies; however, they are not fully understood in respect to the modes of interaction with the natural environment (Kennedy 1995). *A priori* testing, like that done by Hollister and Webber (2000) reinforce the theory that OTCs are effective tools for ameliorating temperatures of surface air and upper levels of soil within the chamber. They discuss, however, the lack of wind shear inside the chamber, which may naturally limit the growth of plants by active pruning.

In a passive greenhouse study conducted by Callaghan *et al*. (1998), it was shown that a sub-arctic dwarf shrub heath increased in abundance, but not biomass when areas were covered with small greenhouses. The heath plants took advantage of warming by becoming more reproductively active and plant response to temperature manipulations was found to be greater in cold summers than warm. Other plant groups, such as lichens, did not do well in periods of higher temperatures and showed decreases in abundance as summer warming increased. Regardless, Callaghan *et al.* (1998) think that most Arctic plants will be able to easily tolerate the predicted temperature increases over the coming decades, although each species has its own unique responses to climate changes (Danks 1999).

Arthropods, such as Acari and Collembola have also been studied. Coulson *et al*. (1996) discovered that mite populations were not affected by temperature increases after an experiment which utilized polythene tents over a period of three years at two sites, a tundra heath and a polar semi-desert. Collembolans enumerated at the same sites showed a decrease in numbers inside the tents at the polar semi-desert site, but not at the tundra heath site, nor in the open-field control treatments. They attributed the low numbers to summer desiccation and winter mortality.

The most likely cause of the low numbers in the OTCs is a brief high temperature event, which could result in the desiccation of both Collembola and Acari within the OTCs. This event would most likely have occurred either prior to sampling in the summer of 2000 or near the end of the previous summer. However, the soil acts as a thermal buffer and protects the soil arthropods, especially as they move deeper (5cm to 10cm) into the soil column, to escape high temperatures on the surface (Coulson *et al*. 1996). The real problem would be rapid desiccation of the soil, occurring quicker than the arthropods can move to areas with higher moisture levels. As there has been very little done on the relationship between arthropods and their preferences for humidity ranges and how these ranges change with temperature (Hayward *et al.* 2000), it is possible that periods of low humidity and high temperature affected the Collembola and Acari within the OTC more than in the control treatments.

A more detailed look at the specimens collected, involving identification to species would be useful to allow comparison of specimens between years, in terms of diversity. The numbers of specimens per order or family are adequate for comparisons of density between sites and over seasons. Collection of more samples from both the OTC and control treatments would also improve the experiment. A study of the daily and diurnal temperature means as well as precipitation records for the days prior to sampling would help in eliminating certain unknowns, which could have resulted in the lower populations of soil arthropods in the OTCs. Comparisons with previous years would also help to clarify the reasons for low populations in the OTCs.

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