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Biodiversity and ecology of terrestrial arthropods on *Umingmat Nunaat* (Axel Heiberg Island), in the High Arctic

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Abstract

Rapid warming is threatening terrestrial ecosystems in the High Arctic. Despite the urgency to understand the situation, there is still much that we do not know about the effect that recent climate warming is having on High Arctic terrestrial ecosystems. Terrestrial arthropods, which are abundant on High Arctic tundra, are ideal focal organisms for monitoring programs aimed at studying terrestrial ecosystems in the High Arctic. *Umingmat Nunaat*, or Axel Heiberg Island, is a very remote location in High Arctic Canada, whose human presence is limited to one seasonally occupied field station operated by McGill University. The McGill Arctic Research Station (MARS) has been in operation since 1960, yet knowledge of terrestrial arthropod communities on *Umingmat Nunaat* is limited.

I studied the biodiversity and ecology of terrestrial arthropods on *Umingmat Nunaat*. Terrestrial arthropods were sampled using yellow pitfall traps at four sites (replicates) in the local area of the McGill Arctic Research Station. A total of 37,935 terrestrial arthropods belonging to 29 morphological groups were collected. Using field collected data, relationships of microhabitat, climate, and seasonality were revealed for terrestrial arthropod assemblages on *Umingmat Nunaat*.

As rapid climate warming threatens the Arctic, the establishment of an arthropod monitoring program on *Umingmat Nunaat* fills a knowledge gap in our understanding of the functioning and dynamics of terrestrial ecosystems in the High Arctic, including how these ecosystems are being impacted by recent climate change. In this thesis, I present a baseline for future ecological monitoring of terrestrial arthropods at the McGill Arctic Research Station on *Umingmat Nunaat* in High Arctic Canada.

Résumé

Le réchauffement climatique rapide menace les écosystèmes terrestres du Haut-Arctique. Malgré l'urgence que représente la compréhension de la situation, il y a encore beaucoup de choses que nous ignorons sur l'effet du réchauffement sur ces écosystèmes terrestres du Haut-Arctique. Les arthropodes terrestres, qui abondent dans la toundra du Haut0-Arctique, sont des organismes cibles idéaux pour les programmes de surveillance visant à étudier les écosystèmes terrestres du Haut-Arctique. L'Île Axel-Heiberg est un endroit particulièrement isolé du Haut-Arctique canadien, dont la présence humaine se limite à une station de recherche occupée de façon saisonnière par l'Université McGill. Cette station de recherche arctique McGill (MARS) est en activité depuis 1960, mais les communautés d'arthropodes terrestres de l'Île Axel-Heiberg n'ont jamais été étudiées en détail.

L'objectif principal de cette thèse est d'étudier les relations entre les arthropodes terrestres et leur environnement sur l'Île Axel-Heiberg, dans le Haut-Arctique, comme données de référence pour un programme de surveillance écologique à long terme au sein de la station de recherche arctique de McGill. Le chapitre 1 établit le contexte et la finalité de la recherche en exposant une synthèse documentaire sur les arthropodes terrestres de l'Arctique et leurs relations avec leur environnement, ainsi que l'importance des projets de surveillance et en bred aperçu de l'histoire de l'Île Axel-Heiberg. À l'aide des données recueillies sur le terrain, le chapitre 2 examine les relations entre le terrain, le climat et la variation saisonnière révélées grâce à cette collecte préliminaire d'arthropodes terrestres sur l'Île Axel-Heiberg, et définit également un protocole de collecte facilement reproductible. À l'aide des données recueillies sur le terrain, des relations entre le microhabitat, le climat et la variation saisonnière sont apparues en ce qui concerne les divers groupes d'arthropodes terrestres sur l'Île Axel-Heiberg. Les arthropodes terrestres ont été échantillonnés à l'aide de pièges jaunes sur quatre sites dans la zone de recherche de la station de recherche arctique de McGill. Un total de 37 935 arthropodes terrestres appartenant à 29 groupes morphologiques ont été collectés. Des préférences distinctes en matière de terrain ont été révélées pour les taxons dominants au sein des mouches et des collemboles. Peu de corrélations significatives entre les arthropodes et le climat one été trouvées, avec les exceptions suivants : L'indice de diversité alpha de Fisher a présenté une corrélation négative significative et très forte avec la vitesse moyenne du vent; l'abondance des tipules a révélé une corrélation positive

significative et très forte avec la température moyenne de l’air; et l’abondance des guêpes parasitoïdes a présenté des corrélations positives très fortes avec la température moyenne de l’air et la pression barométrique moyenne. Dans l’ensemble, l’abondance des arthropodes était la plus élevée au milieu de la période d’étude (les 18 et 19 juillet), bien que certains groupes morphologiques n’aient pas observé ces modèles généraux de phénologie.

Alors que le réchauffement climatique rapide menace l’Arctique, la mise en place d’un programme de surveillance des arthropodes sur l’Île Axel-Heiberg comble une lacune dans notre compréhension du fonctionnement et de la dynamique des écosystèmes terrestres du Haut-Arctique, y compris la façon dont ces écosystèmes sont affectés par le récent changement climatique. Dans cette thèse, je présente une étude de terrain des arthropodes terrestres qui a pour vocation d’orienter la surveillance écologique future au sein de la station de recherche arctique de McGill sur l’Île Axel-Heiberg dans le Haut-Arctique canadien.

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Thesis Format

This thesis is organized into two chapters. Chapter 1 is a literature review that introduces the main themes of the thesis as well as the research questions and objectives. Chapter 2 is written in manuscript style and will be submitted to *The Canadian Entomologist*.

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Contribution of authors

I collected all the data, inventoried all the arthropods, and wrote all of the original manuscript and literature review in this thesis. My supervisors, Hans C. E. Larsson (McGill University) and Christopher M. Buddle (McGill University), are co-authors for Chapter 2, having contributed to the conceptual design for the project and also provided inputs and edits to the manuscript. All other contributions by colleagues are outlined in the acknowledgements sections.

Chapter 1: Introduction and Literature Review

1.1 Research Objectives

The objective of this thesis is to explore the relationships of terrestrial arthropods and their environment on *Umingmat Nunaat* (Axel Heiberg Island), in High Arctic Canada. This fills a vital knowledge gap in our understanding of the functioning of terrestrial ecosystems in the High Arctic, and establishes a baseline for future arthropod monitoring at the McGill Arctic Research Station. Chapter 1 establishes the context and rationale for the research by presenting a literature review about Arctic terrestrial arthropods and their relationships with their environment, as well as the importance of monitoring projects and a brief history of *Umingmat Nunaat*. Chapter 2 examines relationships of ground cover, climate, and seasonality that were revealed from this baseline collection of terrestrial arthropods on *Umingmat Nunaat*, and also establishes an easily repeatable collecting protocol. In Chapter 2, I am specifically asking the following questions:

- What comprises the biodiversity of terrestrial arthropod communities on *Umingmat Nunaat*?
- What are the relationships of terrestrial arthropods and their environment on *Umingmat Nunaat*? (Further subdivided into three parts):
    - How does ground cover relate to terrestrial arthropod abundance and diversity on *Umingmat Nunaat*?
    - How does climate (air temperature, solar radiation, windspeed, barometric pressure) relate to terrestrial arthropod abundance and diversity on *Umingmat Nunaat*?
    - How does seasonality relate to terrestrial arthropod abundance and diversity on *Umingmat Nunaat*?

Answering these questions will: (a) reveal how terrestrial arthropod communities are structured by their environment on *Umingmat Nunaat*, and (b) provide a baseline for future arthropod monitoring work at the McGill Arctic Research Station on *Umingmat Nunaat*.

1.2 Climate change and Arctic arthropods

1.2.1 Climate change and the Arctic

Recent climate change, largely attributed to human activities, is of great global concern. In the 2000s, the Arctic Council—an intergovernmental forum consisting of eight Arctic nations, six indigenous peoples' organisations, and official observers—commissioned the Arctic Climate Impact Assessment; this four-year international effort by 300 scientists concluded that climate change is expected to accelerate over the next 100 years, contributing to major physical, ecological, social, and economic changes, many of which have already begun (Hassol & Correll 2006). On a global scale, the Intergovernmental Panel on Climate Change (2022) concluded that climate change has altered marine, terrestrial, and freshwater ecosystems around the world, leading to local species losses, increases in disease, mass mortality events of plants and animals, and causing measurable economic and livelihood losses and altered cultural practices and recreational activities around the world. For the Arctic region, there is high confidence that climate change is responsible for observed changes to ecosystem structure and phenology in terrestrial and marine ecosystems, and species range shifts in terrestrial, freshwater, and marine ecosystems (IPCC 2022). With current projections of climate warming, species and ecosystems in polar areas will face temperatures beyond their historical experience in the coming decades (IPCC 2022).

Because of this observed and anticipated dramatic climate change and its impacts on societies and ecosystems, research interest in the Arctic is accelerating (Høye & Sikes 2013). Arctic ecosystems and biota are already under pressure, and are particularly vulnerable to current and projected future global warming (Callaghan et al 2004). With recent climate change, species richness in the Arctic will increase through time, causing a potential state shift across the Arctic landscape, while tundra species will decrease in range and abundance as they are forced into refugial areas (Hope et al 2015). Sea level is very likely to rise in future, further restricting the area of tundra and other treeless Arctic ecosystems (Callaghan et al 2004). Co-occurring environmental changes such as enhanced levels of UV-B, deposition of nitrogen compounds from the atmosphere, heavy metal and acidic pollution, radioactive contamination, and increased habitat fragmentation are also happening on an unprecedented scale, and are negatively affecting Arctic ecosystems (Callaghan et al 2004).

1.2.2 Arthropods in the Arctic

During the Pleistocene epoch, glacial ice exterminated the fauna from most parts of Canada, except in refugia where the climate nevertheless changed considerably (Danks 1993). In the aftermath of the last ice age, glaciers retreated and organisms invaded the initially sterile terrain (Danks 1993). These communities changed by addition, loss, and interaction of species, and progressive modifications of the habitat brought greater structural complexity (especially of higher plants), and greater availability of resources such as the accumulation of organic matter, the development of vegetation, and the entry of hosts for parasitoids and ectoparasites (Danks 1993).

In present-day Canada north of 60"N, far more insect and spider species occur in the west than in the east (Danks 198l, Loboda & Buddle 2018). Some of this difference results from the less harsh arctic conditions in the western than in the eastern arctic, and from the fact that the treeline boundary is much less sharp there than in the east, because alpine and arctic zones interlock only in the west (Danks 1993). Isotherms and other climatic indicators curve northward toward the west in mainland North America, so that the Yukon Territory has habitats that are much less harsh than eastern Canadian habitats at the same latitude; therefore, some species recorded on tundra in western Canada may be less truly arctic than their eastern counterparts (Danks 1993). These patterns of northern insect diversity in Canada are consistent with post-glacial migration and colonisation by arctic species—including spiders—from the Beringian refugium (Danks l98l, Loboda & Buddle 2018). The abundance of marginally arctic and low arctic species in the west, and the harsher conditions of the eastern arctic, mean that current ecological factors as well as the history of dispersal from Beringia would produce similar reductions in diversity toward the east (Danks 1993).

Wind and trans-oceanic dispersal help to explain the distribution of some Arctic arthropods. Some soil-dwelling High Arctic arthropods are known to have enough tolerance of seawater to be able to survive long-distance trans-oceanic dispersal (Coulson et al 2002a). In Antarctica, springtails have been shown to be regularly relocated by wind dispersal across terrestrial habitats (Hawes et al 2007). Wind dispersal likely explains why about 75 % of the collembolan species of the Queen Elizabeth Islands of High Arctic Canada have a circumpolar or Holarctic distribution (Fjelleberg 1986). In High Arctic Canada, McAlpine (1965) hypothesised that the entomofauna of harsh Ellef Ringnes Island was introduced via wind dispersal, the source of these arthropods being from the relatively more biologically rich Axel Heiberg Island just 128 km away; strong gales could transport airborne specimens across this distance in a matter of four or five hours, with Amund Ringnes Island, situated between the two, likely acting as a stepping stone for colonization (McAlpine 1965). In Svalbard, a wind dispersal event led to the introduction of a non-resident species of moth in 2000 (Coulson et al 2002b).

On the treeline, almost all the insect orders found in Canada, and many of the major families, are still represented (Downes 1962). In more northern zones (and also in alpine regions), Orthoptera, Hemiptera, and notably Coleoptera decrease in diversity, whereas the Diptera increase (Danks 1993). The large number of Diptera and small number of Coleoptera in arctic zones is especially striking, with beetles comprising just 13% of the insect fauna of the tundra zone worldwide (Chernov et al 2014). More boreal and arctic than temperate species appear to be saprophages and predators, which typically are generalists eating a range of foods in those categories, even though specialist forms are not uncommon (Danks 1980, Danks 1981). Food plant relationships are distorted in the arctic, where the numbers of herbivores are relatively low to begin with, because certain plants such as willows (*Salix spp.*) carry many more herbivorous species than others (Danks 1987), apparently because they are especially nutritious (Danks 1993). In contrast to herbivores where the number of is low compared to availability of host plants, the diversity of parasitoid wasps in the Arctic is relatively high compared to the number of potential hosts (Danks 1993). However, in the Zackenberg Valley of High Arctic Greenland, the wolf spider *Pardosa glacialis* Thorell is apparently free from parasitism by parasitoid wasps that are known to attack the egg sacs of this species at lower latitudes (Koltz et al 2019).

Although some insect species are confined to, or at least concentrated in, arctic zones, many species recorded from these regions inhabit only parts or even fragments of the zones (Danks 1993). Danks (1981) placed arctic insect species into three categories: (1) tundra specialists, (2) species more widely distributed in North America that enter the arctic to varying degrees, and (3) southern species that only just enter the southern arctic.

Within a given zone, and especially as they reach the northern limits of their distribution, organisms are not distributed homogeneously, but are confined to suitable habitats even on a small scale (Danks 1993). This situation is most conspicuous as organisms reach the northern limits of their distribution, where climatic conditions are more harsh, areas of suitable habitat fragment, and populations become reduced and discontinuous (Danks 1993). Even in the high arctic, isolated rich sedge meadows grow in especially favoured sites where moisture is adequate and climates are ameliorated, but comprise only a few percent of the landscape (Babb & Bliss 1974); most of the arctic insect species live in these places (Danks 1981). At a still smaller scale, small patches of arctic vegetation support more species, and much larger populations, than unvegetated areas (Chernov et al. 1977). Because many insect species, at least in arctic and boreal zones, appear to respond more-or-less independently to environmental factors, rather than as a fixed set of species or "community," habitat is the key to understanding their distribution and diversity (Danks 1993).

Arctic insects show a wide range of adaptations to the extreme severity and seasonality of their environment. Important adaptations may be found in morphology (e.g., size, wings), behaviour (e.g., activity patterns, thermoregulation), life cycles, and ecophysiology (e.g., cold hardiness, anaerobiosis, desiccation resistance) (Strathdee & Bale 1998). Cold hardiness in Arctic insects includes freeze tolerance and extreme supercooling abilities, and Arctic insects may behaviourally seek out protected sites in which to overwinter (Danks 2004). Soil-dwelling invertebrates in the High Arctic show incredible tolerance and survivability both to extreme cold and to rapid and large fluctuations in temperature (Hodkinson et al 1998, Coulson & Birkemoe 2000, Convey et al 2015). Arctic insects may show melanism and increased hairiness to trap and absorb more heat (Danks 2004). In the brief, cool summers, they may bask to stay warm and may preferentially choose warmer microhabitats to keep active (Danks 2004). Some Arctic insects may even bask in heliotropic flowers such as *Dryas integrifolia* Vahl and *Papaver radicatum* Rottbøll, which focus heat and generate considerable intrafloral temperatures as they track the sun across the sky (Kevan 1975). Life cycles may be shortened to fit into the brief summers, or otherwise prolonged through diapause (Danks 2004).

1.2.3 Roles of Arctic arthropods in their environment

Invertebrates play significant ecological roles and have a direct impact on ecosystem services, whether impacts on soils at plot and landscape scales, to participating actively in the interactions that develop in soil among physical, chemical and biological processes (Lavelle et al 2006). Detritus-based microinvertebrates, and their predators within the soil and surface-dwelling communities are major drivers of carbon and nitrogen cycling, and changes to their structure and composition are likely to impact nutrient dynamics within tundra ecosystems (Koltz et al 2018a).

Arthropods provide important pollination services in the Arctic. Many plant species in the High Arctic are entirely or almost entirely dependent on insect pollination for seed-set to occur, or are otherwise dependent on pollination in order for maximum seed-set to occur (Kevan 1972). At Lake Hazen, High Arctic Canada, *Dryas integrifolia* Vahl plants growing closer to water produce more seeds than those growing in drier areas—a reflection of the availability and abundance of insect pollinators in those different habitats (Kevan 1972). In Zackenberg Valley, High Arctic Greenland, the diverse community of pollinators visiting *D. integrifolia* plants includes two-thirds of all insect species known from the area (Tiusanen et al 2016). The dominant pollinators in the Arctic are the Diptera, or true flies (Elberling & Olesen 1999). In Zackenberg Valley, abundance of muscid flies (Diptera: Muscidae) in particular was a key predictor for seed-set in *D. integrifolia* (Tiusanen et al 2016). A detailed study of the plant-pollinator network on Uummannnaq Island off the west coast of Greenland revealed all species involved in that network to be closely linked, meaning that any disturbance is spread quickly to the entire network (Lungren & Olesen 2005).

Arthropods form an integral part of Arctic food webs. High Arctic food webs are more open systems than previously thought, receiving energy and nutrient subsidies from allochthonous wind-blown insects and detritus (Hodkinson & Coulson 2004); on nunataks (ice-free areas) of a retreating glacier in Iceland, it was difficult to determine whether some arthropod taxa were established or allochthonous (Ingimarsdóttir et al 2013). A food web constructed of the microbial-invertebrate community of the northern Alaskan tundra found that 99.6% of carbon processed by the invertebrate food web is derived from detrital resources, while 0.06% comes from the consumption of live plants (Koltz et al 2018a). A highly resolved Arctic food web from the Zackenberg Valley of High Arctic Greenland suggests that species in that web are highly connected, with a dense link structure and no compartmentalization or modularity across three predator guilds; thus, both individual predators and predator guilds tap heavily into the prey community of each other (Wirta et al 2015). At Zackenberg, the wolf spider *Pardosa glacialis* Thorell may feed on the predator, the herbivore, the decomposer and/or the pollinator guilds of the food web, thereby diluting the predation pressure in multiple directions (Visakorpi et al 2015). Species interactions and food web dynamics are changing in the Arctic, with potential implications for key ecosystem processes such as decomposition, nutrient cycling and primary productivity (Koltz et al 2018b).

1.2.4 Local-scale distribution of Arctic arthropods

The Arctic tundra is a strongly heterogeneous environment for arthropods to live in (Strathdee & Bale 1998 Hansen et al 2016a). Schaffers et al (2008) found that in grassland habitats, local plant species composition is the most effective predictor of arthropod assemblage composition; on tundra, vegetation composition and its related structures best explain patterns in northern spider assemblages at a regional scale (Bowden & Buddle 2010a, Dahl et al 2018), and changes in habitat along a spatial gradient can significantly affect the structure of these assemblages (Bowden & Buddle 2012). In habitats just metres apart of fen, dwarf shrub heath, and tall shrub tundra in southwest Greenland, each habitat hosts significant indicator species, showing that metre-scale variation among habitats affects arthropod community structure (Hansen et al 2016a). At Toolik Lake, Alaska, spiders were more abundant in open tundra habitat than in shrub-dominated tundra, and lichen cover seemed to be important for the overall abundance of arthropods (Rich et al 2013). In Svalbard, distribution of most spider species was best described by topography, and none of their distributions were accurately predicted by temperature (Dahl et al 2018). Assemblages of linyphiid spiders in Svalbard vary over small local and temporal scales, demonstrating the complexity of Arctic terrestrial invertebrate communities (Dahl et al 2018).

Arthropods are generally more abundant in wet habitats than dry habitats (Bolduc et al 2013, Cameron & Buddle 2017). In *Iqaluktuuttiaq*/Cambridge Bay, Middle Arctic Canada, spider assemblages are strongly structured along moisture gradients, with higher abundance and diversity in wet habitats compared to dry habitats, and spider assemblages also differ considerably between the two habitats (Cameron & Buddle 2017). At Toolik Lake, Alaska, spider communities differed greatly between habitats of moist acidic tundra and dry heath tundra (Wyant et al 2011). In southwest Greenland, assemblage patterns were significantly linked to changes in soil moisture and vegetation height, as well as geographic location (Hansen et al 2016a). local-scale assemblage patterns of spiders, beetles, and butterflies in southwest Greenland were related to soil moisture and temperature (Hansen et al 2016b). At Lake Hazen, High Arctic Canada, *Dryas integrifolia* Vahl plants growing closer to water produce more seeds than those growing in drier areas, reflecting the greater availability and abundance of insect pollinators in wet habitats relative to dry habitats (Kevan 1972).

Elevation also modulates how Arctic arthropod communities are structured along local environmental gradients (Høye et al 2018). While community composition in south Greenland was significantly related to shrub height and soil moisture, this relationship also varied between high and low elevations, and more species were unique to high elevation plots than low elevation plots (Høye et al 2018). In Zackenberg Valley, High Arctic Greenland, elevation and vegetation mass were found to explain the most variance in the composition of the community of prey locally available to the Arctic wolf spider *Pardosa glacialis* Thorell, (Eitzinger et al 2019). Arctic arthropod community responses to environmental change may differ between low and high elevation sites (Høye et al 2018).

Siemann et al (2015) found that herbivorous arthropod diversity was influenced by plant, parasite, and predator diversity in grassland, but was more strongly correlated with parasite and predator diversity than with plant diversity; this suggests that, although increasing plant diversity significantly increased arthropod diversity, local herbivore diversity is also maintained by, and in turn maintains, a diversity of parasites and predators (Siemann et al 2015).

The microarthropod community of the High Arctic is composed of heterogeneous circumpolar species, yet on a landscape scale is extremely dependent on local environmental conditions which may be subject to rapid change (Gwiazdonwicz et al 2020). There are distinct communities of soil-dwelling arthropods beneath different kinds of Arctic vegetation, and plants of different species are a useful proxy for soil conditions that affect the soil microarthropod community on a local scale (Coulson et al 2003). In the path of a receding High Arctic glacier, microarthropod species richness increased the further away from the glacier snout (Gwiazdonwicz et al 2020).

1.2.5 Arctic arthropods and changing temperatures

Arthropods are strongly affected by temperature. Bolduc et al (2013) found that across Arctic Canada, temperature variation accounted for 70% of the deviance in daily arthropod abundance. In Kugluktuk, Low Arctic Canada, there was a strong relationship between mean daily temperature and beetle assemblage structure (Ernst & Buddle 2013). Air temperature best explains variation in the activity level and patterns of flying insects in the High Arctic (Hodkinson et al 1998, Høye & Forchhammer 2008a).

Increasing temperatures may cause a decline in biodiversity across a wide variety of tundra, at least in the short term, with important implications for processes and interactions within tundra ecosystems and between tundra and the atmosphere (Walker et al 2006). The population response of invertebrates to climate warming is greatest and most rapid at the coldest sites (Hodkinson et al 1998). Over a 24-year period in Zackenberg Valley, High Arctic Greenland, increasing temperatures were associated with a gradual decline in arthropod abundance; arthropod abundance then greatly increased while family-level diversity showed the opposite pattern, suggesting increasing dominance of a small number of taxa brought about by this change (Høye et al 2021). Among those arthropod families at Zackenberg that declined from rising temperatures were muscid flies (Loboda et al 2018), a cause for concern as muscid flies are the main drivers of pollination in the High Arctic (Tiusanen et al 2016). Two species of linyphiid spider (Araneae: Linyphiidae) also declined in abundance at Zackenberg in response to rising temperatures and changes in snowmelt timing and moisture availability related to snow depth dynamics (Bowden et al 2018); spider species whose ranges are more constrained to wetter microhabitats are more sensitive to changes in moisture availability (DeVito et al 2004).

Increasing temperatures reduce the performance of cold-adapted invertebrate herbivores, potentially affecting tundra plants' long-term responses to warming due to changes in herbivory rates and selective foraging. (Barrio et al 2016). In two species of High Arctic butterfly at Zackenberg, High Arctic Greenland, wing length decreased significantly in response to warmer summers, with implications for fecundity and dispersal capacity (Bowden et al 2015). Insect herbivory in terrestrial ecosystems decreases with latitude (Kozlov et al 2015). In forest environments, invertebrate herbivores consume 5-15% of woody plant foliage globally, but more studies are needed to predict how tundra plants, which have been historically exposed to low levels of insect herbivory, will cope with the increased levels of damage that are expected to occur due to climate-driven range expansion and increased abundances of plant-feeding insects (Kozlov et al 2015). The spatial distribution of above-ground insect herbivores on their host plant is temperature limited (Hodkinson et al 1998). Distributions of host-specific herbivorous insects that show a restricted occurrence within the overall range of their host plant are predicted to respond more rapidly to climate warming than the distribution of the host plants themselves (Hodkinson & Bird 1998). In the Arctic, the numerical abundance of flying predators/parasitoids of the above-ground herbivores is low, and the spatial distribution of some predators may be thermally restricted and less extensive than that of their prey (Hodkinson et al 1998). In Zackenberg Valley, High Arctic Greenland, spiders as predators are unable to suppress herbivorous arthropods (Visakorpi et al 2015).

Increasing temperatures affect the life cycle of biting insects, with potential negative consequences for entire Arctic ecosystems. In western Greenland, Arctic mosquito larvae develop faster under warmer conditions, and although they also see increased predation by a dytiscid beetle under these conditions, the faster development rate overall leads to fewer days being exposed to this predator and therefore greater probability of surviving to the biting imago stage (Culler et al 2015). Warming also advanced Arctic mosquito phenology so that emergence of biting adults coincided with calving caribou (Culler et al 2015). Caribou increase their movements during peak insect harassment, evading and running away from mosquitoes—behavioural responses that scale up to reduced physiological condition, which can lead to lower reproductive output and higher mortality rates (Joly et al 2020). Caribou affect all trophic levels in the Arctic and the processes that connect them (Joly et al 2020), and are important as a subsistence resource for northern communities (Culler et al 2015). Therefore, temperature-instigated advancement in phenology and life cycle of an Arctic biting insect is impacting the ecology of the region and decoupling human-natural systems.

1.2.6 Snowmelt and Arctic terrestrial ecosystems

Timing of snowmelt is a good predictor of the phenology of most Arctic arthropods. (Høye & Forchhammer 2008b). In Zackenberg Valley, High Arctic Greenland, snowmelt directly affects plant and arthropod phenology (Mortensen et al 2016), with timing of emergence being closely related to the date of snowmelt in nine taxa of common surface-active and flying arthropods (Høye & Forchhammer 2008b). Snow acts as an insulator, and changes in its depth affect the enhancement of thermally dependent reactions, such as microbial activity, affecting soil nutrient composition, respiration, and winter gas efflux. (Cooper 2014). Landscape-level changes to winter snow cover have been documented to have an effect on the biomass of some Arctic arthropods (Legault & Weiss 2013). Snowmelt is predicted to become more variable with climate change, and this may affect organisms in areas of late snowmelt most severely (Høye & Forchhammer 2008b). Snow depth and spring temperatures influence snowmelt timing, determining the start of plant growth and forage availability (Cooper 2014). Greater snow depth means delayed snowmelt timing, and this in turn delays the first and peak flowering dates of Arctic plants and shortens the prefloration period overall (Gillespie et al 2016). Plant–pollinator networks are vulnerable to phenological shifts between insects and plants, and reduced visitation rates to flowers in plots with deep snow (Gillespie et al 2016). At Zackenberg, the duration of the butterfly flight season was significantly positively related to the temporal overlap with floral resources (Høye et al 2014); taxa that are a bit more specialised, such as butterflies and parasitoid wasps, have a more narrow phenological range in the summer, potentially making them most vulnerable to trophic mismatch (Høye & Forchhammer 2008b).

Changes in snow cover and timing of snowmelt also have an effect on the morphology and reproductive output of some Arctic arthropods. In Zackenberg Valley, High Arctic Greenland, earlier snowmelt led to increased body size of females (but not males) of the wolf spider *Pardosa glacialis* Thorell (Høye et al 2009). Meanwhile, in subarctic Churchill, Manitoba, increased winter snow cover produced higher body masses in adults and juveniles of the wolf spider *P. lapponica* Thorell, and females had significantly higher ovary/oocyte mass during their peak reproductive period (Legault & Weiss 2013). Bowden & Buddle (2012) found that female body size was the best explainer for variation in fecundity, and body condition the best predictor for relative reproductive effort in tundra-dwelling wolf spiders, and so changes of snow cover and snowmelt affect reproductive success of these spiders.

1.2.7 Phenology and Arctic terrestrial ecosystems

Ecological changes in the phenology of plants and animals linked to climate change are occurring in all well-studied terrestrial groups (Parmesan 2006). Increased summer temperatures may alter or disrupt the seasonal patterns of insect emergence, particularly in species where the life cycle is cued into the seasonal rhythm (Hodkinson et al 1998). In Zackenberg Valley, High Arctic Greenland, timing of snowmelt directly affected plant and arthropod phenology (Mortensen et al 2016). An advancement of the phenology of surface-dwelling arthropods may expose them to higher levels of solar radiation, which suggests that their locomotory performance would be enhanced and their contribution to ecological processes increased (Høye & Forchhammer 2008a). With climate warming, shifts in phenology within trophic levels may ultimately affect interactions between them (Tiusanen et al 2020). Timing of snowmelt appears to indirectly influence phenology of Arctic-nesting shorebirds as well as plant, arthropod, and shorebird performance through effects on adjacent trophic levels and lagged effects (Mortensen et al 2016). In Siberia, changes in arthropod availability related to the optimal breeding date for breeding birds has advanced such that Arctic shorebirds and passerines must advance the start of their breeding to take advantage of the new optimal breeding time, and this change could affect the entire migratory schedule of the birds (Tulp & Schekkerman 2008). Recent climate change shifts the timing and flowering overlap between dominant and less-competitive plant species (Tiusanen et al 2020). changing the strength of competition among plants (Tiusanen et al 2020). Compared to *Dryas integrifolia* × *octopetala*, a dominant plant species in the Zackenberg Valley of High Arctic Greenland, the relative timing of other plant species shifted along an environmental gradient, with *Silene acaulis* (L.) Jacquin and *Papaver radicatum* Rottbøll flowering earlier toward higher elevation (Tiusanen et al 2020). This shift resulted in larger niche overlap, allowing for an increased potential for competition for pollination in which *Dryas* emerged as a superior competitor by attracting 97.2% of flower visits (Tiusanen et al 2020). Higher *Dryas* density resulted in reduced insect visits and less pollen of *S. acaulis* being carried by pollinators, causing reduced seed set by *S. acaulis* (Tiusanen et al 2020).

1.2.8 Tundra vegetation responses to climate change

Tundra vegetation exhibits strong regional variation in response to warming (Elmsdorf et al 2012). In experimental warming studies of tundra plants, shrubs increased at sites that had higher ambient temperatures, while graminoids increased with experimental warming at the sites with the coldest ambient temperatures (Elmsdorf et al 2012). In the Zackenberg Valley of High Arctic Greenland, there were substantial changes in cover across plant communities of several functional groups and species, biodiversity, and community structure from 1997 to 2008; the fen area in particular changed markedly in that time, most likely in response to a decreasing supply of meltwater (Schmidt et al 2012). Although some High Arctic plant communities exhibit a relatively high degree of resistance towards environmental changes, the derived ecological effects of climate change in other plant communities may be substantial even on a decadal scale, and, hence, occur at a fast pace (Schmidt et al 2012).

A pan-Arctic vegetation transition is underway, which if continued will alter the fundamental architecture and function of Arctic ecosystems with important ramifications for the climate, the biota, and humans (Tape et al 2006). At locations across northern Alaska photographed in 1948-50 and again in 1999-2001, there were distinctive, and in some cases, dramatic increases in the height and diameter of individual shrubs, in-filling of areas that had only a scattering of shrubs in 1948-50, and expansion of shrubs into previously shrub-free areas (Sturm et al 2001). Across this region in Alaska, alders, willows, and dwarf birch have been increasing, with the change most easily detected on hill slopes and valley bottoms (Tape et al 2006). Satellite observations from around the circumpolar Arctic showing increased productivity measured as changes in ‘greenness’, have coincided with a general rise in high-latitude air temperatures and have been partly attributed to increases in shrub cover (Myers-Smith et al 2011). In the Low Arctic tundra north of Inuvik, Northwest Territories, green alder stem density increased by 68% (±24.1) from 1972 to 2004, while average tall shrub tundra cover increased by 15% (±3.6) (Lantz et al 2013). The highest proportions of tall shrub cover grew in areas where there had been historical tundra fires, and predicted increases in the size and frequency of tundra fire are likely to further drive rapid shrub proliferation in the Low Arctic (Lantz et al 2013). Warming temperatures, changes in snow cover, altered disturbance regimes as a result of permafrost thaw, tundra fires, and anthropogenic activities or changes in herbivory intensity are all contributing to observed changes in shrub abundance (Myers-Smith et al 2011). These recently observed increases in shrub cover in many tundra regions are therefore in response to climate warming (Walker et al 2006).

Changes in shrub cover and height in the Arctic have important implications for processes and interactions within tundra ecosystems and between tundra and the atmosphere (Walker et al 2006). Shrub-dominated tundra sites in the Low Arctic of Northwest Territories have decreased albedo, increased net solar radiation, deeper snowpack, and elevated near-surface ground temperatures, indicating that continued increases in shrub cover will affect regional climate, hydrology, permafrost temperatures, and terrain stability (Lantz et al 2013). At Toolik Lake, Alaska, arthropod abundance and diversity were significantly greater in shrub-dominated tundra than in open tundra, and true bugs (Hemiptera), flies (Diptera), and wasps and bees (Hymenoptera) more abundant in shrub-dominated tundra than in open tundra habitat (Rich et al 2013). Shrub expansion could result in a significant shift in Arctic food-web structure and an increase in food availability for insectivorous birds, although future ecosystem change in the Arctic is likely to be heterogeneous as shrub types are expanding at different rates and in different places across the Arctic (McDermott 2017). A large-scale increase in shrub cover will change the structure of tundra ecosystems and alter energy fluxes, regional climate, soil–atmosphere exchange of water, carbon and nutrients, and ecological interactions between species (Myers-Smith et al 2011). In a Scandinavian subarctic dwarf shrub heath community, there were strong effects of nutrient addition on the above-ground biomass of both the dominant dwarf shrubs and the subordinate grasses and mosses, with responses of the latter being of greater magnitude (Richardson et al 2002). The shrubification of the Arctic could be a significant contributor to changes in the high-latitude carbon budget, as well as contributing to important changes in the exchange of surface energy (Sturm et al 2001). Sweet et al (2014) suggested that delayed snowmelt in areas dominated by taller shrubs may have a short-lived impact on the timing of leaf development, likely resulting in no difference in duration of peak photosynthetic period between tall and short stature shrubs. To project future rates of shrub expansion and understand the feedbacks to ecosystem and climate processes, future research should investigate the species or trait-specific responses of shrubs to climate change including: (1) the temperature sensitivity of shrub growth, (2) factors controlling the recruitment of new individuals, and (3) the relative influence of the positive and negative feedbacks involved in shrub expansion (Myers-Smith 2011).

1.3 The use of arthropods in long-term ecological monitoring programs

Long-term monitoring projects are valuable for generating empirical data about changes in populations and communities of arthropods (Bowden et al 2018). For an ecological monitoring program to be successful over the long-term, the perceived benefits of the information must justify the cost; monitoring programs are always limited in their scope by financial constraints, so realistic expectations of costs and benefits will help ensure that monitoring programs survive the early, turbulent stages of development and the challenges posed by fluctuating budgets during implementation (Caughlan & Oakley 2001). Monitoring programs look for ecological indicators that ideally represent key information about structure, function and composition of the ecological system in order to assess the condition of that system (Dale & Beyeler 2001). While the numerous monitoring projects of the National Science Foundation's Long Term Ecological Research Network address many ecological research questions that differ between sites, they are still united on five core research areas: (1) pattern and control of primary production; (2) spatial and temporal distribution of populations selected to represent trophic structures; (3) pattern and control of organic matter accumulation and decomposition in surface layers and sediments; (4) patterns of inorganic inputs and movements of nutrients through soils, groundwater, and surface waters; and (5) patterns and frequency of disturbances (Hobbie et al 2003). Monitoring projects must strike a balance between ensuring that monitoring and survey activities are occurring regularly enough to identify changes to the environment, while at the same time minimising threats brought upon anthropogenically through those very same activities (Convey 2011).

There are limitations to species richness estimation methods (Sikes et al 2013). Functional diversity measures the aspects of diversity that potentially affect community assembly and function, and can explain variation in ecosystem function even when richness does not (Cadotte et al 2011). Higher levels of taxonomic resolution are sufficient for detecting the impacts of disturbance in lineages of terrestrial arthropods with higher levels of phylogenetic constraint, although this does not negate the necessity and importance of species-level identifications in situations with sufficient resources and where study questions demand alpha taxonomy (Timms et al 2013b). Functional diversity should therefore be incorporated into conservation and restoration decision-making, especially for those efforts attempting to reconstruct or preserve healthy, functioning ecosystems (Cadotte et al 2011). Buddle et al (2005) found that, when compared both to raw species richness and the Shannon-Wiener, Simpson's and Fisher's indices for describing alpha diversity, rarefied species richness standardised to the number of individuals collected enables more accurate comparisons of diversity and revealed when sampling was insufficient in forest arthropod assemblages.

Terrestrial invertebrates serve as promising bioindicators for environmental monitoring (Hodkinson & Jackson 2005), and require higher priority within future Arctic monitoring programs (Høye & Sikes 2013, Gillespie et al 2020). Arthropods form a major part of the terrestrial species diversity in the Arctic, and are particularly sensitive to changes in the abiotic environment (Høye & Sikes 2013). Furthermore, we lack baseline and long-term data about the distributions and abundances of Arctic arthropods and their relationships to abiotic variation, as well as their roles in these ecosystems (Høye & Culler 2018). Tundra arthropods are a useful model system for testing general ecological theory about how species respond to environmental variation (Høye & Culler 2018). The Arctic can potentially provide insights to further understand and mitigate the effects of climate change on arthropods worldwide (Høye 2020). Hence, increased research activity on Arctic arthropods would help towards conservation of Arctic biodiversity as well as in understanding the role of Arctic arthropods in ecosystem functioning (Høye & Sikes 2013).

In Arctic entomology, the three most important fields to consider are: trophic interactions, biodiversity assessments, and taxonomic revisions (Høye & Sikes 2013). Ecological monitoring of arthropods should focus on the composition, structure, and processes of nested biodiversity, and the state of taxa (Kim 1993). An arthropod monitoring program should be able to characterise the community, identify surrogates for biodiversity, and establish efficient methods to monitor surrogates and any ecologically important or sensitive taxa (Rohr et al 2007). The current pattern of sampling in the Arctic may bias the scientific consensus that underpin attempts to accurately predict and effectively mitigate climate change in the region (Metcalfe et al 2018). Inclusion of basic research on life history and ecology of Arctic arthropods will achieve a more nuanced understanding of the sensitivity of Arctic and other arthropods to global changes (Høye et al 2021). Poorly sampled regions of the Arctic include the High Arctic islands of the Canadian Arctic Archipelago, and the Atlantic coastline of Russia, as well as sites that are relatively colder, more rapidly warming and sparsely vegetated (Metcalfe et al 2018).

The species-poor Arctic represents a unique opportunity for testing novel, automated arthropod monitoring methods (Høye 2020) In Arctic, subarctic and north boreal biomes, trap type and habitat both influence the abundance, richness, and assemblage composition of arthropods collected, but these effects differ between ecoclimatic zones and depend on taxonomic resolution (Ernst et al 2016). In the High Arctic, sampling in different habitats yields greater diversity than sampling with different traps—the inverse of what is true for sampling in the north boreal zone—and neither factor appears to have a significant effect on the diversity of arthropods collected in the subarctic (Ernst et al 2016). Ernst et al (2016) found that the addition of recessed yellow pan traps to a traditional pitfall trap-based sampling regime results in the capture of many additional unique species, suggesting that colour is an attractant for at least some ground-dwelling taxa (Ernst et al 2016). Yellow pitfall traps are also a useful alternative to transect walks for butterfly recording in tundra habitats (Høye et al 2014).

Monitoring programs often do not take full advantage of the potential afforded by molecular genetic markers, which can provide information relevant to both ecological and evolutionary time frames, while costing less and being more sensitive and reliable than traditional monitoring approaches (Schwartz et al 2007). DNA and population genetic data can provide valuable information, often unattainable via other approaches, for monitoring species of management, conservation and ecological interest (Schwartz et al 2007). Hogg & Hebert (2004) found DNA barcoding to be a powerful tool for identifying species of Arctic Collembola, and should regularly be useful as a complement to traditional, morphological taxonomy. Sikes et al (2017) are building a DNA barcode library to facilitate a metabarcoding approach to monitoring non-marine arthropods in Alaska, overcoming the challenges of a limited taxonomic workforce in the state, which will become increasingly valuable as more species are added and costs to obtain DNA sequences fall.

Spiders and beetles have both been commonly proposed as biological indicator taxa for northern arthropod monitoring projects (Høye et al 2018, Loboda et al 2018, Gillespie et al 2020). Spiders and beetles are both sensitive to loss of vegetation and changes in environmental conditions (Milakovic & Jeffries 2003). In the case of spiders, Loboda et al (2018) found them to be useful bioindicators for understanding the effects of climate change across ecoclimatic regions of northern Canada, being non-randomly distributed and possibly limited by biotic interactions. Spiders are ubiquitous in the Arctic and can be trapped in a standardised manner relatively esily (Gillespie et al 2020) In North America, the diversity and assemblage structure of northern beetles are strongly negatively correlated with latitude, likely explained by the mediating effects of climate, particularly temperature (Ernst & Buddle 2015). Høye et al (2018) found beetles to be better indicators for specific habitats than spiders at a site in southern Greenland.

1.4 A brief history of *Umingmat Nunaat*/Axel Heiberg Island

Umingmat Nunaat, or Axel Heiberg Island, is an incredibly remote location in Arctic Canada. An uninhabited landmass of comparable area to Nova Scotia or Switzerland, the island lies in the northernmost reaches of the continent between latitudes 78º08’ and 81º22’ N—separated from neighbouring *Umingmak Nuna*/Ellesmere Island by a narrow channel (F. Müller 1961a). Its western half is a land of mountains, glaciers and icefields, while the eastern side is more gently sloped with rolling hills (personal observations). Fiords cut deep into the island’s interior (personal observations). The climate is a dry polar desert, but scattered around the landscape are lush oases filled with life (Adams 1984).

Human history and the island have intertwined only occasionally. The nomadic Thule people, and possibly the Dorset before them, occupied a site on the east coast of the island (Kalkreuth & Sutherland 1998, Schledermann 1975). But this proto-Inuit site had been abandoned for centuries by the time the first European expeditions ventured into the region. Otto Sverdrup’s Norwegian expedition of the schooner *Fram* sighted the island in 1899, and was responsible for naming it Axel Heiberg after the expedition’s financier (B. Müller 1961). In the 40 years that followed, the island was visited just a handful more times, with visits mainly limited to the coast, until the outbreak of the Second World War put a pause on any further exploration of *Umingmat Nunaat* (B. Müller 1961).

In 1953, Canadian engineer and businessman Dr. George Jacobsen led a reconnaissance expedition to the eastern side of *Umingmat Nunaat*, his team becoming the first people to visit the island by aircraft (F. Müller 1961). The island made an impression on Jacobson, and back in Montréal he collaborated with several McGill University professors in the fields of geography, geology, and meteorology to plan out a more substantial expedition (F. Müller 1961). And so launched the Jacobsen-McGill Arctic Research Expedition of 1959-1962. This joint expedition of Dr. Jacobsen and McGill University had two main objectives: to study the geomorphology of the remote western-central part of *Umingmat Nunaat*, and to foster an educational environment to train up successive waves of students in their chosen disciplines in Arctic science. Under the leadership of McGill University glaciologist Dr. Fritz Müller, a small reconnaissance party went up in 1959 and located an area suitable for concentrated study (Adams 2009). Major operations commenced the following year, which included the construction of the first two buildings of the base camp (F. Müller 1861).

In support of the original goals of Jacobsen and McGill, the expedition's legacy was the establishment of a permanent research base for McGill University on *Umingmat Nunaat*. When the Jacobsen-McGill Arctic Research Expedition concluded at the end of the 1962 season, the buildings remained in place as a permanent research base for McGill University, operated to the present day by the University's Department of Geography. The seasonally occupied McGill Arctic Research Station (MARS) has supported a plethora of research projects in its many decades of operation. Since the early years, research activities have encompassed the disciplines of glaciology (e.g., Müller 1963a, Müller 1963b), geophysics (e.g., May 1963, Becker 1963), meteorology (e.g., Diem 1963, Havens 1963), geology (e.g., Fricker 1963, Kranck 1963), geomorphology (e.g., Rudberg 1962, Maag 1963), botany (e.g., Parmelee 1963, Beschel 1963) and more recently, microbiology (Pollard et al 2009). But remarkably, in all that time, no one ever conducted an ecological study of the terrestrial arthropods on the island.

1.5 Connecting Statement:

This chapter provided the context and background information for the research presented in the subsequent chapter. Chapter 2 is an empirical field study looking at relationships of microhabitat, climate, and seasonality on terrestrial arthropod communities on *Umingmat Nunaat*/Axel Heiberg Island, establishing a baseline for monitoring.

Chapter 2: Structure and dynamics of terrestrial arthropod communities on *Umingmat Nunaat* (Axel Heiberg Island), in the High Arctic

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2.1 Abstract

The Arctic is warming faster than anywhere else on the planet, and this rapid warming is threatening terrestrial ecosystems in the High Arctic. Despite the urgency to understand the situation, there is still much that we do not know about the effect that recent climate warming is having on High Arctic terrestrial ecosystems. Arthropods, which are very abundant on High Arctic tundra, are ideal focal organisms for monitoring projects aimed at studying terrestrial ecosystems in the High Arctic. *Umingmat Nunaat*, or Axel Heiberg Island, is a very remote location in High Arctic Canada whose terrestrial arthropod communities have not been studied in any great detail. This research was a baseline study of terrestrial arthropod communities on *Umingmat Nunaat*, which investigated relationships of ground cover, climate, and seasonality on arthropod abundance and diversity in the vicinity of the McGill Arctic Research Station (MARS). Arthropods were collected from 56 yellow pitfall traps at four replicate sites over six sampling periods from 05 July-02 August, 2018. In total, 37,935 terrestrial arthropods were collected and identified into 29 morphological categories representative of their taxonomy and functional diversity. Redundancy Analyses revealed distinct differences in ground cover preference among the dominant taxonomic groups within the Diptera and Collembola. Spearman's rank correlation coefficient revealed few significant correlations of arthropods and climate, except for the following exceptions: Fisher's alpha diversity had a significant, very strong negative correlation with average windspeed; Tipulomorpha abundance had a significant, very strong positive correlation with average air temperature; and parasitoid wasp abundance had very strong positive correlations with both average air temperature and average barometric pressure. Overall, arthropod abundance was highest in the middle of the study period (18-19 July), while arthropod alpha diversity was highest late in the study period (28-29 July)—although some morphological groups did not follow these general patterns in phenology. This

baseline study of terrestrial arthropod communities on *Umingmat Nunaat* lays the foundations for an arthropod monitoring program at MARS, which will fill a vital knowledge gap in our understanding of High Arctic terrestrial ecosystems, including how these ecosystems are being affected by recent climate change.

2.2 Introduction

Recent climate change is altering ecosystems around the world, leading to local species losses, increases in disease, and mass mortality events, as well as causing measurable economic and livelihood losses and altered cultural practices and recreational activities (IPCC 2022). Arctic ecosystems and biota are particularly vulnerable to current and projected future global warming (Callaghan et al 2004). In their most recent report, the Intergovernmental Panel on Climate Change (2022) stated that there is a high degree of confidence that climate change is responsible for observed changes to ecosystem structure and phenology in Arctic terrestrial and marine ecosystems, as well as species range shifts in Arctic terrestrial, freshwater, and marine ecosystems. The vulnerability of the Arctic region to recent and rapid climate change, including its resultant social and economic impacts, is accelerating research interest in the Arctic (Høye & Sikes 2013).

Arthropods are the dominant terrestrial organisms found in the Arctic (Høye & Sikes 2013). They exhibit a wide range of adaptations to overcome the challenges of living in the harsh Arctic environment, including in their morphology (e.g., more hairs to trap heat, darker colouration for greater heat absorbance, etc.), behaviour (e.g., thermoregulation, seeking out warmer microhabitats, etc.), life cycles (e.g., diapause), and ecophysiology (e.g., cold hardiness, anaerobiosis, desiccation resistance) (Strathdee & Bale 1998, Danks 2004). Terrestrial arthropods in the Arctic perform important ecosystem services through nutrient cycling in soils (Lavelle et al 2006), as pollinators (e.g., Tiusanen et al 2016), and as integral parts of Arctic food webs (e.g., Hodkinson & Coulson 2004). Arthropod assemblages in the Arctic are affected by vegetation composition, moisture, and elevation, and can differ markedly in microhabitats just metres apart (Bowden & Buddle 2010a, Cameron & Buddle 2017, Høye et al 2018). Activity and abundance of Arctic arthropods is strongly dictated by air temperature (Bolduc et al 2013, Ernst & Buddle 2013,). Timing of snowmelt is a good predictor for the phenology of most Arctic arthropods. (Høye & Forchhammer 2008b). Recent climate change has been linked to declines in abundance of Arctic arthropods, the restructuring of Arctic arthropod assemblages, and shifts in phenology, with much broader implications for Arctic terrestrial ecosystems as a whole (Høye et al 2021, Tulp & Schekkerman 2008).

Long-term monitoring projects are valuable for generating empirical data about changes in populations and communities of arthropods (Bowden et al 2018). Monitoring programs look for ecological indicators that ideally represent key information about the structure, function and composition of an ecological system in order to assess the condition of that system (Dale & Beyeler 2001). Ecological monitoring of arthropods should focus on the composition, structure, and processes of nested biodiversity, and the state of taxa (Kim 1993); it should be able to characterise the community, identify surrogates for biodiversity, and establish efficient methods to monitor surrogates and any ecologically important or sensitive taxa (Rohr et al 2007).

Terrestrial invertebrates serve as promising bioindicators for environmental monitoring (Hodkinson & Jackson 2005), and require higher priority within future Arctic monitoring programs (Høye & Sikes 2013, Gillespie et al 2020). Arthropods form a major part of the terrestrial species diversity in the Arctic, and are particularly sensitive to changes in the abiotic environment (Høye & Sikes 2013). Furthermore, we lack baseline and long-term data about the distributions and abundances of Arctic arthropods and their relationships to abiotic variation, as well as their roles in these ecosystems (Høye & Culler 2018). Tundra arthropods are a useful model system for testing general ecological theory about how species respond to environmental variation (Høye & Culler 2018). The Arctic can potentially provide insights to further understand and mitigate the effects of climate change on arthropods worldwide (Høye 2020). Hence, increased research activity on Arctic arthropods would help towards conservation of Arctic biodiversity as well as in understanding the role of Arctic arthropods in ecosystem functioning (Høye & Sikes 2013).

Umingmat Nunaat, or Axel Heiberg Island, is a remote island in High Arctic Canada. An uninhabited landmass of comparable area to Nova Scotia or Switzerland, the island lies in the northernmost reaches of North America, between latitudes 78º08’ and 81º22’ N—separated from neighbouring *Umingmak Nuna*/Ellesmere Island by a narrow channel (F. Müller 1961a). Its western half is a land of mountains, glaciers and icefields, while the eastern side is more gently sloped with rolling hills (personal observation). Fiords cut deep into the island's interior (personal observation). The climate is a dry polar desert, but scattered around the landscape are lush oases filled with life (personal observation).

The only regular human presence on *Umingmat Nunaat* is a seasonally occupied field station operated by McGill University. The McGill Arctic Research Station has been in operation since 1960, supporting a plethora of research projects over the decades, including those in the disciplines of glaciology (e.g., Müller 1963a, Müller 1963b), geophysics (e.g., May 1963, Becker 1963), meteorology (e.g., Diem 1963, Havens 1963), geology (e.g., Fricker 1963, Kranck 1963), geomorphology (e.g., Rudberg 1962, Maag 1963), botany (e.g., Parmelee 1963, Beschel 1963) and more recently, microbiology (Pollard et al 2009). But remarkably, in all those decades, the biodiversity and ecology of terrestrial arthropods on the island was never studied.

The objective of this study was to investigate the biodiversity and ecology of terrestrial arthropod communities on *Umingmat Nunaat*. More specifically, this study characterizes (1) whether there are correlations between ground cover and terrestrial arthropod abundance and diversity on *Umingmat Nunaat*, (2) whether there are correlations between climate (i.e., air temperature, solar radiation, windspeed, and barometric pressure) and terrestrial arthropod abundance and diversity on *Umingmat Nunaat*, and (3) whether there are correlations between seasonality and terrestrial arthropod abundance and diversity on *Uminmat Nunaat*. Doing so fills a large knowledge gap in our understanding of High Arctic terrestrial ecosystems in the face of recent climate change, and establishes a baseline for future arthropod monitoring at the McGill Arctic Research Station on *Umingmat Nunaat* in High Arctic Canada.

2.3 Study Area

The study area was the environs of the McGill Arctic Research Station (MARS), itself located at coordinates 79°24'54.5"N 90°44'51.9"W in the rugged interior of western-central *Umingmat Nunaat*/Axel Heiberg Island, Nunavut, in High Arctic Canada. MARS is located about 8 km inland from Expedition Fiord, which cuts deep into the western interior of the island—the name

"Expedition Fiord" is often applied to this region as a whole, including as a synonym for MARS. Within this region, enclosed by mountains and glaciers, the field station sits on a gypsum dome overlooking a small and naturally acidic lake called Colour Lake. The study area was a 3.2 km transect running through the basin of Colour Lake and following the lake's drainage into Wolf Creek. Compared to the surrounding polar desert landscape that characterises the island, the basin of Colour Lake is a relatively lush oasis. Within the study area, Colour Lake drains into a wetland that is lush with vegetation. The water from this wetland then drains in a southwest direction through a cut in a basalt dyke to join up with Wolf Creek. Although Wolf Creek is predominantly fed by meltwater from the nearby Wolf Mountain, this creek also serves as the outlet for Colour Lake. The creek bed of Wolf Creek consists of variably sized rocks and is sparsely vegetated, but the slopes that flank the creek bed are well vegetated. Wolf Creek continues to flow outside of the study area and eventually flows into the marine waters of Expedition Fiord, approximately 8 km downstream from MARS. The study area is overall quite lush in comparison to much of the surrounding landscape—an oasis within the polar desert of *Umingmat Nunaat*.

2.4 Methods

2.4.1. *Sampling and specimen processing*

In the summer of 2018, I sampled terrestrial arthropods in the Expedition Fiord region of western-central *Umingmat Nunaat*/Axel Heiberg Island, Nunavut, in High Arctic Canada (Figure 2.1). Within the study area, I established four sampling sites (i.e., replicates), labelled Sites 1-4, spaced approximately 800 m apart and following the direction of flow of water from Colour Lake and its outlet Wolf Creek (Figure 2.2). Site 1 was located on the north shore of Colour Lake, at coordinates 79°25'14.2"N 90°44'48.1"W (Figure 2.2). Site 2 was bordering the Colour Lake wetland at coordinates 79°24'58.9"N 90°46'42.4"W (Figure 2.2). Site 3 and Site 4 were both located along Wolf Creek; Site 3 was located on the south side of the creek at coordinates 79°24'40.2"N 90°48'11.5"W, and Site 4 was further downstream on the north side of the creek at coordinates 79°24'45.4"N 90°50'20.9"W (Figure 2.2).

Each of the four sampling sites consisted of a 10 m x 60 m transect, oriented perpendicular to the water (Figure 2.3, Figure 2.4). A yellow pitfall trap was placed every 10 m along each transect, for a total of 14 yellow pitfall traps per site, and 56 yellow pitfall traps across all sites. The traps were plastic yellow bowls dug into the ground to combine the roles of both a pan trap and a pitfall trap (Ernst et al 2016). The bowls function as pan traps because insect pollinators are attracted to the colouration; and by digging them into the ground, the pan traps double as pitfall traps because ground-dwelling arthropods fall in. Yellow is the predominant colour of wildflowers on *Umingmat Nunaat* (personal observation). Into each yellow pitfall trap, a few centimetres of 50% propylene glycol solution were added to act as a non-toxic, mild preservative. Finally, a few drops of dish detergent were also added into each trap to break the surface tension.

The study period was from 5 July 2018 to 2 August 2018 (Table 2.1). The four study sites with their combined 56 yellow pitfall traps were active continuously during that period. I collected the contents of each trap every four to five days (depending on weather conditions) and each sample was placed in a sample bag with ethanol solution for preservation. Collecting the contents of each trap every four to five days gave me a total of six sampling periods during the study period. The six sampling periods correspond with the following dates: the first sampling period was on 9-10 July 2018, the second sampling period was on 13-14 July 2018, the third sampling period was on 18-19 July 2018, the fourth sampling period was on 23-24 July 2018, the fifth sampling period was on 28-29 July 2018, and the sixth sampling period was on 2 August 2018 (Table 2.1). 56 yellow pitfall traps, each sampled six times, amounts to a total of 336 individual sample bags. However, just one sample was lost to trap disturbance—a yellow pitfall trap was trampled by a muskox—so I finishd the field season with 335 samples.

Climate data was obtained from a Campbell Scientific automated meteorological station located within the MARS base camp (79°24'54.5"N 90°44'51.9"W). The climatic variables that were obtained from this automated station for summer 2018 were: average air temperature, average solar radiation, average windspeed, and average barometric pressure (Figure 2.33, Figure 2.34, Figure 2.35, Figure 2.36, Figure 2.37, Figure 2.38, Figure 2.39, Figure 2.40).

Ground cover data was collected using a 1 m x 1 m quadrat. At the location of each yellow pitfall trap, I placed the quadrat down on the ground directly beside each trap—always on the interior face of the transect—and took a photo of the quadrat from directly overhead. Repeating this procedure for all 56 of the yellow pitfall traps across all four sites, I had a total of 56 photos showing local ground cover beside each trap. I then analysed the ground cover from each photo by further organising the quadrat into 81 subdivisions, and assigning each of those 81 subdivisions one of the following ground cover classifications:

F = graminoids (grasses and sedges)
H = herbaceous plants
M = mosses
L = lichens
S = shrubs (i.e., *Cassiope tetragona* Don and *Salix arctica* Pallas)
Br = bare rock
Bs = bare soil

All arthropod specimens were sorted in the laboratory and identified into one of the following 29 morphological categories: Poduromorpha, Entomobryomorpha, Symphypleona, Thysanoptera, Coccoidea (nymph), Coccoidea (imago), Staphylinidae (larva), Staphylinidae (imago), Curculionidae, Diptera (larva), Tipulomorpha, Culicomorpha, Bibionomorpha, Empidoidea, Aschiza, Acalytratae, Muscoidea, Oestroidea, Lepidoptera (larva), Lepidoptera (imago), Symphyta (larva), Symphyta (imago), Chalcidoidea, Ichneumonidae, Braconidae, *Bombus*, Acari, Linyphiidae, and Lycosidae. Flies were identified using McAlpine (1981). Wasps were identified using Goulet & Huber (1993). Spiders were identified using Dondale & Redner (1990) and Paquin & Duperre (2003). These categories were chosen because they were narrowed down enough to generally show functional diversity while at the same time not requiring exhaustive effort to identify—important due to the sheer number of the arthropods that needed to be processed (Timms et al 2013b).

2.4.2. *Data analyses*

I examined species diversity by first constructing rarefaction curves to determine whether adequate sampling had been conducted (Buddle et al 2005). Rarefaction curves were created using the *rarefy* function (Oksanen et al 2014) in R. Rarefaction curves did approach an asymptote, so species richness could be used as a metric of diversity along with other measures of species diversity: Shannon, Simpson, Pielou's evenness, and Fisher's alpha (Figure 2.5, Figure 2.6).

To test for relationships of terrestrial arthropod communities and ground cover, absolute values of arthropods and ground cover were converted into relative abundance values for each of the 56 traps. These relative abundance values were then plotted into redundancy analyses using the *rda* function (Legendre & Legendre 2012) in R, providing a visual representation of the relationships between traps, arthropod taxa, and the different types of ground cover. Two RDA plots were generated—one for the entire collection of arthropods, and the other for those taxa within the order Diptera (true flies), which was the group that made up the bulk of the collection. This analysis addresses the research objective of how ground cover relates to terrestrial arthropod abundance and diversity on *Umingmat Nunaat*.

To test for relationships of arthropods and climate, an average was obtained from each of the daily mean climate values, corresponding to each of the six sampling periods. Arthropod abundance was calculated as the average number of individuals per trap for each sampling period. Spearman's rank correlation coefficient was used to reveal correlations of arthropod abundance and diversity with climate. This analysis addresses the research objective of how climate (air temperature, solar radiation, windspeed, and barometric pressure) relates to terrestrial arthropod abundance and diversity on *Umingmat Nunaat*.

To test for relationships of arthropods and seasonality, the same diversity indices and arthropod abundance values as described above were plotted as a function of the six sampling periods. This analysis addresses the research objective of how seasonality relates to terrestrial arthropod abundance and diversity on *Uminmat Nunaat*.

2.5 Results

2.5.1 *Arthropod sampling*

37,935 terrestrial arthropods were collected during the 2018 field season (Figure 2.7). Diptera stood out as the dominant group with a total of 30,280 individuals represented, or nearly 80% of the entire collection. Among the Diptera, the most abundant taxa were the Culicomorpha (midge flies and relatives) with 12,597 individuals, Muscoidea (house flies and relatives) with 8,844 individuals, Bibionomorpha (fungus gnats) with 7,526 individuals, and Tipulomorpha (crane flies) with 958 individuals. Several other dipteran taxa also were present, but in much lower abundance.

The next most common group to be represented was the Collembola (springtails), with a total of 5,680 individuals. These were split mainly between the collembolan orders Entomobryomorpha (elongate-bodied springtails), with 4,003 individuals, and Poduromorpha (plump-bodied springtails) with 1,671 individuals. A third collembolan order, Symphypleona (globular springtails), was also present but represented by a mere six individuals.

The dipteran and collembolan taxa made up the overwhelming bulk of the collection, while outside these groups numerous other taxa were also present but in considerably lower numbers. The next most common groups were spiders and parasitoid wasps. There were 970 Araneae (spiders) collected in total, and these were split between two families: the Lycosidae (wolf spiders) with 826 individuals, and Linyphiidae (dwarf spiders) with 137 individuals. Parasitoid wasps were represented by 628 individuals, split between the Ichneumonoidea with 549 individuals (520 of Ichneumonidae and 29 of Braconidae), and Chalcidoidea with 79 individuals.

Many other taxa were also part of the 2018 collection, but present in very low numbers. Of 37,935 arthropods, only 128 were mites (Acari). Furthermore, just 83 beetles (Coleoptera) were sampled, of which 80 were a kind of flightless weevil of the genus *Isochnus* Thompson; and the remaining three were rove beetles (family Staphylinidae). A type of mealybug (Coccoidea: Pseudococcidae) was represented in the samples by only 46 individuals, all but one belonging to the mobile 1st-instar nymphal stage, or “crawler”. Just 49 Lepidoptera imagoes were sampled, along with 39 caterpillars. Just nine bumblebees (*Bombus spp.*) were sampled, three of which were *B. polaris* Curtis—one queen, one drone, and one worker—and the remaining six were all queens of *B. hyperboreus* Schönherr, the social parasite of *B. polaris*. Thrips (Thysanoptera) were represented by a mere six individuals. Only five sawflies (Hymenoptera: Symphyta) were sampled—two imagoes and three larvae, presumably of the family Tenthredinidae.

Rarefaction curves illustrated an adequate sampling of sites and sampling periods, and therefore Shannon diversity index, Simpson's diversity index, Pielou's evenness, and Fisher's alpha could all be applied as measures of diversity (Figure 2.5, Figure 2.6).

2.5.2. *Ground cover*

Clear ground cover affinities were revealed for several taxa within the two dominant groups of Collembola and Diptera that made up the bulk of the 2018 collection. The two dominant orders of Collembola showed ground cover preferences that were distinct from one another; the collembolan order Poduromorpha was positively correlated with graminoids and mosses, and negatively correlated with bare rock, while the collembolan order Entomobryomorpha was positively correlated with herbaceous plants, lichens, and shrubs, and negatively correlated with bare soil (Figure 2.31).

Similarly, the dominant taxa within the Diptera also showed ground cover preferences that were distinct from each other. The dipteran taxon Tipulomorpha was positively correlated with bare rock, and negatively correlated with graminoids and mosses. The dipteran taxon Culicomorpha was positively correlated with lichens and shrubs, and negatively correlated with bare soil and bare rock. The dipteran taxon Muscoidea was positively correlated with bare soil, and negatively correlated with lichens, herbaceous plants, and shrubs (Figure 2.32)

2.5.3. *Climate*

The language used below to interpret the results of Spearman's rank correlation coefficient (R_s) is from Fowler et al (2009).

Few significant correlations of arthropod diversity and abundance with climate were found (Table 2.4). Of the diversity indices tested, only Fisher's alpha showed one significant correlation, having a very strong negative correlation with average windspeed (p-value = 0.05; Table 2.4). Additionally, Tipulomorpha abundance showed a perfect positive correlation with average air temperature (p-value = 0.005; Table 2.4)). Parasitoid abundance showed very strong positive correlations with both average air temperature (p-value = 0.05; Table 2.4) and average barometric pressure (p-value = 0.05; Table 2.4). These correlations do not imply causation.

2.5.4. *Seasonality*

Shannon and Simpson's diversity followed similar trajectories over the season; they were lowest during the 2nd (Shannon = 1.400226, Simpson's = 0.6509864; Table 2.2) and 3rd (Shannon = 1.412201, Simpson's = 0.6674857; Table 2.2) sampling periods, and attained their highest values at the end of the study period during the 6th sampling (Shannon = 2.098208, Simpson's = 0.7803963; Table 2.2). The variance estimate for Shannon diversity index was σ^2 = 0.058279338. The variance estimate for Simpson's diversity index was 0.0044729699 (Table 2.5).

Pielou's evenness was highest during the 1st (evenness = 0.6440443; Table 2.2) and 6th (evenness = 0.6602179; Table 2.2) sampling periods (i.e., the beginning and end of the study period), and was lowest during the 3rd sampling period (evenness = 0.4503919; Table 2.2). The variance estimate for Pielou's evenness was σ^2 = 0.0050254577 (Table 2.5).

Fisher's alpha was lowest during the 2nd sampling period (Fisher's = 2.184242; Table 2.2), but increased steadily to reach its highest value during the 6th and final sampling period (Fisher's = 3.346981 Table 2.2). The variance estimate for Fisher's alpha was σ^2 = 0.1603812 (Table 2.5).

Overall arthropod abundance saw two distinct peaks during the 3rd and 5th sampling periods, but the 3rd sampling period (mean # of individuals per trap = 279.7857143) was when arthropod abundance was at its highest point of the summer (Table 2.2). The 3rd sampling period was partitioned by two marked declines in arthropod abundance, during the 2nd (mean # of individuals per trap = 24.57142857) and 4th (mean # of individuals per trap = 80.98181818) sampling periods (Table 2.2). After a second, smaller peak during the 5th sampling period, (mean # of individuals per trap = 163.7678571) Arthropod abundance again declined during the 6th and final sampling period (mean # of individuals per trap = 77.80357143; Table 2.2). The variance estimate for overall arthropod abundance is σ^2 = 7359.6461 (Table 2.5).

Tipulomorpha abundance peaked late in the study period, and was highest during the 6th sampling (mean number of individuals per trap = 7.696428571). There was also a much smaller peak during the 3rd sampling (mean number of individuals per trap = 2.553571429), partitioned by decreases during the 2nd (mean number of individuals per trap = 0.178571429 and 4th (mean number of individuals per trap = 0.571428571) sampling periods. The variance estimate for average Tipulomorpha abundance is $\sigma^2 = 7.3311721$ (Table 2.5).

Culicomorpha abundance was highest by far during the 3rd sampling period (mean number of individuals per trap = 141.8035714). There was a sharp decline in abundance by the 4th sampling period (mean number of individuals per trap = 14.89285714), followed by a slight increase again during the 5th sampling period (mean number of individuals per trap = 35.76785714) and finally a decrease at the end of the study period (mean number of individuals per trap = 14.23214286). The variance estimate for average Culicomorpha abundance is $\sigma^2 = 2272.0501$ (Table 2.5).

Bibionomorpha abundance showed a very similar pattern to that of Culicomorpha, with a substantial peak during the 3rd sampling period (mean number of individuals per trap = 61.19642857) that then sharply declined by the 4th sampling period (mean number of individuals per trap = 14.64285714), followed by a slight increase during the 5th sampling period (mean number of individuals per trap = 29.07142857) and finally a decrease at the end of the study period (mean number of individuals per trap = 16.73214286). The variance estimate for average Bibionomorpha abundance is $\sigma^2 = 361.08574$ (Table 2.5).

Muscoidea abundance was extremely low during the 2nd sampling period (mean number of individuals per trap = 0.857142857), but increased during the 3rd sampling period (mean number of individuals per trap = 41.39285714). After declining slightly during the 4th sampling period (mean number of individuals per trap = 26.66071429), Muscoidea abundance then increased substantially again to reach its highest point of the summer during the 5th sampling period (mean number of individuals per trap = 64.35714286) before sharply decreasing again by the end of the study (mean number of individuals per trap = 20.10714286). The variance estimate for Muscoidea abundance is $\sigma^2 = 472.47757$ (Table 2.5).

Parasitoid wasp abundance followed a similar pattern to that of Tipulomorpha, increasing substantially in the late study period. Parasitoid abundance was highest during the 6th and final sampling period (mean number of individuals per trap = 5.446428571). There was also a much smaller peak during the 3rd sampling (mean number of individuals per trap = 1.25), partitioned by decreases during the 2nd (mean number of individuals per trap = 0.107142857) and 4th (mean number of individuals per trap = 0.490909091) sampling periods. The variance estimate for parasitoid wasp abundance is $\sigma^2 = 4.0133546$ (Table 2.5)

Araneae abundance was relatively high during the 1st sampling period (mean number of individuals per trap = 4.035714286), but decreased sharply during the 2nd sampling period (mean number of individuals per trap = 0.107142857). Spider abundance then increased during the 3rd samping period (mean number of individuals per trap = 3.089285714) but decreased again by the 4th sampling period (mean number of individuals per trap = 1.236363636). However, spider abundance then abruptly increased to reach its highest point of the summer during the 5th sampling period (mean number of individuals per trap = 5.285714286), before decreasing slightly during the 6th and final sampling period (mean number of individuals per trap = 3.654545455). The variance estimate for Araneae abundance is $\sigma^2 = 3.0257286$ (Table 2.5).

2.6 Discussion

The objective of this thesis was to characterise relationships of terrestrial arthropod communities in relation to ground cover, climate, and seasonality on *Umingmat Nunaat* in High Arctic Canada. Several taxa within the two dominant groups of Diptera and Collembola showed ground cover preferences that differed from each other. Fisher's alpha diversity showed a significant, very strong negative correlation with average windspeed. Tipulomorpha abundance showed a significant, perfect positive correlation with average air temperature. Parasitoid wasp abundance showed significant, very strong positive correlations with both average air temperature and average barometric pressure. Overall, arthropod abundance was highest in the mid-season (18-19 July), while arthropod diversity was highest in the late season (28-29 July)—but arthropod assemblages were dynamic, and some taxa did not follow those general phenological patterns.

2.6.1. *Ground cover*

In my samples, the two dominant orders of Collembola (Poduromorpha and Entomobryomorpha) showed ground cover preferences that differed from each other; Poduromorpha was associated with graminoids and mosses, and Entomobryomorpha was associated with shrubs, herbaceous plants, and lichens. Similarly, within Diptera, the four most dominant taxa had ground cover preferences that were distinctly different from each other; Bibionomorpha with graminoids and mosses, Culicomorpha with lichens and shrubs, Tipulomorpha with bare rock, and Muscoidea with bare soil. These findings are supported in the literature, of the Arctic tundra being a strongly heterogeneous environment, with changes in microhabitat along a spatial gradient significantly affecting the structure of terrestrial arthropod assemblages (Strathdee & Bale 1998, Bowden & Buddle 2010a, Hansen et al 2016a, Dahl et al 2018). This is similarly seen with soil-dwelling microarthropods, which includes some of the Collembola, where there are distinct communities beneath different kinds of Arctic vegetation (Coulson et al 2003). These differences in ground cover preference among closely related groups is suggestive of very fine scale niche partitioning.

2.6.2. *Climate*

When looking at the data from 2018, it is clear that the season was extreme or unusual. On a circumpolar scale, the June, July, and August (JJA) 2018 average surface air temperature north of 65ºN was above average for most of the Arctic region, and in Arctic Canada was 17th highest out of the previous 69 years (Arctic Regional Climate Centre Network 2018). Exceptionally, parts of Arctic Canada and central Greenland were experiencing below normal temperatures in summer 2018 (Arctic Regional Climate Centre Network 2018). On *Umingmat Nunaat*, we experienced two separate episodes of cold temperatures and snowy conditions in July 2018, each one lasting about a week. The first interval of cold weather, from 9 July to 15 July, coincided with my second sampling period (Figure 2.33, Figure 2.34). The second interval of cold weather, from 19 July to 26 July, coincided with my fourth sampling period (Figure 2.33, Figure 2.34). Between these two intervals of cold weather, there was a three-day window in which average solar radiation and air temperature rose substantially, with average air temperature peaking at 8.87ºC on 18 July; this warmer weather coincided with my third sampling period (Figure 2.33, Figure 2.34).

Contrary to much of the literature, my data found few significant correlations of arthropods and climate on *Umingmat Nunaat*. This is almost certainly explained by how the climate data was obtained. Climate data for all four sites was obtained from the same source, a Campbell Scientific meteorological station located within the MARS basecamp. The meteorological station is situated on a hill that is at a higher elevation than any of the sites, and the distance of this station to each of the four study sites is variable, ranging from 540 m away (in the case of Site 2) to 1.89 km away (in the case of Site 4). Therefore, the climatic conditions recorded by the meteorological station in the MARS basecamp may not be representative of the conditions occurring on a finer scale at each of the four study sites.

Of the biodiversity indices that were tested, Fisher's alpha did show a significant, very strong negative correlation with average windspeed. Wind is well documented in numerous open systems to have a negative effect on arthropod activity (Lee & Barnard 2015, Asmus et al 2018). If fewer arthropods are active in higher winds, then fewer arthropods would be falling into the traps, and so diversity in the traps would be lower.

Both Tipulomorpha abundance and parasitoid wasp abundance showed significant, very strong positive correlations with average air temperature. Tipulomorpha (crane flies) and parasitoid wasps shared very similar phenological patterns during the 2018 season, having relatively low abundance for much of the study period before exploding in abundance at the very end of the study period. The 6th sampling period, when both crane fly and parasitoid wasp abundance exploded, also coincides with the warmest average air temperatures recorded for the study period. Arthropods are strongly affected by temperature. Bolduc et al (2013) found that across Arctic Canada, temperature variation accounted for 70% of the deviance in daily arthropod abundance. In Kugluktuk, Low Arctic Canada, there was a strong relationship between mean daily temperature and beetle assemblage structure (Ernst & Buddle 2013). Air temperature best explains variation in the activity level and patterns of flying insects in the High Arctic (Hodkinson et al 1998, Høye & Forchhammer 2008a). Therefore, the findings of Tipulomorpha and parasitoid wasp abundance having a very strong positive correlation with average air temperature is consistent with the literature.

2.6.3. *Seasonality*

When we arrived on *Umingmat Nunaat* on 1 July, significant snowmelt had already occurred, with the only remaining snow cover on the landscape limited to just a few bands at the highest elevations of some of the nearby mountains. Late June was when the highest average air temperature and average solar radiation values were recorded for 2018, both of which peaked on the same date of 29 June. The period in late June just prior to our arrival on *Umingmat Nunaat* was likely a period of significant snowmelt in which the last of the winter snows melted away, coinciding with the relatively high air temperature and solar radiation at the time. Timing of snowmelt is a good predictor of the phenology of most Arctic arthropods, directly affecting phenology of both plants and arthropods (Høye & Forchhammer 2008b, Mortensen et al 2016). In Zackenberg Valley, High Arctic Greenland, snowmelt directly affects plant and arthropod phenology (Mortensen et al 2016), with timing of emergence being closely related to the date of snowmelt in nine taxa of common surface-active and flying arthropods (Høye & Forchhammer 2008b). Snow acts as an insulator, and changes to its depth affects the enhancement of thermally dependent reactions, such as microbial activity, affecting soil nutrient composition, respiration, and winter gas efflux. (Cooper 2014). Snow depth and spring temperatures influence snowmelt timing, determining the start of plant growth and forage availability (Cooper 2014). Greater snow depth means delayed snowmelt timing, and this in turn delays the first and peak flowering dates of Arctic plants and shortens the prefloration period overall (Gillespie et al 2016). Plant–pollinator networks are vulnerable to phenological shifts between insects and plants, and reduced visitation rates to flowers in plots with deep snow (Gillespie et al 2016). At Zackenberg, the duration of the butterfly flight season was significantly positively related to the temporal overlap with floral resources (Høye et al 2014); taxa that are a bit more specialised, such as butterflies and parasitoid wasps, have a more narrow phenological range in the summer, potentially making them most vulnerable to trophic mismatch (Høye & Forchhammer 2008b).

The results of the first sampling period, occurring on 09-10 July, were probably typical for the early summer season on *Umingmat Nunaat*, since the warm temperatures and snowmelt that occurred just prior to that sampling would have enabled Arctic arthropods to emerge without delay. Because abundance and diversity of arthropods was still relatively low during the first sampling period, this was probably linked to availability of host plants at the time. On the date of arrival, only a handful of plant species were in bloom, predominantly *Saxifraga oppositifolia* Linnaeus and *Salix arctica* Pallas (pers. observation). The activity of many Arctic pollinators is constrained by availability of their preferred flowering plants (e.g., Høye et al 2014), so even though temperatures were warm and the snow had melted, many arthropods would not emerge until later in the season when flowering plant diversity was greater. It is also worth noting that the traps were yellow, but in the early season the predominant colour of blooming wildflowers was purple (characterised by *S. oppositifolia*). It is possible that the yellow trap colouration was less attractive to early-season arthropods, due to that colour not becoming more common until later in the summer. During the first sampling period, spiders were notably abundant relative to other arthropod groups. Arctic spiders are terrestrial predators and not constrained by availability of flowering plants, so the relatively high temperatures and solar radiation and associated snowmelt in late June were likely sufficient parameters for spiders to emerge and to be active early in the summer, while many other arthropod groups would not emerge until later due to availability of their associated plants.

It is interesting that both arthropod diversity and abundance decreased from the first sampling period to the second sampling period. As previously discussed, this is no doubt explained by the cold and snowy weather conditions that characterised the second sampling period. During that time, average barometric pressure plummeted to its lowest point of the summer, and intermittent flurries were causing periodic snow cover to form on the tundra; there was very little observable arthropod activity, aside from bumblebees (personal observation). If these atypically cold and snowy conditions had not occurred, it is likely that the second sampling period would have seen an increase in arthropod abundance and diversity relative to the first sampling period.

The third sampling period was characterised by an explosion in arthropod abundance. Overall arthropod abundance was at its highest point of the entire study. This was largely influenced by two of the dipteran taxa, Culicomorpha and Bibionomoprha, having their highest abundance during this sampling period, and with these two taxa being so dominant in the entire collection. The third sampling period was also when Pielou’s evenness was at its lowest value, because arthropod abundance, while high, was disproportionately composed of the two dipteran taxa of

Bibionomorpha and Culicomorpha while other taxa remained in relatively low abundance. This explosion in arthropod abundance coincided with an abrupt rise in average air temperature and average solar radiation. After a week-long period of snow and cold weather, the emergence time of many arthropods was likely delayed until this break in the weather occurred. It is likely that if there had not been that period of cold and snowy weather during the second sampling period, we instead would have seen a more gradual increase in both arthropod abundance and diversity across the first three sampling periods.

The fourth sampling period was associated with another period of below average temperatures and snow. Arthropod abundance and diversity decreased during the fourth sampling period, although not as low as in the second sampling period.

The fifth sampling period was when arthropod diversity was at its highest point. This was the height of the 2018 summer season on *Umingmat Nunaat*, with warm temperatures and a large variety of flowering plants in bloom. Spiders and muscoid flies were at their greatest abundance during this sampling period. The large variety of flowering plants in bloom likely contributed to an increase in diversity as insect pollinator emergence was timed with these blooms.

By the sixth sampling period, overall arthropod abundance and diversity were beginning to decrease again. This is probably typical for the late season on *Umingmat Nunaat*, as the short summer was winding down. By this time, the leaves of the Arctic willows (*Salix arctica* Pallas) were starting to change colour (personal observation). While most arthropods were declining in abundance, two notable exceptions were the Tipulomorpha and parasitoid wasps, which both were at their greatest abundance of the entire study. The sixth sampling period likely coincided with a synchronised emergence event for the crane flies. I hypothesise that this emergence event occurred this late in the summer season to avoid significant predation by breeding birds. At the time of the sixth sampling period, local nesting birds had concluded their breeding season, and in fact the adults of some species such as Baird's Sandpipers and Snow Buntings had already departed south on their migration, leaving behind the less experienced juveniles (personal observation). During summer 2018, I frequently observed crane flies to fall prey to locally nesting birds, their relatively large size making them significant targets for Snow Buntings and other species. The synchronised emergence event of crane flies that occurred late in the season in 2018 may have been timed to be outside the breeding season of locally nesting birds to reduce predation (Seastedt 1980). As for parasitoid wasps, these are noted to have a relatively narrow phenological range in the summer (Høye & Forchhammer 2008b), and their emergence was likely timed with that of their hosts. As this increase in abundance of parasitoid wasps occurred relatively late in the summer season, I hypothesise that the hosts of these wasps are the developmental stages of arthropods preparing to go into diapause for winter.

Overall, arthropod abundance showed two notable peaks that occurred during the third and fifth sampling periods—corresponding to 18-19 July and 28-29 July respectively—and two notable dips that occurred during the second and fourth sampling periods—corresponding with 13-14 July and 23-24 July respectively. The three most abundant taxa in all the samples—Culicomorpha, Muscoidea, and Bibionomorpha—mirrored and largely influenced these abundance patterns. Spiders also showed similar abundance patterns to the above taxa, but spiders in contrast were very abundant during the very first sampling period relative to other arthropod groups. Most arthropod groups were declining in abundance by the sixth and final sampling period on 02 August. However, parasitoid wasps and Tipulomorpha notably differed from this pattern in that they were at their greatest abundance during the final sampling period.

2.6.4. *Additional discussion*

Some arthropod taxa may have been underrepresented in the samples due to the method of collection. While yellow pitfall traps are a widely accepted tool for collecting a broad range of northern arthropod taxa (e. g., they are less effective at targeting some groups. Arthropods with more sedentary life histories would be less likely to encounter the traps than those that are more active. For example, there were six times more wolf spiders (Lycosidae) than sheet-web spiders (Linyphiidae) in the 2018 samples. Wolf spiders are active hunters that I regularly observed traversing the tundra on *Umingmat Nunaat*, making them more likely to incidentally encounter and fall into the traps compared to sheet-web spiders, which are more sedentary (on *Umingmat Nunaat*, I have found them mainly underneath rocks). There may not necessarily have been fewer linyphiid spiders than wolf spiders on the landscape, but rather the traps were more likely to trap wolf spiders because of their more active life history. This is suggested in the literature by

Gillespie et al (2020), who noted that pitfall traps can bias samples toward wandering species. Similarly, a species of mealybug (Coccoidea: Pseudococcidae) was encountered in the samples, but in all but one instance it was just the first-instar nymphs that were represented. Adult mealybugs—the females, at least—are mostly sessile and stay fastened to their host plant (Marshall 2006). It is therefore extremely unlikely that an adult female mealybug would ever fall into a yellow pitfall trap, unless it was attached to a piece of plant matter that incidentally blew into a trap. The earlier developmental stages of the mealybug are much more mobile however, and so these were the only ones that were encountered (there was also a single specimen belonging to an undetermined developmental stage, but this one appeared to be mobile as well with well-developed legs). Active collection, rather than passive traps, would be the best way to capture these more sedentary arthropods.

Trap colouration may have affected sampling. Yellow is the standard colour used for pan traps in the Arctic (Ernst et al 2016), and indeed yellow is one of the predominant colours of wildflowers on *Umingmat Nunaat*, seen there on common species such as *Dryas integrifolia* Vahl and *Papaver spp* Linnaeus, among many others. But another very common colour of wildflowers on *Umingmat Nunaat* is purple, seen on common species such as *Saxifraga oppositifolia* Linnaeus and *Silene acaulis* (Linnaeus) Jacquin. In the field, I observed that some moths seemed to favour foraging from purple flowers. Incidentally, moths were scarce in the 2018 sampling, with a mere 11 adult specimens represented. If a different colour pan trap were used, it is possible that these results may have varied.

Additionally, yellow pitfall traps would not be suited for capturing flighted insects that do not feed as adults. On *Umingmat Nunaat*, this includes sawflies (Tenthredinidae), of which only two adults were collected in 2018, presumably having fallen into the traps incidentally. Also included in this category are adults of the Arctic woolly bear moth (*Gynaephora groenlandica* Wocke ex. Homeyer). While three caterpillars of this species were collected—since they fell in because the traps were doubling as pitfall traps—no adults were collected in 2018. Adult females of *G. groenlandica* are flightless and sedentary, while adult males are flighted but do not feed; therefore, adults of this species would be exceedingly unlikely to be collected by yellow pitfall traps.

2.6.5 *Conclusion*

In the Arctic, both microhabitat type and seasonal change play a role in structuring terrestrial arthropod communities. The dominant dipteran and collembolan taxa showed distinctly different ground cover preferences from each other, suggesting very fine scale niche partitioning among closely related groups. Few significant correlations of arthropods and climate were found in this study, a stark contrast to much of the literature, but likely explained by how the climate data was obtained. A more ideal scenario would be to have weather instrumentation set up at each of the study sites, rather than relying on climate data from a single source that may not be representative of what is happening on a finer scale at each site. Finally, the results showed that arthropod communities are dynamic, with diversity and abundance of various taxa changing throughout the short season. This project supports the finding of previous research, that fine scale microhabitat level sampling is necessary to fully capture Arctic arthropod diversity.

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2.9. Tables and figures

Table 2.1. Locations and sampling dates for each of the 56 yellow pitfall traps

Summary of sites											
Site 1	**Coordinates**	**Elevation**	**Location Accuracy**	**Activation date**	**Deactivation date**	**1st collection date**	**2nd collection date**	**3rd collection date**	**4th collection date**	**5th collection date**	**6th collection date**
1.a.i.	N 79°25.237' W090°44.801'	182 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.b.i.	N 79°25.240' W090°44.785'	181 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.a.ii.	N 79°25.239' W090°44.843'	184 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.b.ii.	N 79°25.243' W090°44.814'	184 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.a.iii.	N 79°25.242' W090°44.844'	183 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.b.iii.	N 79°25.245' W090°44.803'	184 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.a.iv.	N 79°25.245' W090°44.861'	187 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.b.iv.	N 79°25.248' W090°44.836'	187 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.a.v.	N 79°25.248' W090°44.883'	188 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.b.v.	N 79°25.254' W090°44.863'	191 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.a.vi.	N 79°25.251' W090°44.931'	194 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.b.vi.	N 79°25.253' W090°44.910'	193 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.a.vii.	N 79°25.252' W090°44.927'	198 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
1.b.vii.	N 79°25.255' W090°44.918'	197 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
Site 2	**Coordinates**	**Elevation**	**Location Accuracy**	**Activation date**	**Deactivation date**	**1st collection date**	**2nd collection date**	**3rd collection date**	**4th collection date**	**5th collection date**	**6th collection date**
2.a.i.	N 79°24.982' W090°46.706'	182 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.b.i.	N 79°24.986' W090°46.703'	182 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.a.ii.	N 79°24.984' W090°46.732'	180 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.b.ii.	N 79°24.986' W090°46.731'	179 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18

2.a.iii.	N 79°24.984' W090°46.752'	177 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.b.iii.	N 79°24.989' W090°46.751'	176 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.a.iv.	N 79°24.986' W090°46.774'	176 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.b.iv.	N 79°24.992' W090°46.776'	178 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.a.v.	N 79°24.989' W090°46.804'	178 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.b.v.	N 79°24.994' W090°46.804'	180 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.a.vi.	N 79°24.991' W090°46.338'	182 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.b.vi.	N 79°24.993' W090°46.841'	183 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.a.vii.	N 79°24.996' W090°46.831'	183 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
2.b.vii.	N 79°24.997' W090°46.844'	180 m	5 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
Site 3	**Coordinates**	**Elevation**	**Location Accuracy**	**Activation date**	**Deactivation date**	**1st collection date**	**2nd collection date**	**3rd collection date**	**4th collection date**	**5th collection date**	**6th collection date**
3.a.i.	N 79°24.670' W090°48.191'	161 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.b.i.	N 79°24.668' W090°48.210'	162 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.a.ii.	N 79°24.664' W090°48.188'	161 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.b.ii.	N 79°24.664' W090°48.225'	162 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.a.iii.	N 79°24.662' W090°48.207'	165 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.b.iii.	N 79°24.657' W090°48.211'	168 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.a.iv.	N 79°24.655' W090°48.172'	171 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.b.iv.	N 79°24.653' W090°48.191'	172 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.a.v.	N 79°24.649' W090°48.159'	173 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.b.v.	N 79°24.648' W090°48.178'	173 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.a.vi.	N 79°24.647' W090°48.164'	174 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.b.vi.	N 79°24.645' W090°48.183'	175 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18

3.a.vii.	N 79°24.646' W090°48.157'	176 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
3.b.vii.	N 79°24.645' W090°48.153'	178 m	6-9 m	05-Jul-18	02-Aug-18	09-Jul-18	13-Jul-18	18-Jul-18	23-Jul-18	28-Jul-18	02-Aug-18
Site 4	**Coordinates**	**Elevation**	**Location Accuracy**	**Activation date**	**Deactivation date**	**1st collection date**	**2nd collection date**	**3rd collection date**	**4th collection date**	**5th collection date**	**6th collection date**
4.a.i.	N 79°24.756' W090°50.348'	156 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.b.i.	N 79°24.757' W090°50.336'	155 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.a.ii.	N 79°24.772' W090°50.383'	156 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.b.ii.	N 79°24.767' W090°50.351'	155 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.a.iii.	N 79°24.776' W090°50.376'	157 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.b.iii.	N 79°24.768' W090°50.328'	155 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.a.iv.	N 79°24.773' W090°50.352'	155 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.b.iv.	N 79°24.771' W090°50.333'	156 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.a.v.	N 79°24.778' W090°50.390'	153 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.b.v.	N 79°24.776' W090°50.352'	154 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.a.vi.	N 79°24.779' W090°50.378'	154 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.b.vi.	N 79°24.782' W090°50.329'	153 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.a.vii.	N 79°24.789' W090°50.394'	155 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18
4.b.vii.	N 79°24.788' W090°50.353'	157 m	5 m	05-Jul-18	02-Aug-18	10-Jul-18	14-Jul-18	19-Jul-18	24-Jul-18	29-Jul-18	02-Aug-18

Table 2.2. Diversity indices for each of the six sampling periods, as well as all six sampling periods pooled. Replicate sites are pooled.

	1st sampling	2nd sampling	3rd sampling	4th sampling	5th sampling	6th sampling	Entire collection
Shannon Diversity Index	1.824715	1.400226	1.412201	1.720260	1.749536	2.098208	1.783294

Evenness	0.6440443	0.5305780	0.4503919	0.5742368	0.5435239	0.6602179	0.5473424
Richness	17	14	23	20	25	24	26
Total number of individuals	2919	1325	15646	4434	9158	4350	37832
Average population size	172	94.64	680	221.7	366.3	181.3	1455
Simpson’s index (D)	0.21	0.35	0.33	0.21	0.24	0.17	0.22
Simpson’s Diversity Index (1-D)	0.7942315	0.6509864	0.6674857	0.7850643	0.7568385	0.8337579	0.7803963
Simpson’s Reciprocal Index (1/D)	4.859830	2.865218	3.007390	4.652555	4.112493	6.015324	4.553657
Fisher's Alpha	2.391741	2.184242	2.648505	2.701262	3.132479	3.346981	2.725884

Table 2.3. Proportions of ground cover classifications at each of the 56 traps. Larger proportions are denoted by a darker shade, in increments of 0.2.

Trap	Graminoids	Herbs	Shrubs	Mosses	Lichens	Bare rock	Bare soil
1.a.i.	0.0246914	0.5061728	0.0864198	0.037037	0.0246914	0	0.3209877
1.b.i.	0.0246914	0.1358025	0.4444444	0.0123457	0.2592593	0.0123457	0.1111111

1.a.ii.	0	0.345679	0.1851852	0.2469136	0.1481481	0	0.0740741
1.b.ii.	0.1234568	0.4197531	0.1481481	0.1481481	0.0617284	0.037037	0.0617284
1.a.iii.	0	0.2469136	0.0246914	0	0.2098765	0	0.5185185
1.b.iii.	0	0.4567901	0.0987654	0.2098765	0.1481481	0	0.0864198
1.a.iv.	0.1358025	0.1481481	0.2962963	0.1728395	0.1358025	0	0.1111111
1.b.iv.	0.037037	0.2345679	0.1111111	0.0617284	0.2222222	0	0.3333333
1.a.v.	0.0740741	0	0.0493827	0	0	0.037037	0.8395062
1.b.v.	0.3333333	0.0493827	0.3703704	0.037037	0.037037	0.0123457	0.1604938
1.a.vi.	0.0246914	0.037037	0.2345679	0.0123457	0	0.0123457	0.6790123
1.b.vi.	0	0	0.037037	0	0	0.0123457	0.9506173
1.a.vii.	0	0.2592593	0.1234568	0.0740741	0.345679	0.037037	0.1604938
1.b.vii.	0.0123457	0.037037	0.0864198	0	0	0.1975309	0.6666667
2.a.i.	0.3580247	0	0.2345679	0.308642	0.0864198	0	0.0123457
2.b.i.	0.4567901	0	0.2839506	0.0740741	0.1728395	0	0.0123457
2.a.ii.	0.4938272	0	0.1728395	0.1728395	0.0246914	0	0.1358025
2.b.ii.	0.617284	0	0.1234568	0.1358025	0.037037	0	0.0864198
2.a.iii.	0.5061728	0	0.0864198	0.1975309	0.0246914	0.0493827	0.1358025
2.b.iii.	0.5061728	0	0.037037	0.2839506	0.037037	0	0.1358025
2.a.iv.	0.2469136	0	0.2839506	0.0740741	0.1358025	0.0617284	0.1975309
2.b.iv.	0.2469136	0	0	0.2716049	0.2469136	0	0.2345679
2.a.v.	0.2592593	0	0.4691358	0.037037	0.0864198	0.0493827	0.0987654
2.b.v.	0.4074074	0	0.0246914	0.3703704	0.0864198	0.0123457	0.0987654
2.a.vi.	0.2098765	0	0.2345679	0.1975309	0.2716049	0.0123457	0.0740741
2.b.vi.	0.1728395	0	0.3950617	0.0987654	0.1111111	0.0123457	0.2098765
2.a.vii.	0.308642	0	0.2716049	0.1851852	0.1728395	0.0493827	0.0123457
2.b.vii.	0.2469136	0	0.0123457	0.2962963	0.2222222	0.1111111	0.1111111
3.a.i.	0.5555556	0.0864198	0.2469136	0.0740741	0.0246914	0	0.0123457
3.b.i.	0.4320988	0.1604938	0.2222222	0.0246914	0.1234568	0	0.037037
3.a.ii.	0.2962963	0.0123457	0.4814815	0.0987654	0.0123457	0	0.0987654
3.b.ii.	0.4938272	0.1728395	0.0493827	0.1358025	0.0740741	0	0.0740741
3.a.iii.	0.5061728	0.0864198	0.3703704	0.0246914	0	0	0.0123457
3.b.iii.	0.5925926	0.0987654	0.0740741	0.0123457	0.0493827	0	0.1728395
3.a.iv.	0.2839506	0.1728395	0.1604938	0.0493827	0	0	0.3333333
3.b.iv.	0.654321	0.0246914	0.1111111	0.1604938	0.0493827	0	0
3.a.v.	0.037037	0.0123457	0.0246914	0	0	0	0.9259259
3.b.v.	0.2962963	0.0864198	0.1234568	0.0123457	0	0	0.4814815

3.a.vi.	0.0123457	0.0493827	0	0	0	0	0.9382716
3.b.vi.	0.0493827	0.0493827	0.0740741	0	0.0123457	0	0.8148148
3.a.vii.	0.0123457	0.0617284	0	0	0	0	0.9259259
3.b.vii.	0	0	0.1358025	0	0	0.0246914	0.8395062
4.a.i.	0.0740741	0.0864198	0.1358025	0.3580247	0.345679	0	0
4.b.i.	0.0617284	0.0246914	0.654321	0.0493827	0.2098765	0	0
4.a.ii.	0.0123457	0.0123457	0.0493827	0.2222222	0.691358	0.0123457	0
4.b.ii.	0	0.0123457	0.8271605	0	0.1604938	0	0
4.a.iii.	0.0123457	0.037037	0.8024691	0	0.1481481	0	0
4.b.iii.	0	0.0493827	0.6419753	0.0123457	0.2592593	0	0.037037
4.a.iv.	0.0246914	0.2469136	0.0864198	0.0123457	0.5802469	0.0246914	0.0246914
4.b.iv.	0.0246914	0.1604938	0.1851852	0	0.5432099	0	0.0864198
4.a.v.	0	0.1234568	0.4444444	0.0123457	0.3950617	0	0.0246914
4.b.v.	0	0.0740741	0.0493827	0.037037	0.3209877	0.1481481	0.3703704
4.a.vi.	0	0.1358025	0.3580247	0.0246914	0.4320988	0.0246914	0.0246914
4.b.vi.	0	0.0987654	0.0493827	0	0.1975309	0.0987654	0.5555556
4.a.vii.	0	0.0246914	0.037037	0	0.5061728	0.3580247	0.0740741
4.b.vii.	0.0123457	0.0740741	0.0864198	0.0246914	0.2962963	0.345679	0.1604938

Table 2.4. Spearman's rank correlation coefficients and associated p-values for various diversity indices and arthropod abundances with climate. Significant p-values are denoted with an asterisk.

Response		Average air temperature	Average solar radiation	Average windspeed	Average barometric pressure
Shannon diversity index	R_s	0.71428571	0.65714286	-0.5428571	0.31887407
	P-value	0.20	0.20	0.50	> 0.50
Simpson's diversity index	R_s	0.54285714	0.54285714	-0.4285714	0.23190841
	P-value	0.50	0.50	0.50	> 0.50
Pielou's evenness	R_s	0.37142857	0.6	-0.3142857	0.08696566
	P-value	0.50	0.50	> 0.50	> 0.50

Fisher's alpha	R_s	0.82857143	0.77142857	-0.9428571	0.840668
	P-value	0.20	0.20	0.05*	0.10
Overall arthropod abundance	R_s	0.485714286	0.085714286	-0.6	0.579771036
	P-value	0.50	> 0.50	0.50	0.50
Tipulomorpha abundance	R_s	1	0.54285714	-0.7714286	0.81167945
	P-value	0.005*	0.50	0.20	0.20
Culicomorpha abundance	R_s	0.37142857	-0.0857143	-0.3142857	0.17393131
	P-value	0.50	> 0.50	> 0.50	> 0.50
Bibionomorpha abundance	R_s	0.71428571	0.14285714	-0.6571429	0.75370235
	P-value	0.20	> 0.50	0.20	0.20
Muscoidea abundance	R_s	0.54285714	0.37142857	-0.7714286	0.57977104
	P-value	0.50	0.50	0.20	0.50
Parasitoid abundance	R_s	0.94285714	0.6	-0.8857143	0.92763366
	P-value	0.05*	0.5	0.10	0.05*
Araneae abundance	R_s	0.71428571	0.6	-0.6	0.23190841
	P-value	0.20	0.50	0.50	> 0.50

Table 2.5. Variance estimations for various diversity indices and arthropod abundance values

Response	Variance (σ^2)	Standard deviation (σ)	Count	Mean (μ)	Sum of squares
Shannon	0.058279338	0.24141114	6	1.7008577	0.34967603

diversity index					
Simpson’s diversity index	0.0044729699	0.066880265	6	0.74806072	0.026837819
Pielou’s evenness	0.0050254577	0.070890463	6	0.56716547	0.030152746
Fisher's alpha	0.1603812	0.40047622	6	2.7342017	0.96228723
Overall arthropod abundance	7359.6461	85.78838	6	113.20828	44157.877
Tipulomorpha abundance	7.3311721	2.7076137	6	2.8511905	43.987032
Culicomorpha abundance	2272.0501	47.666027	6	37.491071	13632.301
Bibionomorpha abundance	361.08574	19.002256	6	22.39881	2166.5145
Muscoidea abundance	472.47757	21.736549	6	26.321429	2834.8654
Parasitoid abundance	4.0133546	2.0033359	6	1.8705087	24.080127
Araneae abundance	3.0257286	1.7394622	6	2.901461	18.154372

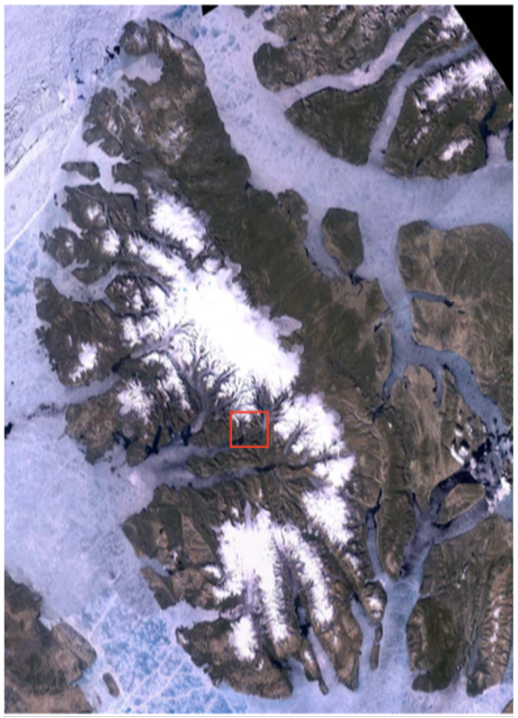

Figure 2.1. A satellite image of *Umingmat Nunaat*/Axel Heiberg Island, in High Arctic Canada. The red box indicates the general region of the McGill Arctic Research Station (MARS) in the western-central part of the island (Expedition Fiord)

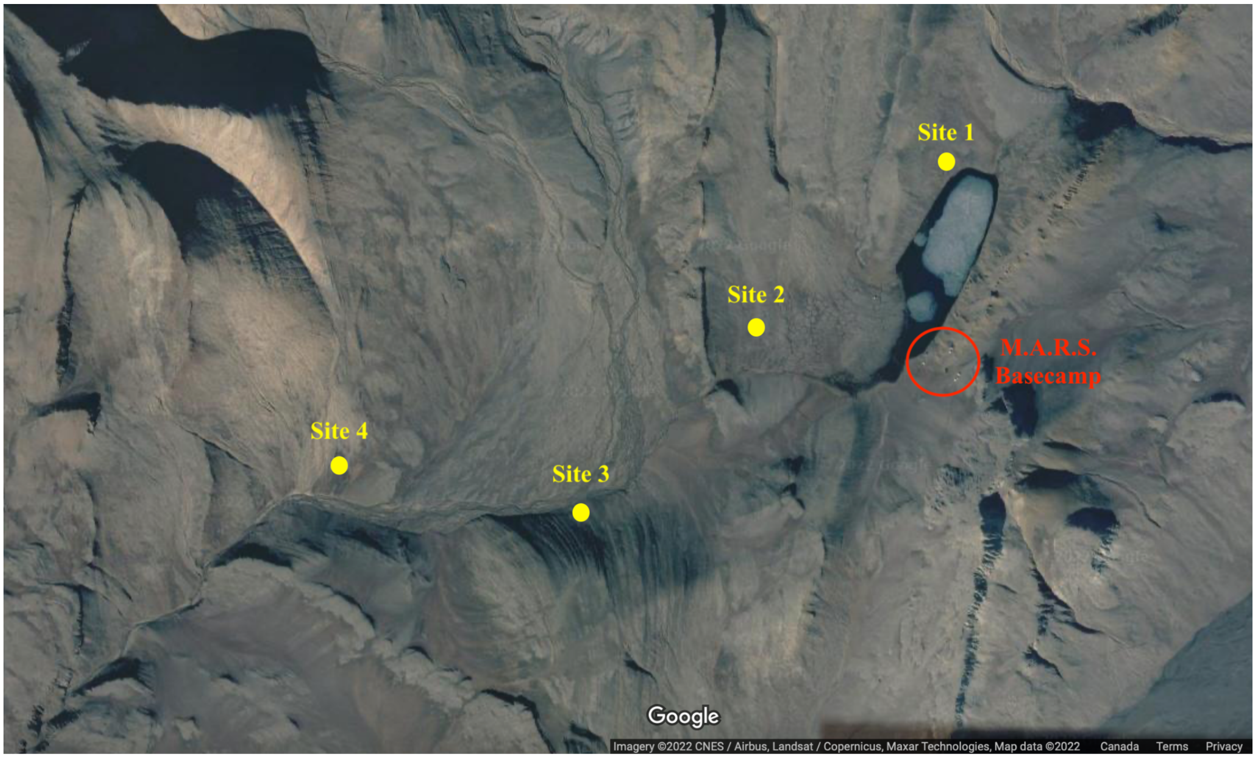

Figure 2.2. A satellite image showing the location of the four replicate study sites in the vicinity of the McGill Arctic Research Station (MARS) on *Umingmat Nunaat*/Axel Heiberg Island. The four study sites were spaced approximately 800 m apart, and followed the flow of water from Colour Lake into its outlet Wolf Creek. Map data ©2022 Google.

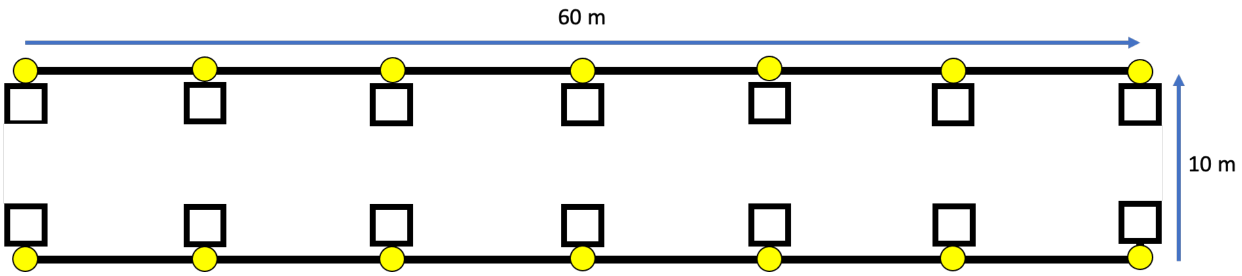

Figure 2.3. A diagram showing the layout of each of the four replicate study sites. Each site was a 60 m x 10 m transect, oriented perpendicular to the adjacent water body. A yellow pitfall trap was placed every 10 m along the transect. A 1 m x 1 m quadrat was placed next to each trap, on the interior of the transect.

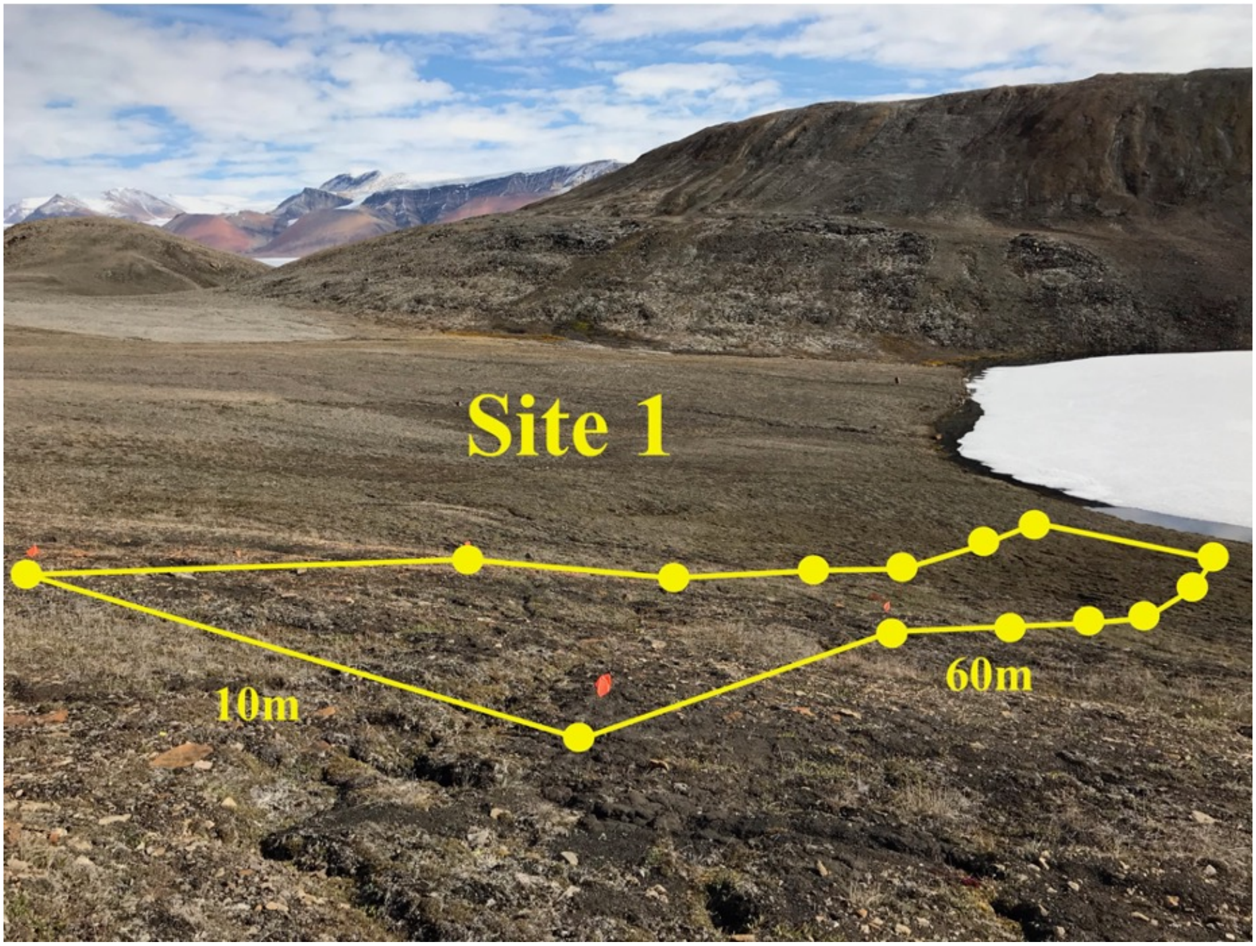

Figure 2.4. An image of Site 1. This site was located on the northern edge of Colour Lake. This image shows how the sites were oriented perpendicular to the water. Every 10 m along the transect, a yellow pitfall trap was placed.

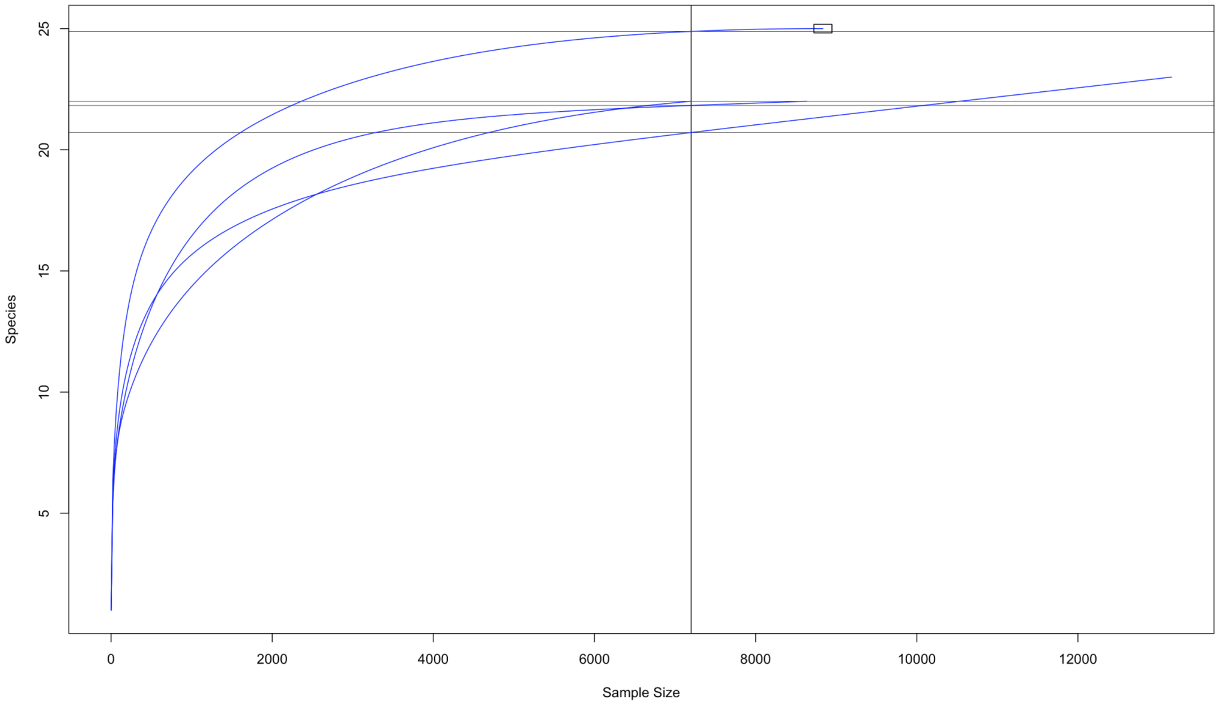

Figure 2.5. Rarefaction curves of taxon richness for each of the four replicate sites. Only when sampling has reached asymptotic can taxon richness be used as a measure of biodiversity—as is the case here. Rarefied taxon richness values are as follows: Site 1 = 24.88418, Site 2 = 22.00000, Site 3 = 20.71170, Site 4 = 21.82849.

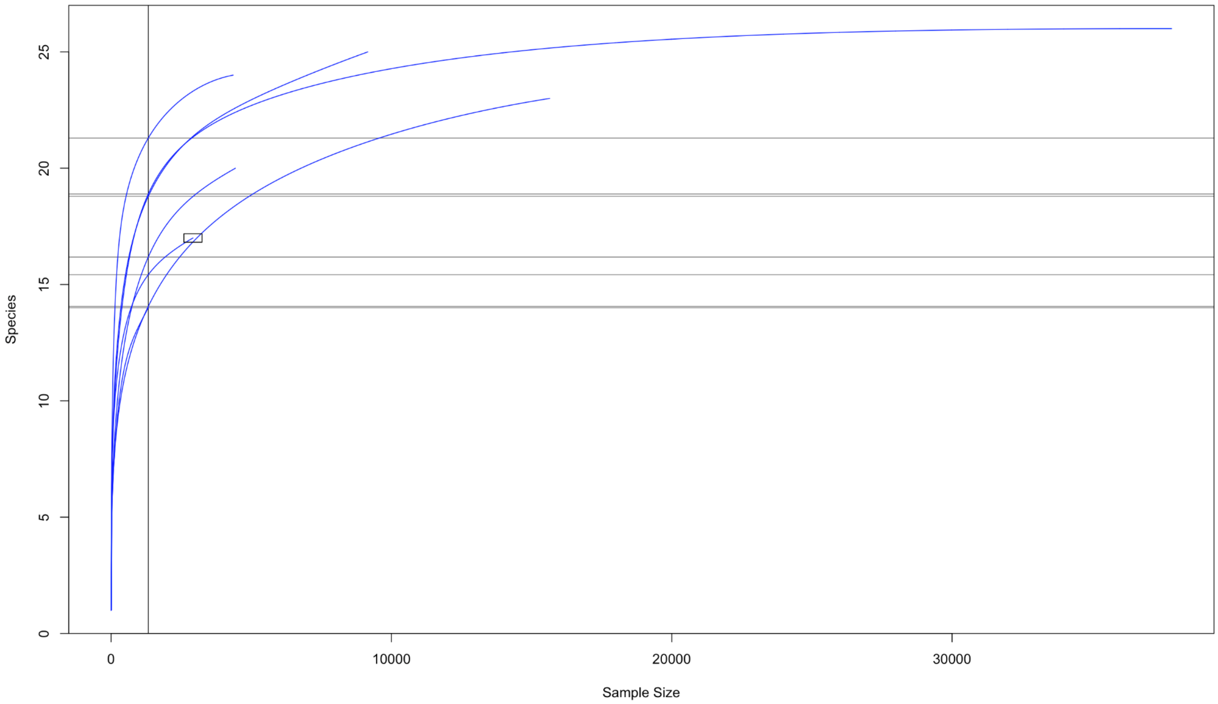

Figure 2.6. Rarefaction curves of taxon richness for each of the six sampling periods, as well as for all six sampling periods pooled. Only when sampling has reached asymptotic can taxon richness be used as a measure of biodiversity—as is the case here. Rarefied taxon richness values are as follows: 1st samping = 15.42152, 2nd sampling = 14.00000, 3rd sampling = 14.05682, 4th sampling = 16.18215, 5th sampling = 18.78917, 6th sampling = 21.29476, Entire collection = 18.89032.

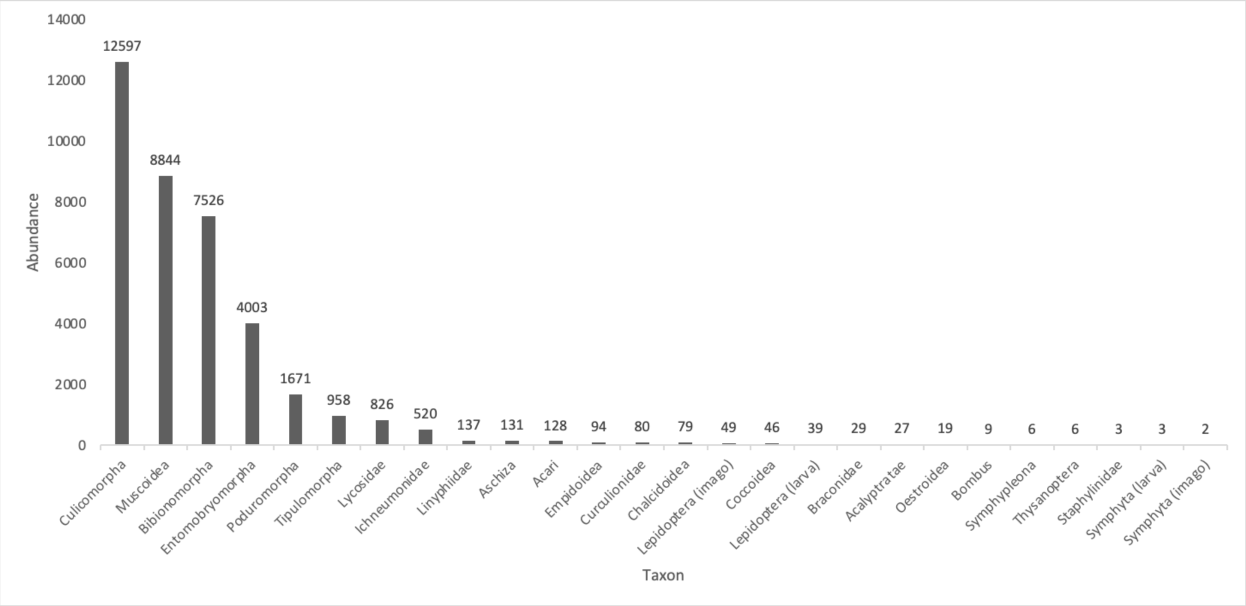

Figure 2.7. Rank abundance graph of the 2018 collection of arthropods. All replicates are pooled.

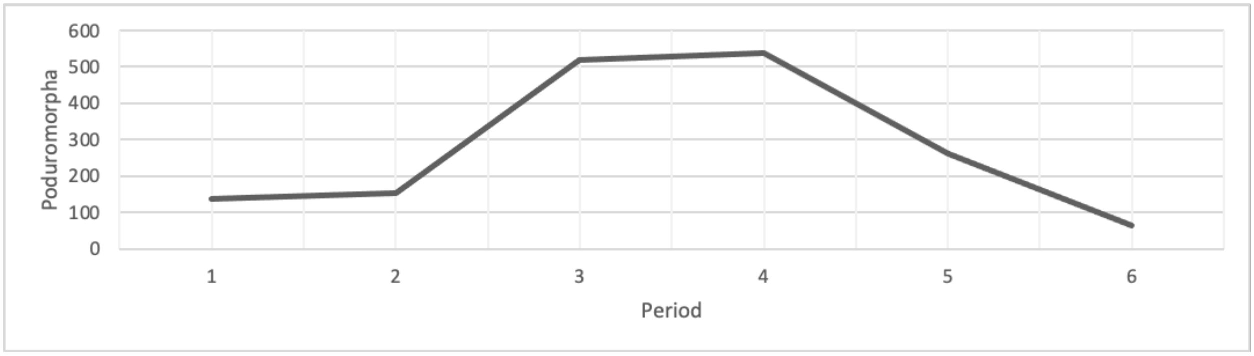

Figure 2.8. Poduromorpha turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

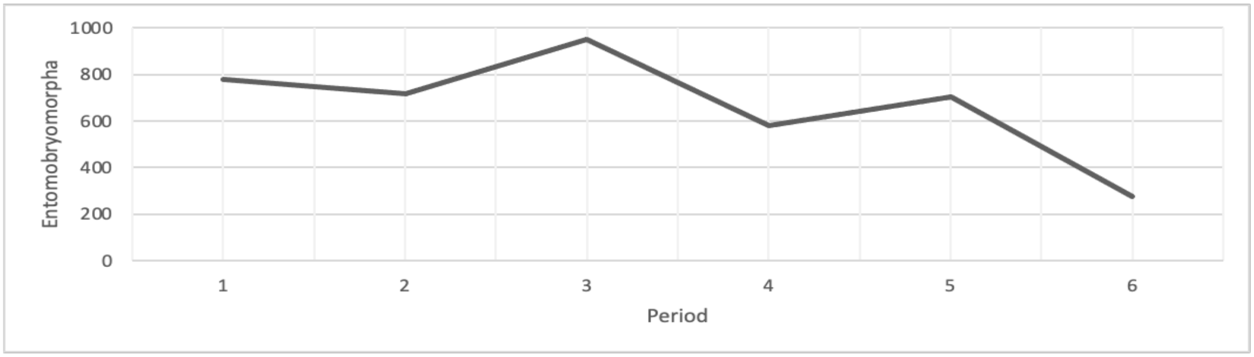

Figure 2.9. Entomobryomorpha turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

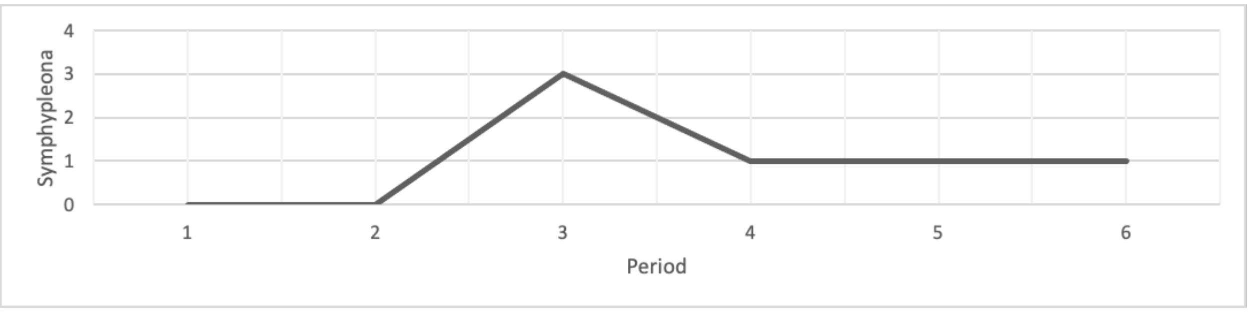

Figure 2.10. Symphypleona turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

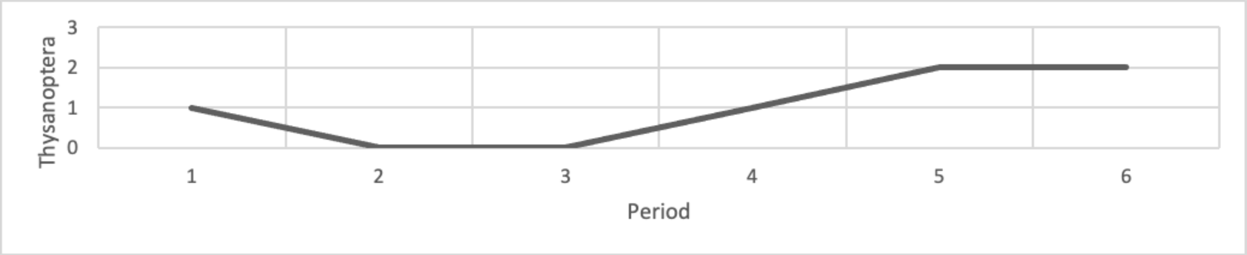

Figure 2.11. Thysanoptera turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

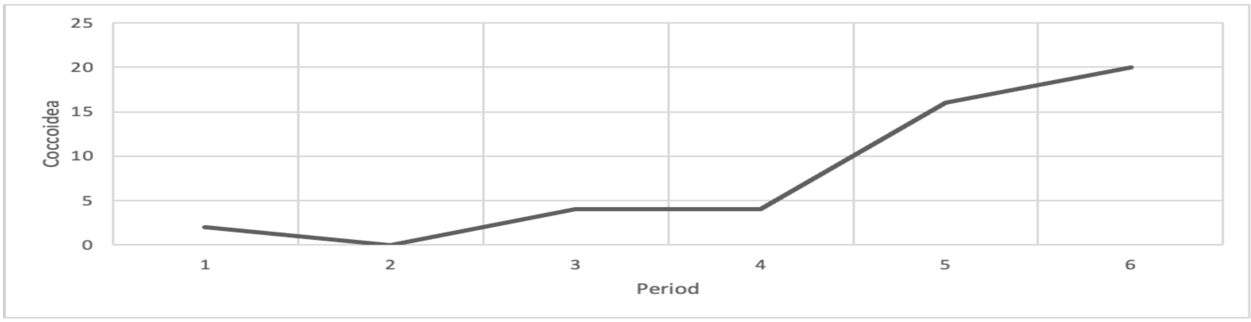

Figure 2.12. Coocoidea turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

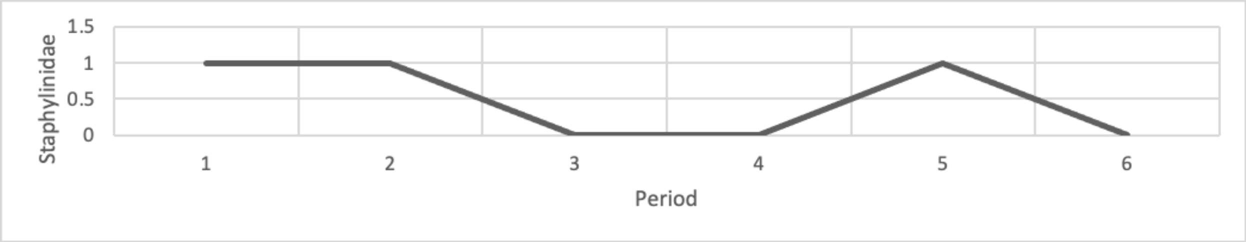

Figure 2.13. Staphylinidae turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

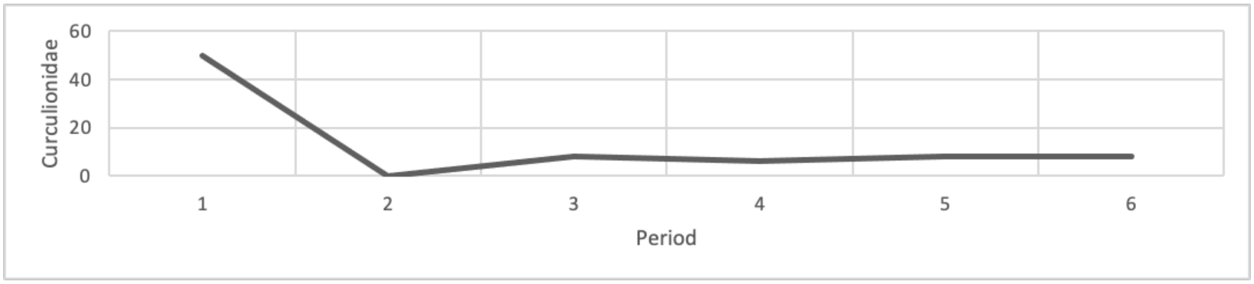

Figure 2.14. Curculionidae turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

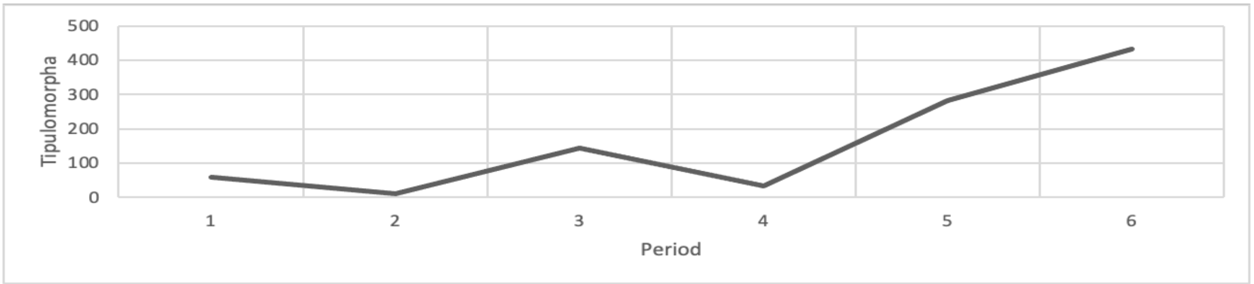

Figure 2.15. Tipulomorpha turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

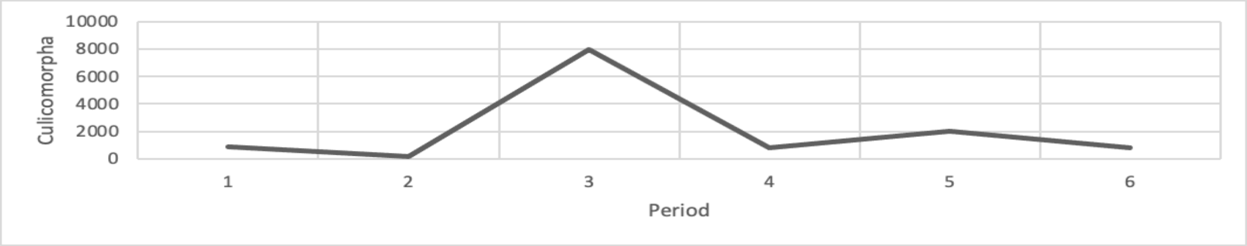

Figure 2.16. Culicomorpha turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

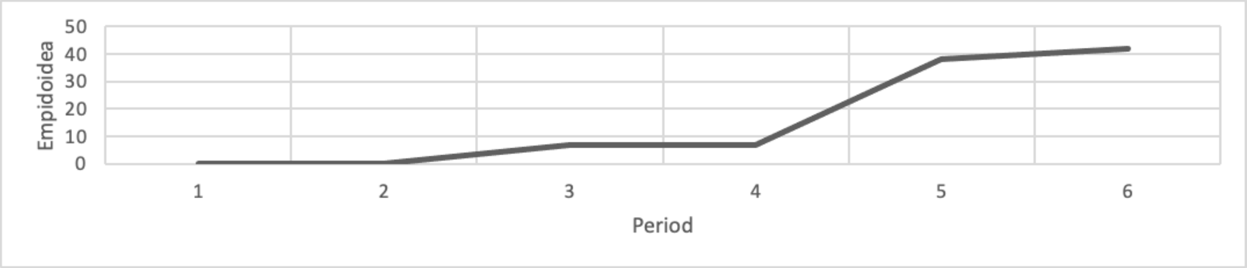

Figure 2.17. Empidoidea turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

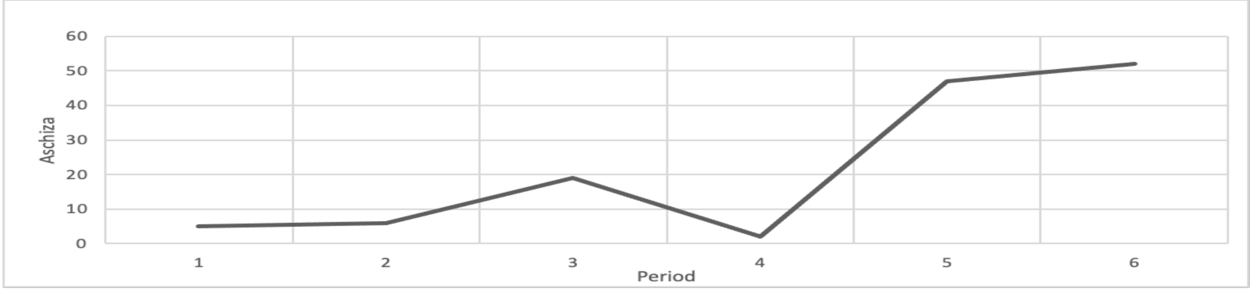

Figure 2.18. Aschiza turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

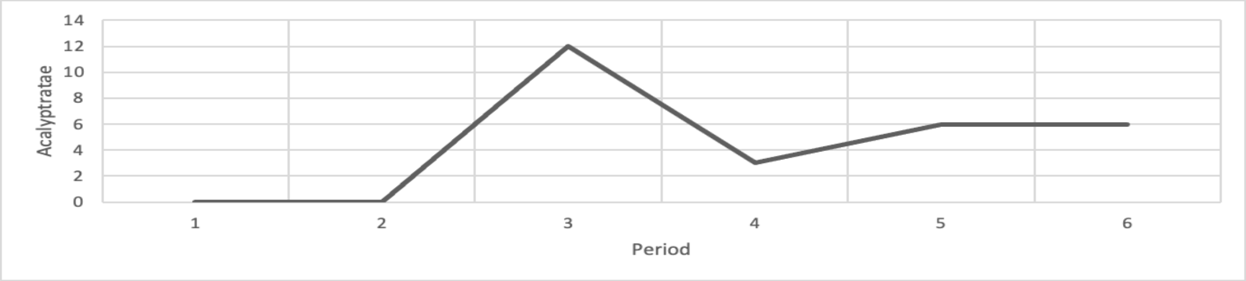

Figure 2.19. Acalyptratae turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

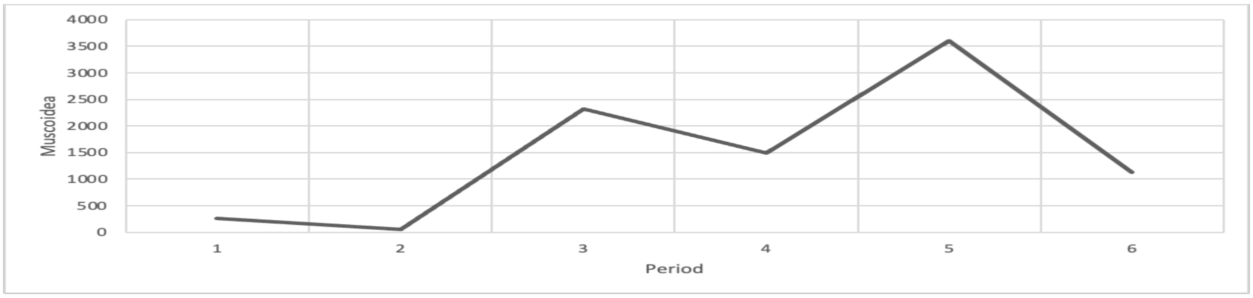

Figure 2.20. Muscoidea turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

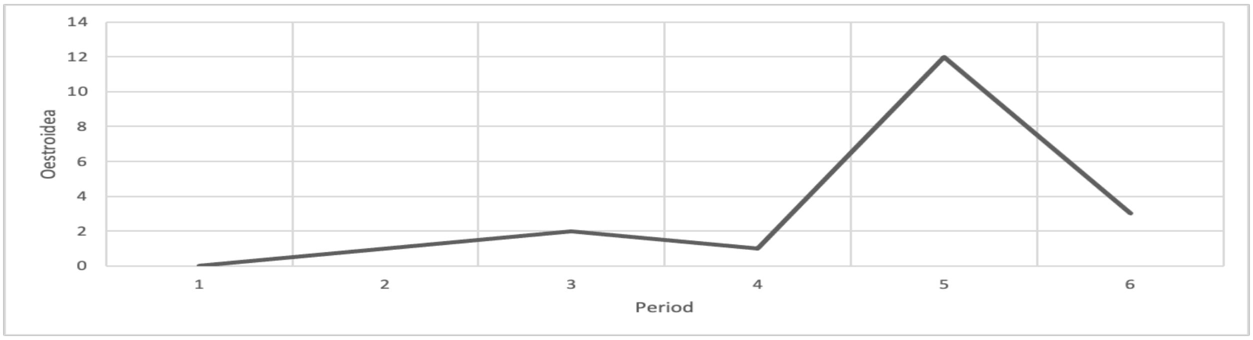

Figure 2.21. Oestroidea turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

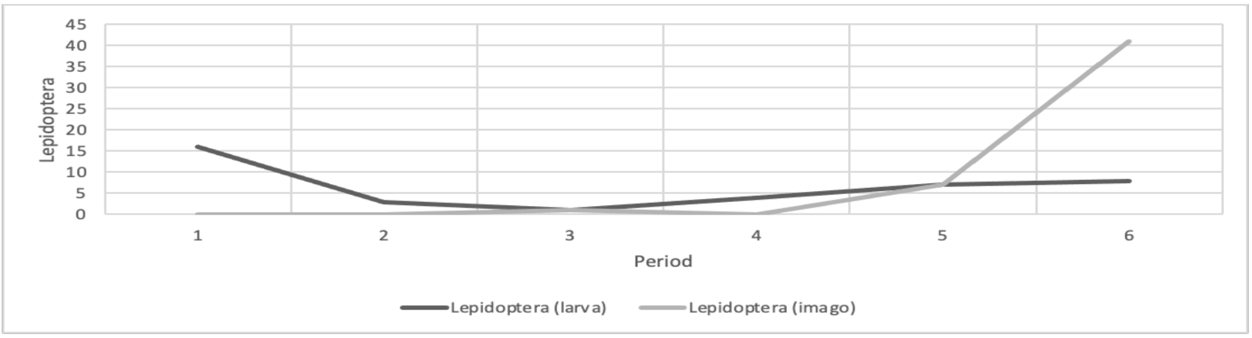

Figure 2.22. Lepidoptera turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

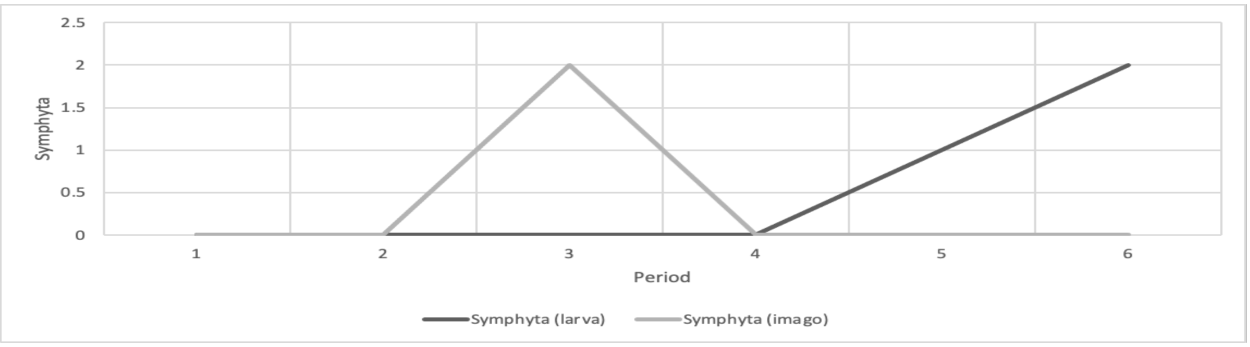

Figure 2.23 Symphyta turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

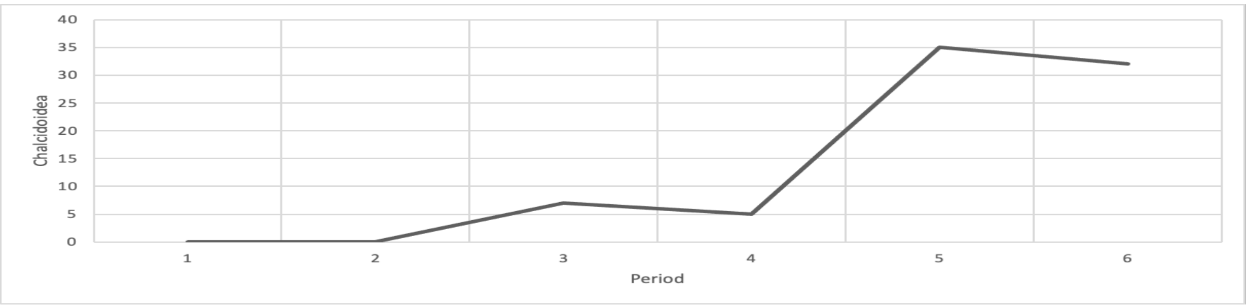

Figure 2.24. Chalcidoidea turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

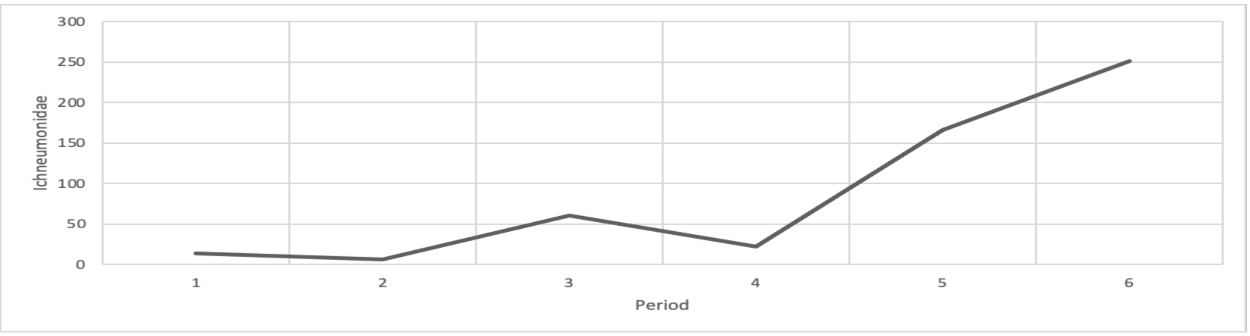

Figure 2.25. Ichneumonidae turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

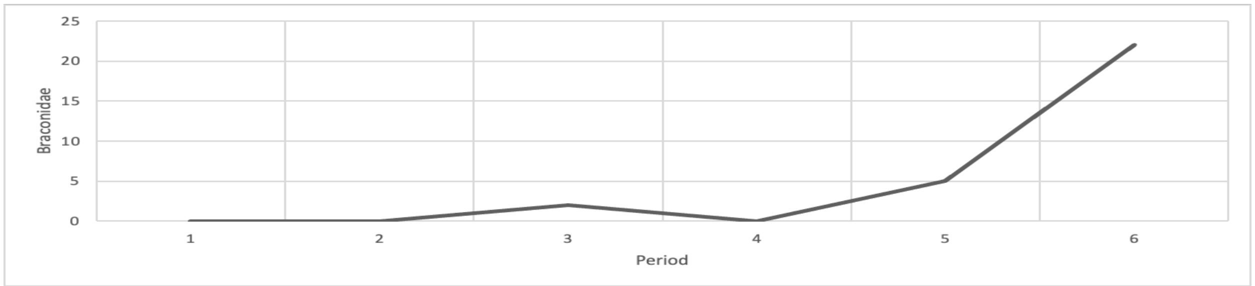

Figure 2.26. Braconidae turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

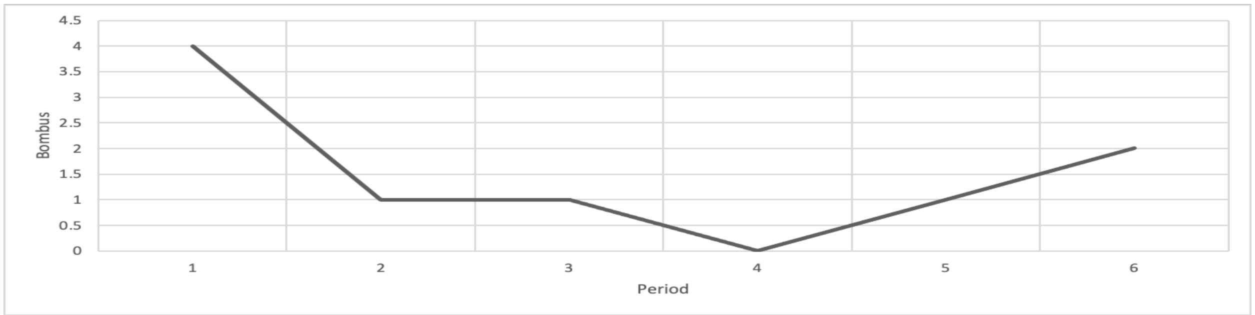

Figure 2.27. *Bombus* turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

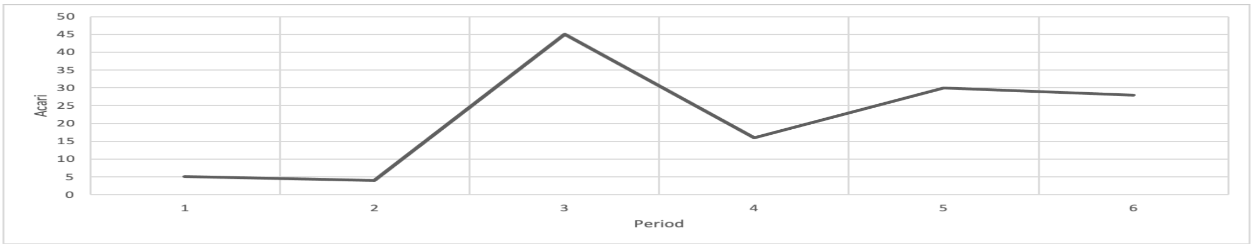

Figure 2.28. Acari turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

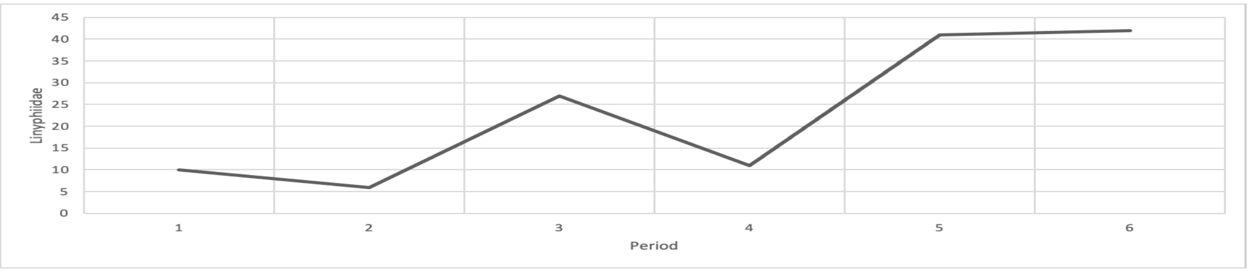

Figure 2.29. Linyphiidae turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

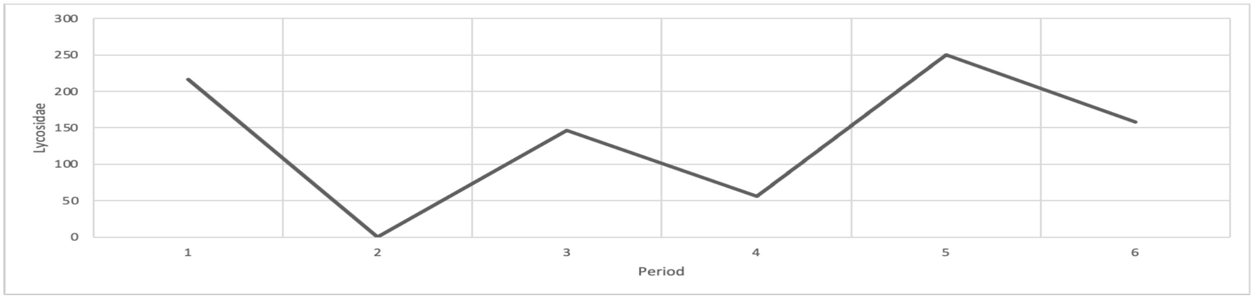

Figure 2.30. Lycosidae turnover across the six sampling periods. Plotted values are the total abundance of this taxon at each time period. Replicates are pooled.

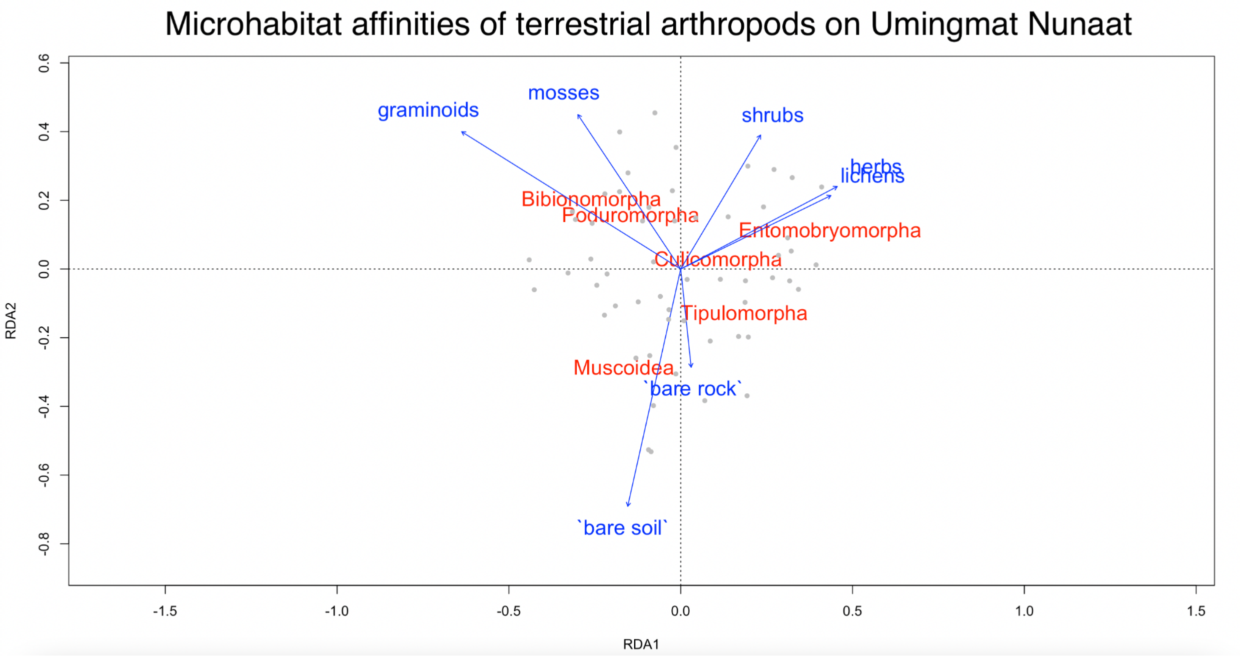

Figure 2.31. Redundancy analysis of the arthropod community across all replicates and time periods.

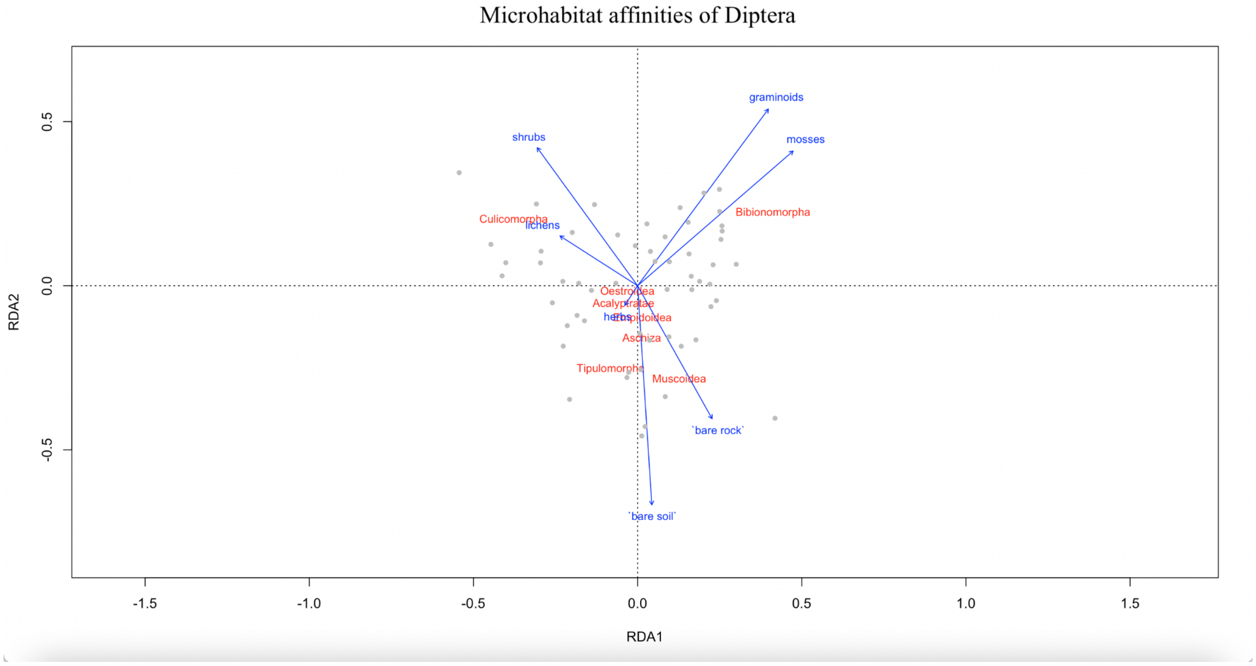

Figure 2.32. Redundancy analysis of Dipteran community across all replicates and time periods.

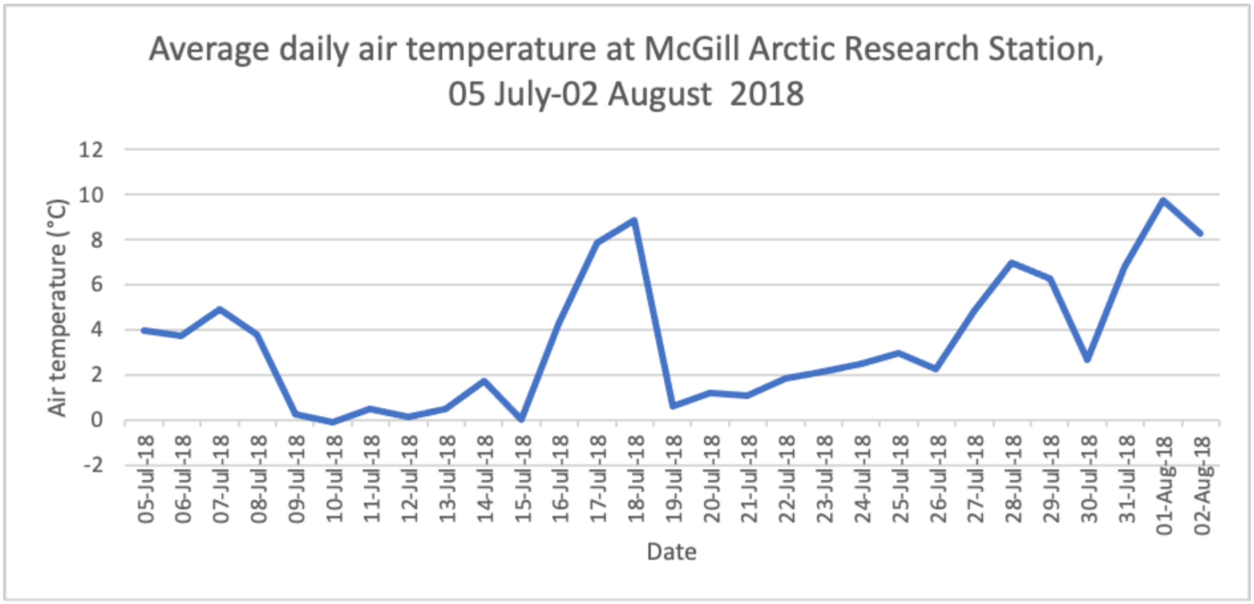

Figure 2.33. Average daily air temperature at the McGill Arctic Research Station, recorded during the study period from 05 July to 02 August, 2018. This climate data was collected from an automated Campbell Scientific meteorological station within the MARS base camp, located at coordinates 79°24'54.5"N 90°44'51.9"W. Air temperature was generally highest toward the end of the study period, peaking on 01 August (9.77°C). However, there was another distinct peak in the middle of the study period in which air temperature rose abruptly, peaking on 18 July (8.87°C). This peak in the middle of the study period was partitioned by two week-long intervals in which average air temperature was relatively low, often just hovering slightly above 0°C.

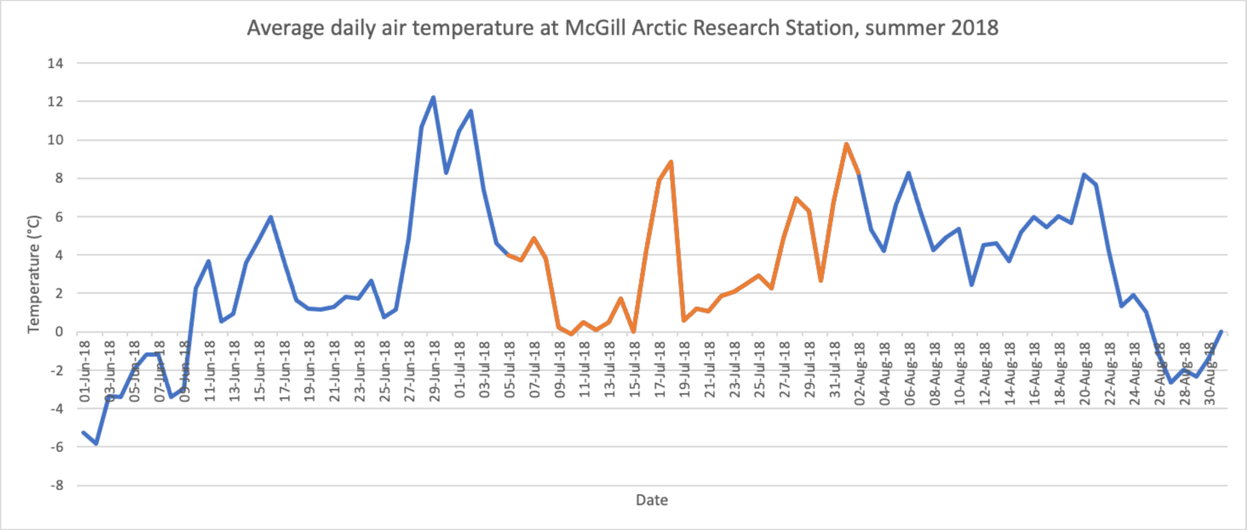

Figure 2.34. Average daily air temperature at the McGill Arctic Research Station, recorded for the entire summer from 01 June to 31 August, 2018. The study period is coloured in orange. This climate data was collected from an automated Campbell Scientific meteorological station within the MARS base camp, located at coordinates 79°24'54.5"N 90°44'51.9"W. Average air temperature was at its highest point of the summer in late June and early July, just prior the start of the study period, peaking on 29 June (12.2°C). The two disjunct, week-long intervals of low temperatures that occurred during July within the study period are prominent, and represent some of the coldest days on average of the entire summer.

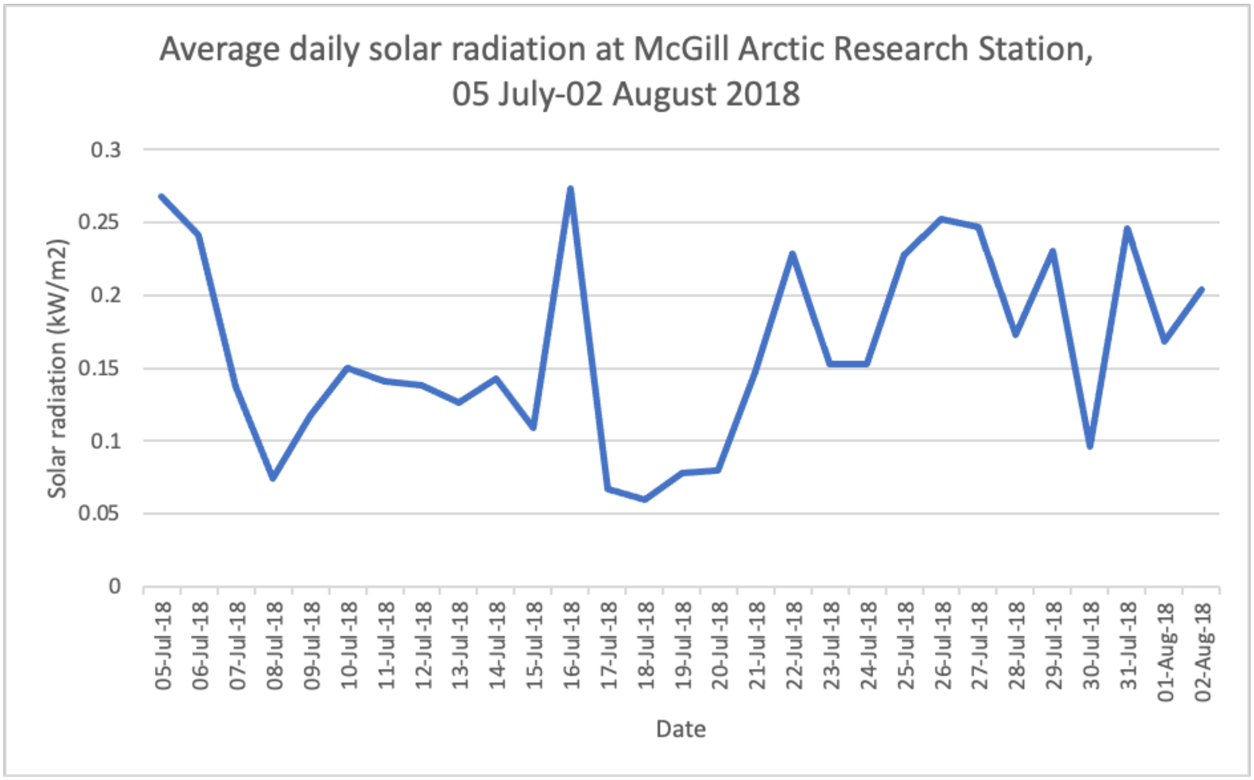

Figure 2.35. Average daily solar radiation at the McGill Arctic Research Station, recorded during the study period from 05 July to 02 August, 2018. This climate data was collected from an automated Campbell Scientific meteorological station within the MARS base camp, located at coordinates 79°24'54.5"N 90°44'51.9"W. Average solar radiation was relatively high on 05 July, the first day of the study period (0.268kW/m^2), but decreased sharply over the following days. There was a sudden, abrupt increase in solar radiation on 16 July (0.273kW/m^2), followed by another sharp decline the following day, and average solar radiation reached its lowest point of the study period on 18 July (0.06kW/m^2). Afterwards, solar radiation generally increased for the later part of the study period.

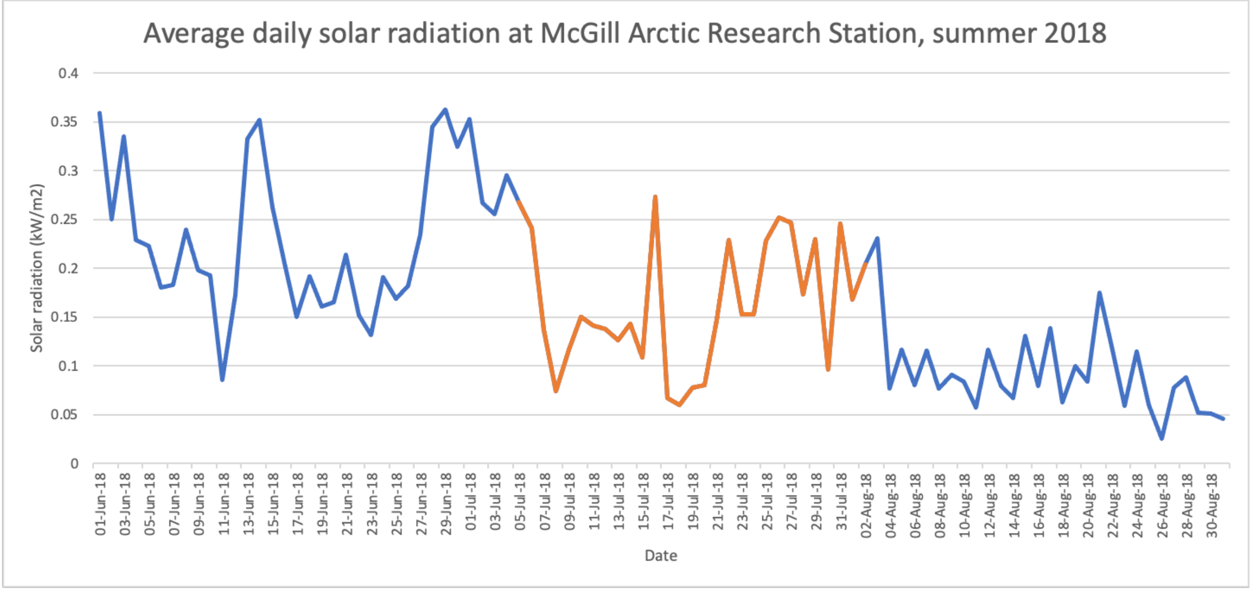

Figure 2.36. Average daily solar radiation at the McGill Arctic Research Station, recorded for the entire summer from 01 June to 31 August, 2018. The study period is coloured in orange. This climate data was collected from an automated Campbell Scientific meteorological station within the MARS base camp, located at coordinates 79°24'54.5"N 90°44'51.9"W. When visualising the entire summer, it is possible to see the gradual decline in solar radiation with time, as the sun drops lower and lower in the sky over the course of the High Arctic summer. Similar to average air temperature, average solar radiation was at its highest point of the summer in late June and early July, and peaked on 29 June (31.223kW/m^2), the same date that the highest average air temperature value was recorded. Within the study period, the two intervals in which average solar radiation sharply decreased, interrupted by a brief rise in the middle of July, is prominent even when viewed against the whole summer.

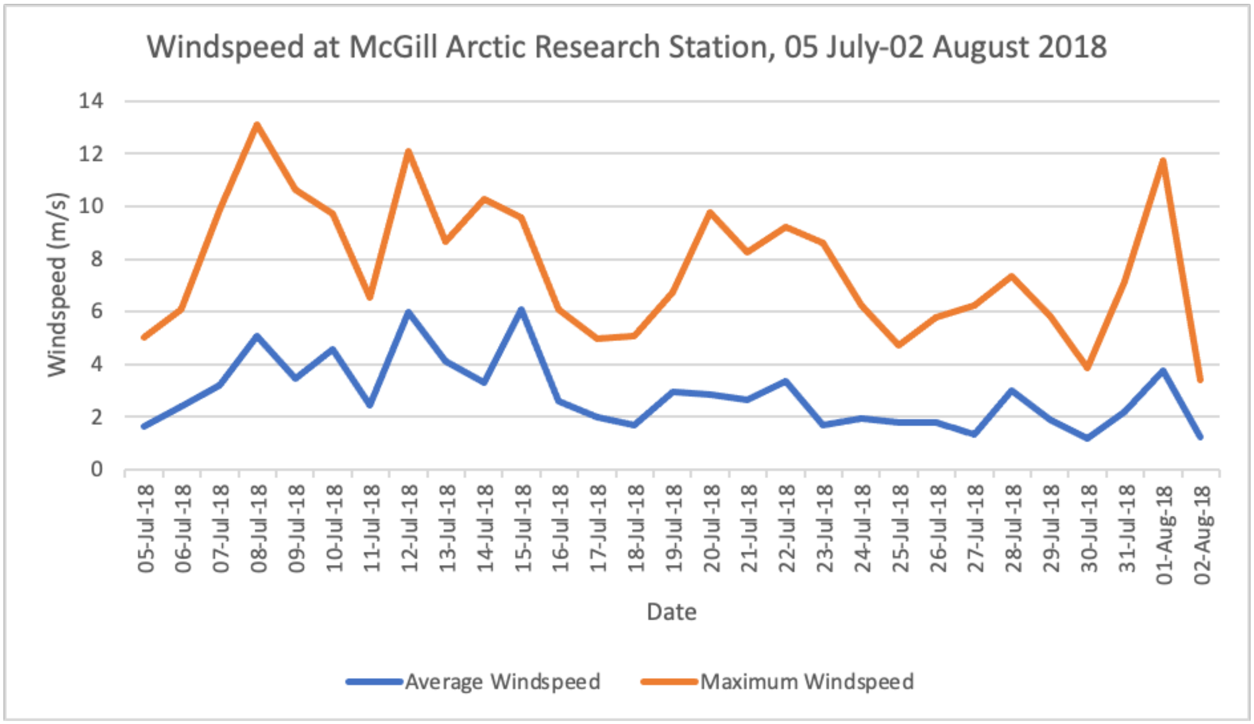

Figure 2.37. Average and maximum daily windspeed at the McGill Arctic Research Station, recorded during the study period from 05 July to 02 August, 2018. This climate data was collected from an automated Campbell Scientific meteorological station within the MARS base camp, located at coordinates 79°24'54.5"N 90°44'51.9"W. The highest maximum windspeed of the study period was recorded on 08 July (13.11m/s^2). Across the entire study period, average windspeed stayed in the range of 1.187 m/s^2 to 6.088m/s^2.

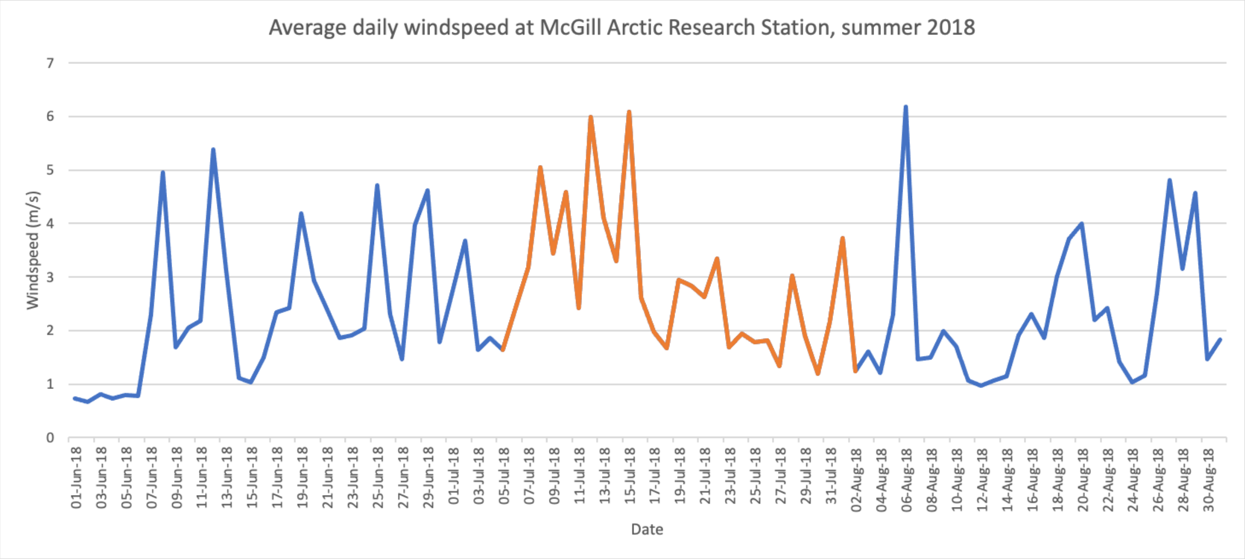

Figure 2.38. Average daily windspeed at the McGill Arctic Research Station, recorded for the entire summer from 01 June to 31 August, 2018. The study period is coloured in orange. This climate data was collected from an automated Campbell Scientific meteorological station within the MARS base camp, located at coordinates 79°24'54.5"N 90°44'51.9"W. The highest average windspeed of the summer was recorded on 06 August (6.174m/s^2), after the study period had concluded. The next two highest peaks in average winspeed did however occur within the study period, on 15 July (6.008m/s) and 12 July (5.985m/s).

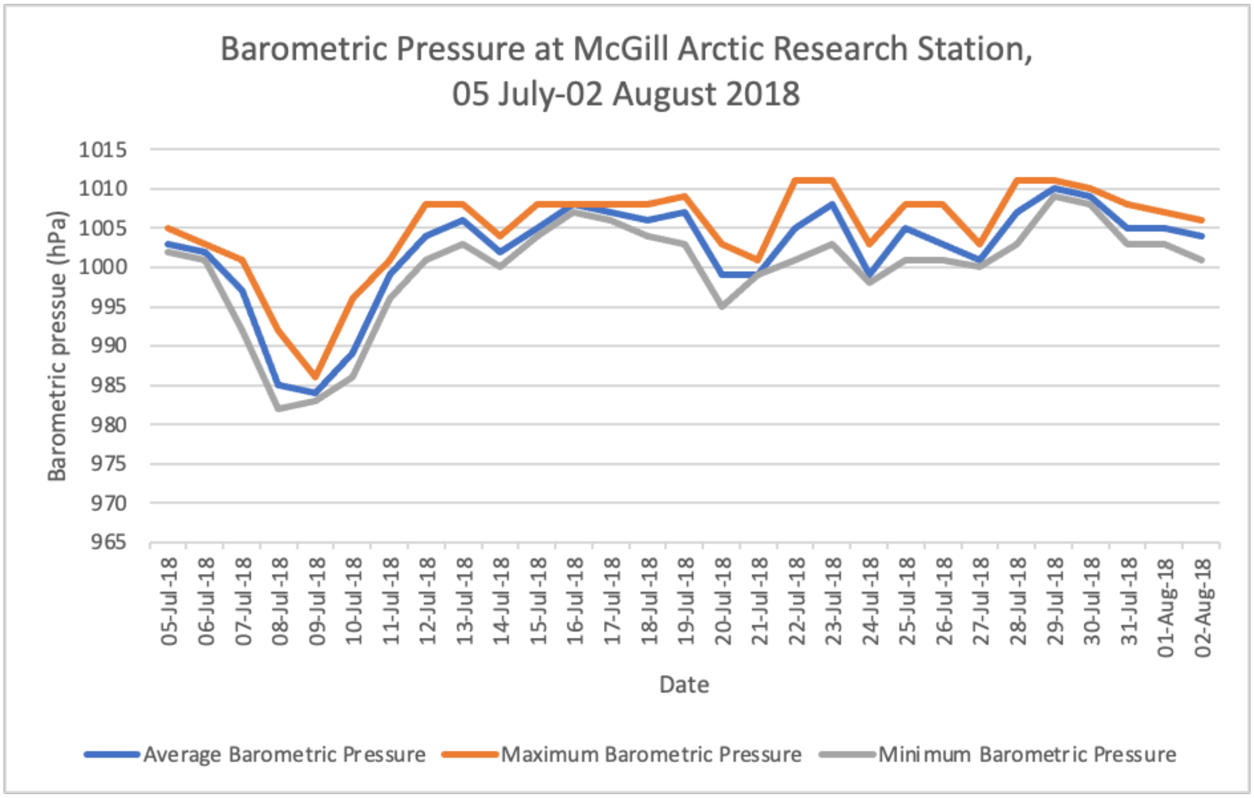

Figure 2.39. Average, maximum, and minimum daily barometric pressure at the McGill Arctic Research Station, recorded during the study period from 05 July to 02 August, 2018. This climate data was collected from an automated Campbell Scientific meteorological station within the MARS base camp, located at coordinates 79°24'54.5"N 90°44'51.9"W. There was an abrupt decrease in barometric pressure early in the study period, with average barometric pressure reaching its lowest point on 09 July (984hPa). Afterward, average barometric pressure increased, and for the rest of the study period stayed in the range of 999hPa to 1010hPa.

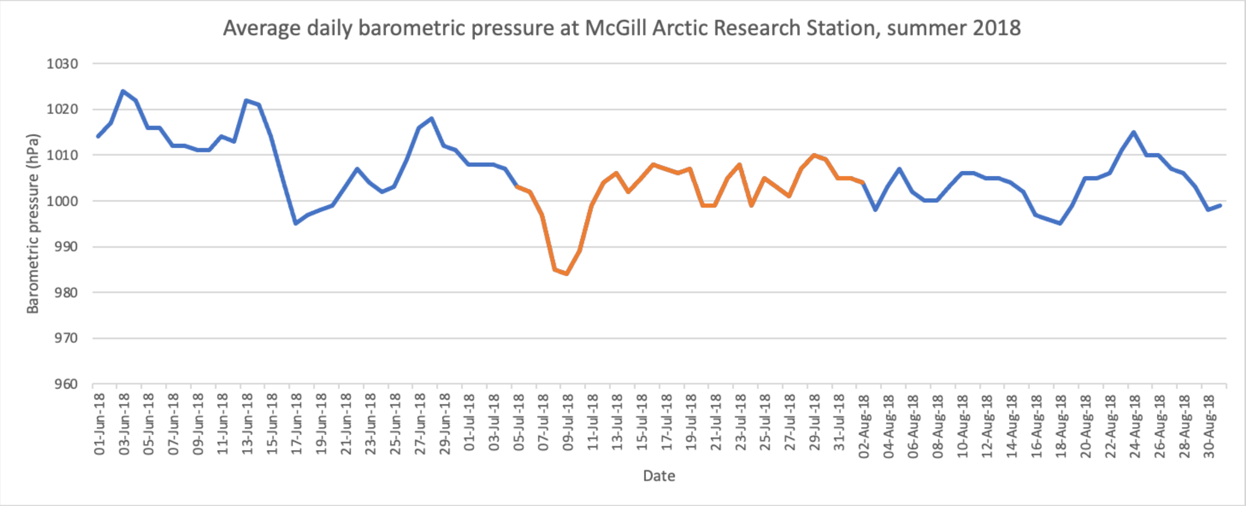

Figure 2.40. Average daily barometric pressure at the McGill Arctic Research Station, recorded for the entire summer from 01 June to 31 August, 2018. The study period is coloured in orange. This climate data was collected from an automated Campbell Scientific meteorological station within the MARS base camp, located at coordinates 79°24'54.5"N 90°44'51.9"W. Average barometric pressure was at its highest point early in the summer, peaking on 03 June (1024hPa). Average barometric pressure dropped substantially at the beginning of the study period, reaching its lowest point of the summer on 09 July (984hPa) before rising again a few days later.

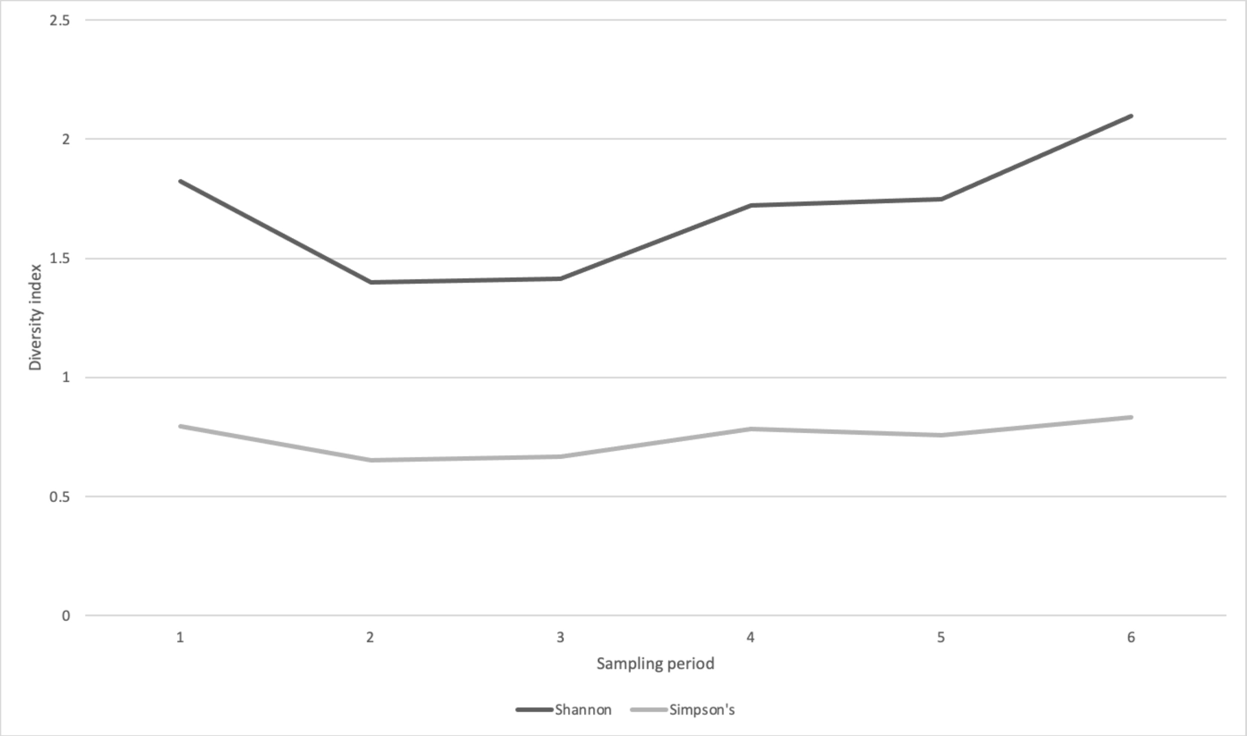

Figure 2.41. A summary of Shannon diversity index and Simpson's Diversity index as a function of the sampling period (1 to 6).

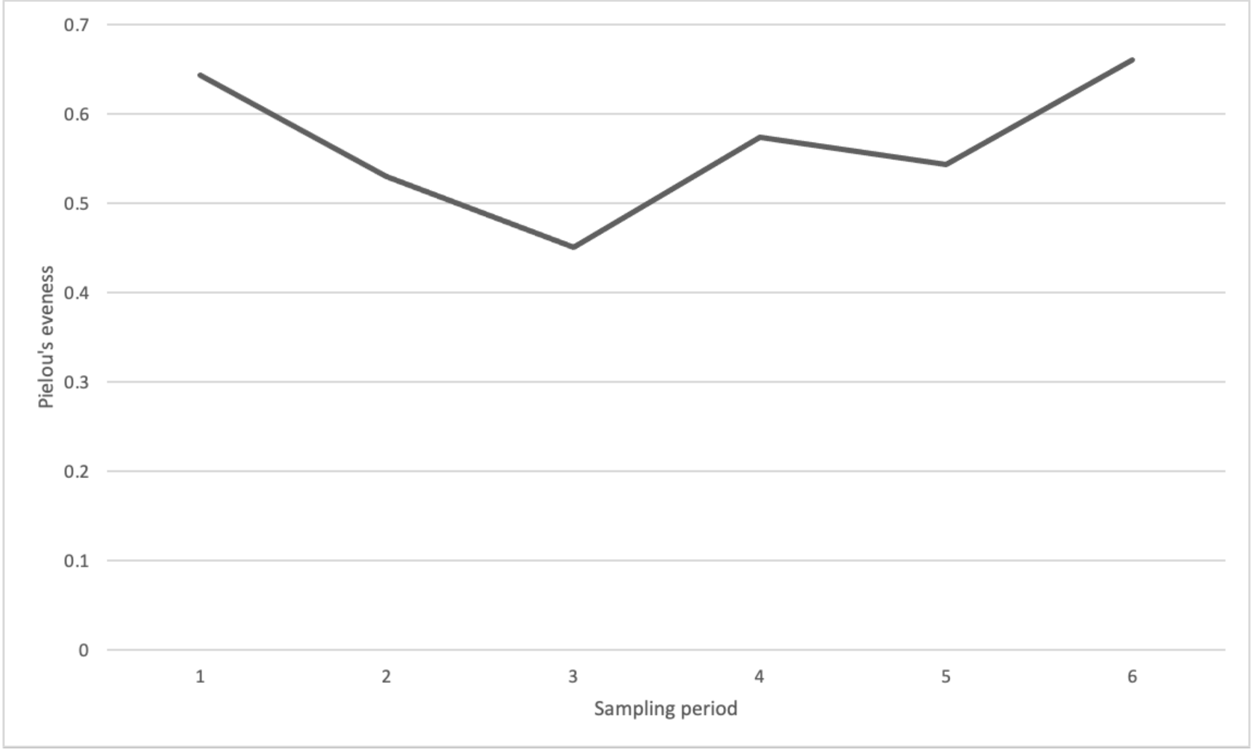

Figure 2.42. A summary of Pielou's evenness as a function of the sampling period (1 to 6).

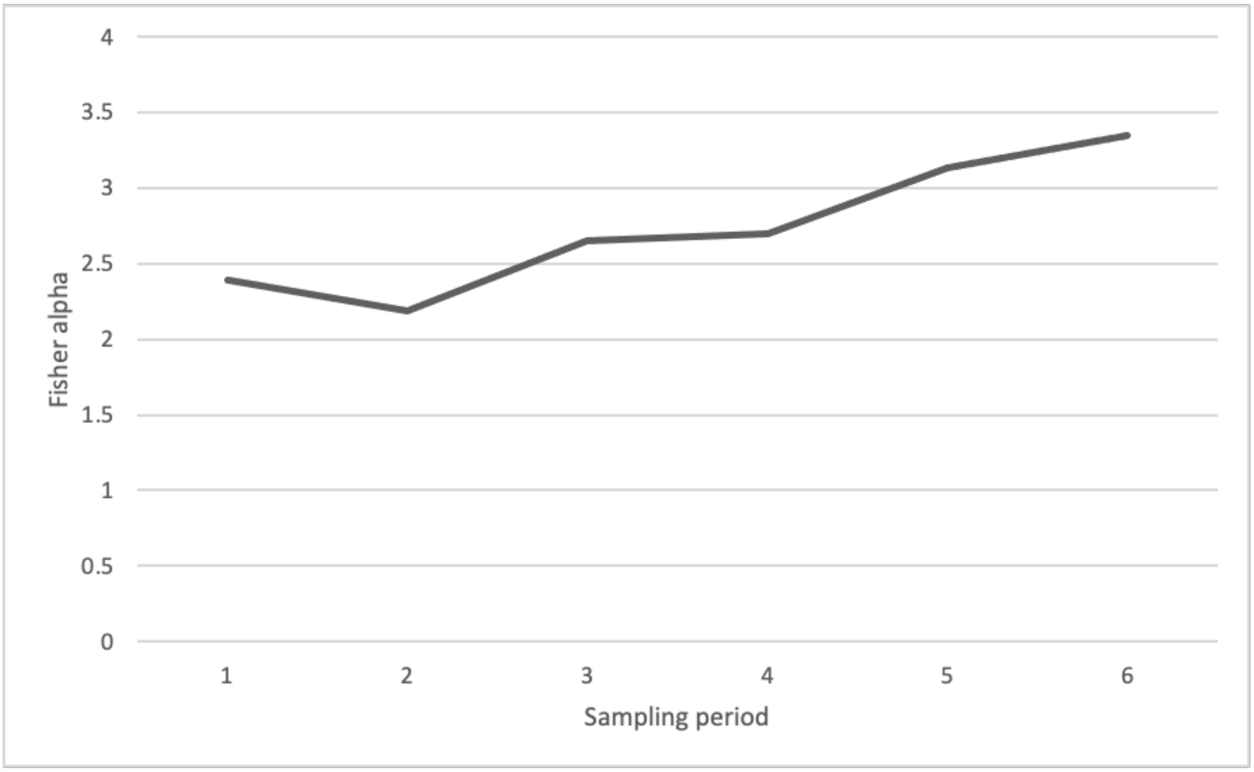

Figure 2.43. A summary of Fisher alpha as a function of the sampling period (1 to 6)

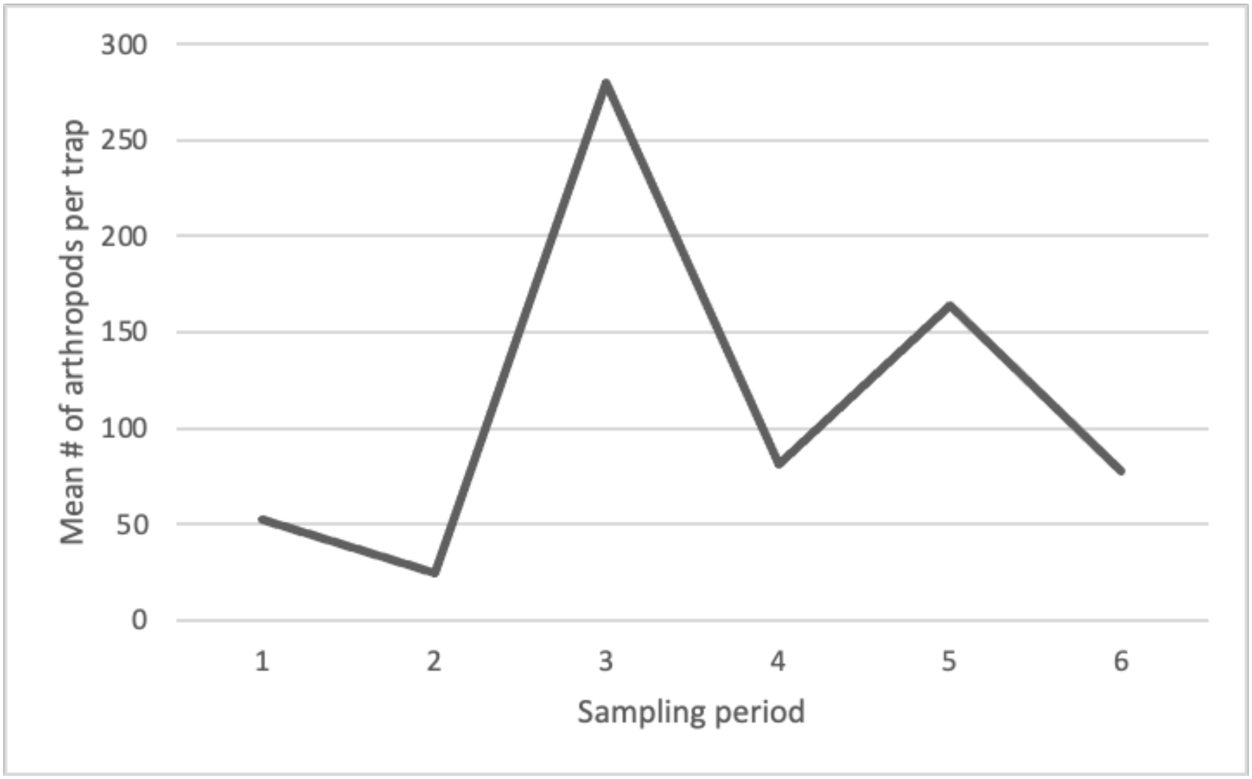

Figure 2.44. A summary of the mean number of arthropods collected per trap as a function of the sampling period (1 to 6).

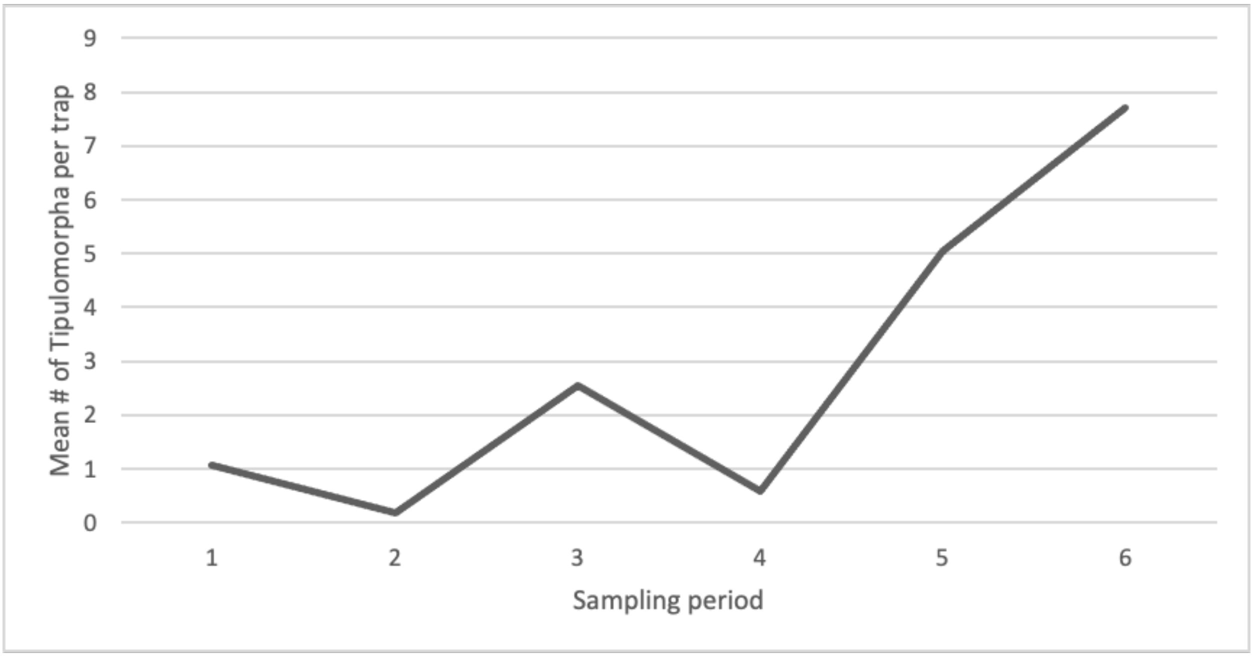

Figure 2.45. A summary of the mean number of Tipulomorpha (crane flies) collected per trap as a function of the sampling period (1 to 6).

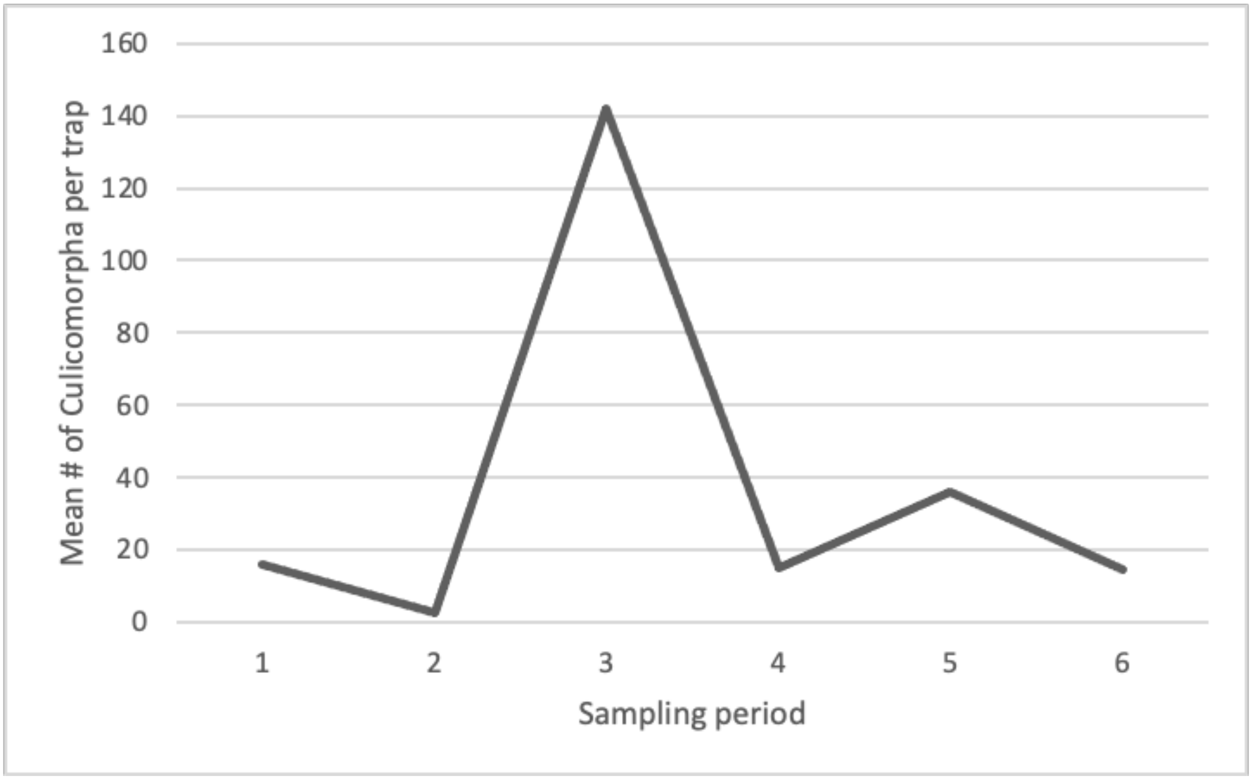

Figure 2.46. A summary of the mean number of Culicomorpha (midge flies and relatives) collected per trap as a function of the sampling period (1 to 6).

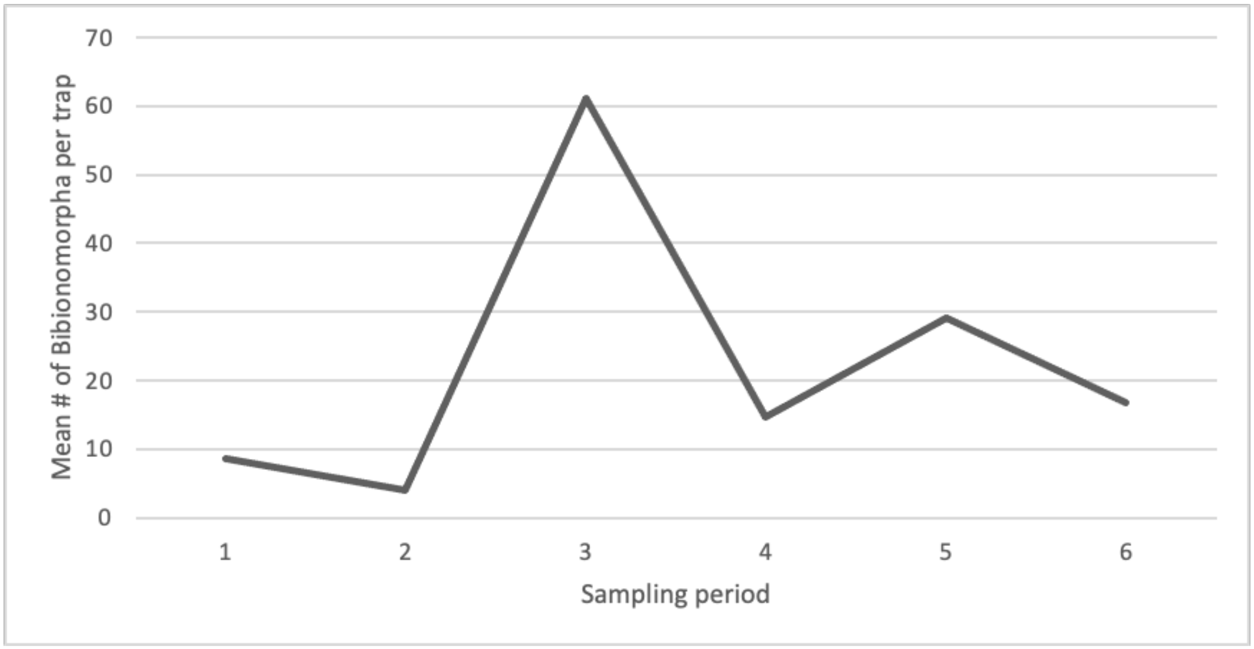

Figure 2.47. A summary of the mean number of Bibionomorpha (fungus gnats) collected per trap as a function of the sampling period (1 to 6).

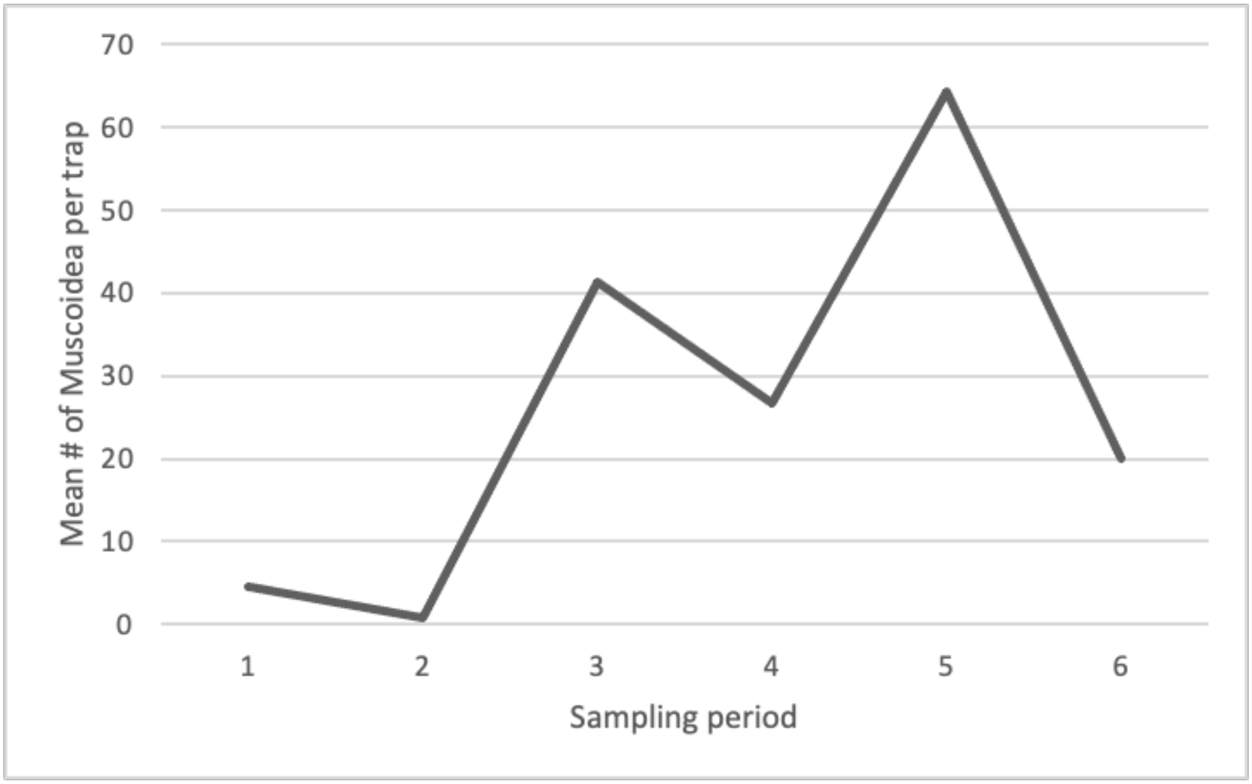

Figure 2.48. A summary of the mean number of Muscoidea (house flies and relatives) collected per trap as a function of the sampling period (1 to 6).

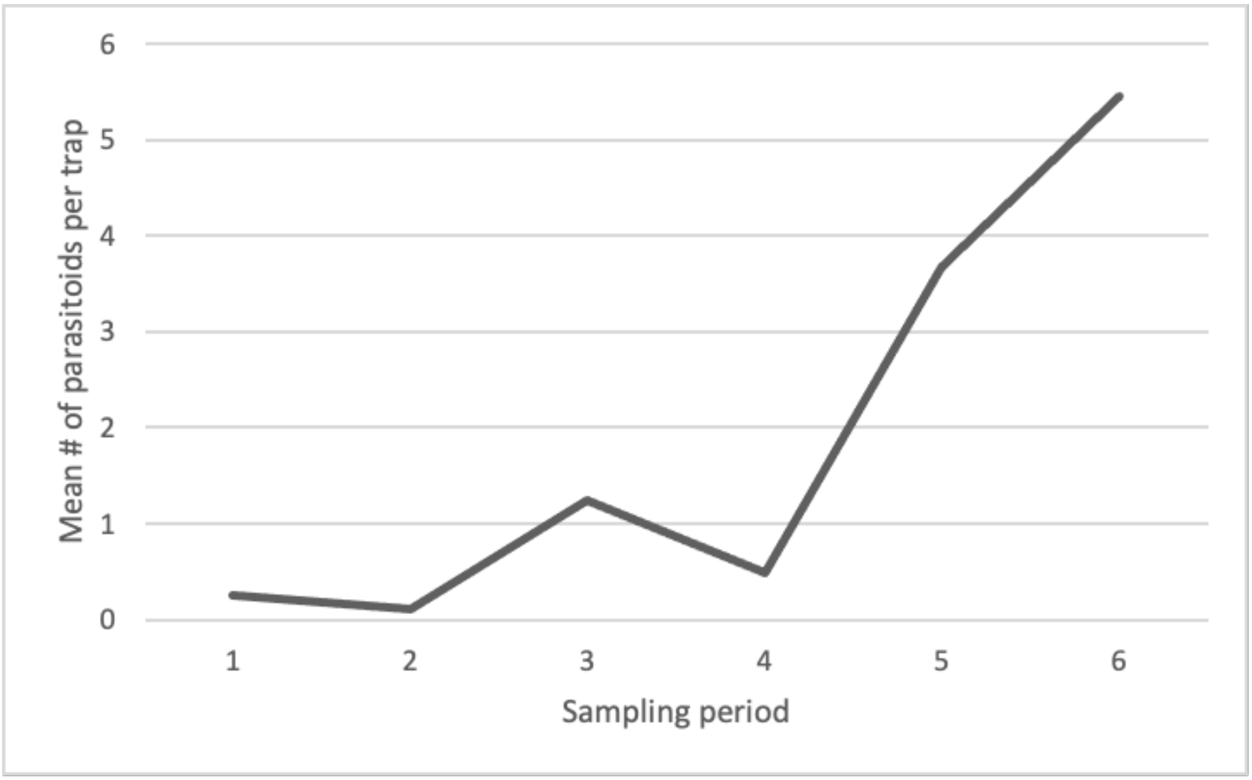

Figure 2.49. A summary of the mean number of parasitoid wasps collected per trap as a function of the sampling period (1 to 6).

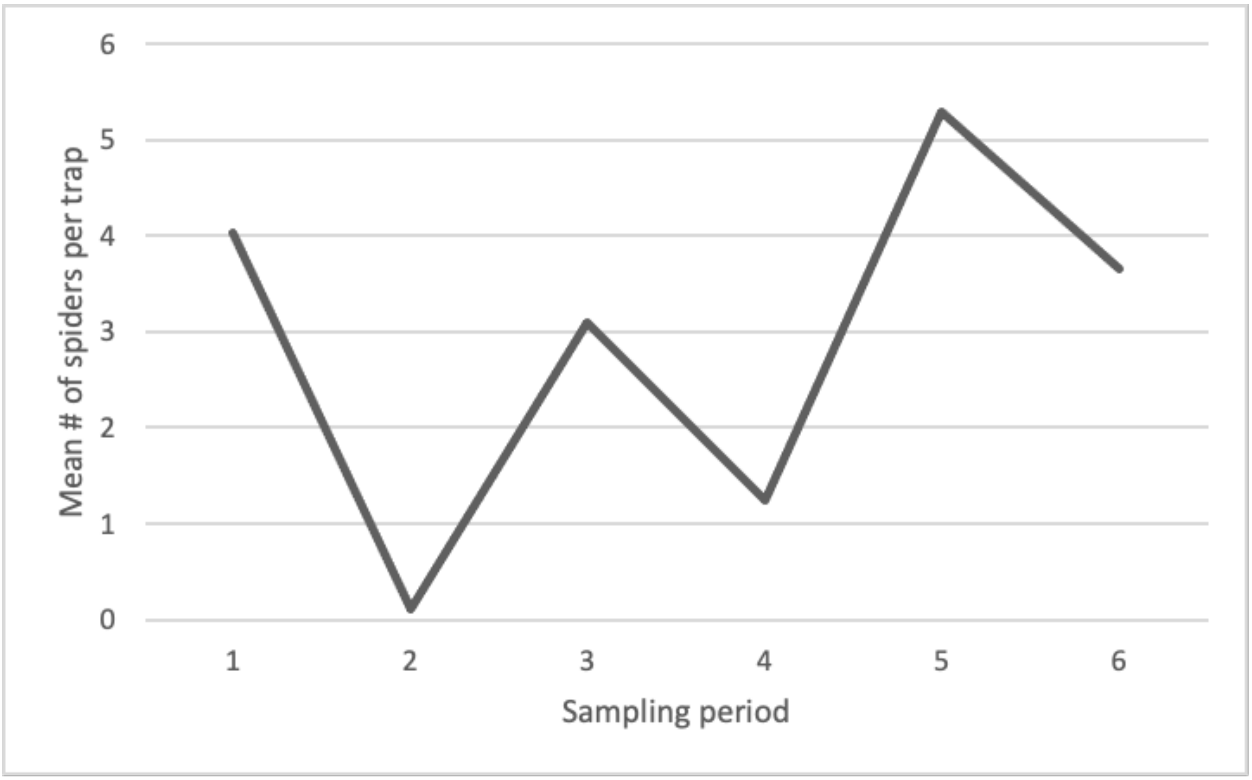

Figure 2.50. A summary of the mean number of Araneae (spiders) collected per trap as a function of the sampling period (1 to 6).

Thesis summary and conclusions

This thesis established important baseline data on the terrestrial arthropod communities of *Umingmat Nunaat* (Axel Heiberg Island), in the High Arctic. My research provides a snapshot in time of the state of terrestrial arthropod communities on an uninhabited and understudied island in the High Arctic, which can be used as a basis of comparison for monitoring change. This baseline will greatly benefit the expanding efforts now underway to study the ecology of the region.

Chapter 1 was a literature review that established the context and rationale for the research. It outlined Arctic terrestrial arthropods and their relationships with their environment, as well as the importance of monitoring projects and a brief history of *Umingmat Nunaat*. Chapter 2 examined relationships of ground cover, climate, and seasonality that were revealed from this baseline collection of terrestrial arthropods on *Umingmat Nunaat*, and also established an easily repeatable collections protocol.

The Arctic is warming faster than anywhere else on the planet, and monitoring is essential to understanding how this is affecting Arctic ecosystems. This baseline research paves the way for building up a more significant ecological monitoring program at the McGill Arctic Research Station that will fill a vital gap in our understanding of how terrestrial ecosystems are being affected by recent climate warming.