Soil Mesostigmata (Arachnida: Parasitiformes) in boreal forests of Alberta: diversity and utility as indicators of disturbance

by

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A thesis submitted in partial fulfillment of the requirements for the degree of
Master of Science
in
Ecology

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Abstract

Soils provide numerous ecosystem services, including provision of nutrients for plants, sequestration of greenhouse gases, and serving as habitat for soil animals. Soil animal diversity is immense, and many undescribed taxa still remain. One prominent group that inhabits soils is mites (Arachnida: Acariformes, Parasitiformes). Globally, there are 55,000 species of mites described, but true species richness is believed to be ~1,000,000. Soil mites can be split into two superorders, Acariformes and Parasitiformes. Within Parasitiformes, Mesostigmata is the most species-rich order with 11,000 described species. In soils, mesostigmatid mites mainly prey on nematodes and collembolans. Mesostigmatid mites are important for ecosystem function as they are connected to the three main energy flows in soil: primary production from plants, and fungal and bacterial energy channels. Although Mesostigmata are commonly found in soils, in North America little is known about their diversity or the environmental and spatial factors that influence their assemblages. In Chapter 2, I identified mesostigmatid mites from the boreal forest in northern Alberta to catalogue their diversity. Soil samples were collected by the Alberta Biodiversity Monitoring Institute (ABMI) and provided by the Royal Alberta Museum. In total I identified 109 species/morphospecies of Mesostigmata from 46 genera and 21 families. Once identified, I made a public pictorial database illustrating all the species/morphospecies found in my thesis. This database will hopefully aid other researchers in their identifications of mesostigmatid mites. In Chapter 3, I analyzed environmental and spatial features to assess their influence on Mesostigmata assemblages. I found that moss cover, precipitation and disturbance intensity were the variables most strongly correlated with assemblage structure. In addition, I found that distance between sampling points explained as much as environmental variables, and that Mesostigmata assemblages become more dissimilar from each other with increasing distance.

In contrast to mesostigmatid mites, oribatid mites (Acariformes: Oribatida) are mainly detritivores and fungivores. They are the most diverse mite group found in soils, as well as the most abundant. Current protocols employed by the ABMI require identification of oribatid mites to species, but there has been no assessment by ABMI as to whether they are useful indicators of disturbance. In Chapter 4, I tested whether mesostigmatid and oribatid mites can act as bioindicators for three disturbance types that commonly affect boreal forests in Alberta (fire, harvest and linear features) at three taxonomic levels (species, genus and family). I found that mesostigmatid mites were bioindicators for all three-disturbance types, while assemblages of oribatid mites indicated only fire and linear disturbance. In addition, I found that genus- and family-level identifications could be used instead of species-level identifications, as they both can adequately indicate disturbance. This suggests that coarse taxonomy can be used instead of species-level identifications, which may ease the identification process for researchers.

Preface

A version of Chapter 3 will be submitted to Forest Ecology and Management. Zhuoyan Song and Heather Proctor will be a co-authors on this manuscript. I was responsible for mesostigmatid mite identifications, data analyses (with support from Zhuoyan Song), and writing the manuscript. Heather Proctor was the supervisory author, who helped with project creation and editing of the manuscript.

A version of Chapter 4 will be submitted to Ecological Indicators. The co-authors on this paper will be Zhuoyan Song, Tyler Cobb, Lisa Lumley, and Heather Proctor. Zhuoyan Song helped with data analyses, Tyler Cobb and Lisa Lumley edited the manuscript and provided logistical support for the project, and Heather Proctor was the supervisory author, who helped with project creation and editing of the manuscript.

Acknowledgements

The completion of my thesis would not have been possible without the continuous support from my supervisor, Heather Proctor. I have not only learned a lot about soil mites, but how to be a researcher. You were always willing to take short meetings with me, and I could not have asked for a better MSc. supervisor. I can never thank you enough for taking a chance on me, a guy from Toronto who thought mites were pretty cool. I would also like to thank my committee members Rolf Vinebrooke and Tyler Cobb, my examining committee Maya Evenden and Andy Keddie, and soil Oribatida taxonomist at the Royal Alberta Museum Lisa Lumley for your guidance and help during my thesis.

I would like to thank my current and former lab mates (in no particular order): Andrew Cook, Alexandra Grossi, Zhuoyan Song, Qi Liu and Christianne Uherek, and honorary lab mate Emily Durkin. Thank you for being awesome lab mates and friends over the past 2 years. Special thank you to Zhuoyan for taking my many stats/R questions over these years. My knowledge in both has grown vastly and I cannot thank you enough for helping me. Thank you to my summer assistants Emily Chao and Alyssa Turnbull, both of you were vital in helping me finishing my degree.

Thank you to the people outside of my lab who have made my time in Edmonton enjoyable. These include my fellow entomology peers, Tamarack/Graduate residence friends and University of Alberta Triathlon Club members. From learning how to two step and to swim (without dying both inside and out), to eating endless amounts of Wendy’s, to watching The Office, Stranger Things, and Making a Murderer its been awesome.

And lastly, this degree would not have been possible without the support of my family, my mom and dad, Sharon and Shawn, and my brother and sister, Alec and Laura. Thank you for everything you have done, and will do.

Table of Contents

List of Tables

List of Figures

1 Chapter 1: General Introduction

1.1 Soil health and the use of bioindicators

Soil is an immensely important commodity that provides a multitude of ecosystem services that benefit humans (Costanza et al. 1997). These include nutrient cycling, structural role in supporting plants and animals, and sequestration of greenhouse gases (Dominati et al. 2010). However, increasing soil degradation has worsened soil quality ('health') (Parr 1992). Soil health can be monitored using ecological indicators, which can be physical, chemical or biological in nature and can monitor ongoing and past disturbance events (Karlen et al. 1997). Disturbance is a discrete event in time that alters ecosystem, community or population structure, and changes resource and substrate availability (White and Pickett 1985). Biological indicators (bioindicators) often estimate the effect of disturbance through presence/absence and abundance data of different taxa (Pulleman et al. 2012). Although the use of charismatic taxa like birds and mammals as bioindicators may garner more interest from outside observers (Paoletti 1999), invertebrates offer significantly more diversity (Wilson 1988). This diversity and pervasive presence within a habitat means their assemblages can be analyzed with a multivariate approach, going beyond the singular presence/absence approach often used with other taxa (Bedano et al. 2011). Soil invertebrates are frequently classified according to body length, with one common classification being microfauna (< 100 μm), mesofauna (100 – 2000 μm) and macrofauna (> 2000 μm) (Bardgett 2005). Among soil mesofauna, mites (Arachnida: Acariformes and Parasitiformes) are the most taxonomically and ecologically diverse.

1.2 Background information on Arachnida and 'Acari'

Mites are placed in the subphylum Chelicerata, within the phylum Arthropoda (Walter and Proctor 2013). Although species-rich, Chelicerata only has three classes: Pycnogonida (sea spiders), Merostomata (horseshoe crabs) and Arachnida (Arabi et al. 2012). Arachnida is the only group of chelicerates to have colonized land (Walter and Proctor 2013) and is made up of 12 major taxa, including Araneae (spiders), Opiliones (harvestman), Pseudoscorpiones, Ricinulei, Scorpiones and Solifugae (sun spiders) (Shultz 2007). Mites are morphologically distinct from other arachnids as they lack conspicuous segmentation, with little separation between the two main body sections (the gnathosoma and idiosoma) (Krantz 2009a). Mites are extremely diverse with 55,000 species described; however, true richness is believed to be ~1,000,000 (Krantz 2009b). Mite species are placed into two superorders, Acariformes and Parasitiformes, that have been traditionally grouped together as the subclass Acari (Lindquist et al. 2009a). Morphological evidence along with more recent DNA sequence data has raised the possibility that mites have a diphyletic origin, meaning that a mite-like body plan arose twice (Dunlop and Alberti 2008). This is supported by fossil evidence, as the earliest acariform fossils are hundreds of millions of years older than the oldest parasitiform ones (Walter and Proctor 2013). Molecular data suggests that the sister group of Acariformes is Solifugae or Ricinulei (Dabert et al. 2010, Pepato et al. 2010, Pepato and Klimov 2015); however, in other analyses, Pseudoscorpiones has been returned as the sister group to Acariformes (Ovchinnikov and Masta 2012) and Parasitiformes (Dabert et al. 2010). At 42,000 described species (Walter and Proctor 2013), Acariformes is the more diverse superorder and contains the orders Trombidiformes and Sarcoptiformes. The suborders

Prostigmata (Trombidiformes) and Oribatida (Sarcoptiformes) comprise the majority of species in Acariformes and are relatively well studied in comparison to the two other suborders, Sphaerolichida and Endeostigmata (Dunlop and Alberti 2008; Walter et al. 2009). Parasitiformes is made up of the orders Opilioacarida, Holothyrida, Ixodida (ticks) and Mesostigmata. Mesostigmata is the most species rich with 11,000 described species, many of which live in soil habitats (Walter and Proctor 2013). The taxonomic relationship Acari is shown in Table 1-1**.**

1.3 Overview of Mesostigmata and brief commentary on Oribatida

Within Mesostigmata there are three suborders, Monogynaspida, Trigynaspida and Sejida (Lindquist et al. 2009b). Morphological differences between the suborders include number and shapes of shields covering the oviporus (female ovipositional opening), and the number of setae around it. Almost all Mesostigmata belong to the Monogynaspida and its two main cohorts, Gamasina and Uropodina (Walter and Proctor 2013). Mesostigmata occupy a variety of niches including predators in soil, predators in vertebrate and invertebrate nests, and parasites of vertebrates and invertebrates (Dowling and OConnor 2010). Although the majority of named species are predators, many of the better studied taxa are parasites, including the devastating parasite of honeybees, *Varroa* (Varroidae), which has been one of the causes of global honeybee decline (Sammataro et al. 2000).

Soil communities have been called “the poor man’s tropical forest” because of the high species richness and abundance of soil fauna, which can include up to a 1000 species within a 1 m^2 area (Anderson 1975; Giller 1996). Although mesostigmatid mites can be abundant in soil, with up to 12,000 individuals/m^2, (Christian 2000), they are not the most abundant or diverse mite taxon found in soil, as oribatid mites can reach densities up to 100,000 individuals/m^2, and typically comprise 60-90% of all mite species found (Gulvik 2007, Norton and Behan-Pelletier 2009). Like most mesofauna, Mesostigmata in soil live in between the existing air-filled pore spaces rather than making their own burrows (Coleman et al. 2004). They reproduce through various sexual systems (diplodiploidy, arrhenotoky, parahaploidy and thelytoky) (Norton et al. 1993). Dispersal ability amongst soil Mesostigmata is species-specific, as some are phoretic on insects or small mammals, while others rely solely on walking to disperse (Siepel 1995; Ruf and Beck 2005).

Soil mesostigmatid mites are mainly predators and in particular areas can have roughly the same biomass of larger bodied predators (e.g., spiders, centipedes) at the same sites (Scheu et al. 2003). Soil Mesostigmata affect ecosystem function through their indirect connections to the three main energy flows in soil: primary production from plants, the fungal decomposition pathway, and the various bacterial mineralization and decomposition channels (Ruf and Beck 2005). Mesostigmata predate mostly on decomposers such as collembolans and nematodes (Scheu 2002, Klarner et al. 2013). Some genera and species are specialists on particular prey groups, that can sometimes be reflected in cheliceral morphology (Buryn and Brandl 1992); however, some species are omnivorous (Madej and Skubala 1996, McMurtry and Croft 1997). Interestingly, body size of Mesostigmata seems to have no relation to trophic position, as body mass does not correlate with trophic position (Klarner et al. 2013)

Oribatid mites feed mainly on detritus and fungi and are important for ecosystem functioning in soil systems through their influence on microbial populations and transportation of fungal spores (Maraun et al. 1998). Although once thought to be generalists, Schneider et al.(2004) showed that many species of oribatid mites specialize on particular food sources, such as litter or fungi. Oribatid mites vary drastically in body types, some being large and heavily armoured, while others are small and unsclerotized. These differences in morphology make some groups more susceptible to predation, as Schneider and Maraun (2009) found heavy predation by mesostigmatid mites on small, unsclerotized oribatid mites. Oribatid mites exhibit relatively long generation times, which differs from other detritivores/fungivores like Collembola (Moore et al. 1988; Norton and Behan-Pelletier 2009).

Compared to oribatid mites, little is known about how biotic and abiotic factors influence Mesostigmata. Unsurprisingly, Mesostigmata will have different species richness/abundance, community composition or both within different plant-based habitat types (Nielsen et al. 2008; Beaulieu 2012; Nielsen et al. 2012; Díaz-Aguilar et al. 2013; Minor et al. 2016); this is commonly found with soil invertebrates as aboveground vegetation influence below ground properties. Abiotic factors like pore volume and moisture have been shown to affect abundance of Mesostigmata (Berg et al. 1998; Nielsen et al. 2008); while elevation, slope position (different geographical areas on a slope) topographic (wetness) index and global solar radiation seem less important (Minor and Ermilov 2015). Spatial influence (how geographic distance between assemblages structures composition, independent of environmental factors) has been shown to affect oribatid mite assemblages. This has been attributed to their having limited long distance dispersal ability, partly due to having no specialized stage for dispersal (Lindo and Winchester 2009; Minor 2011), with a notable exception from *Archegozetes magnus*

(Sellnick) (Beaty et al. 2013). In fact, spatial distance can correlate more strongly with variation in oribatid assemblages than environmental variables (Caruso et al. 2012). For Mesostigmata, significant spatial influence was shown by Nielsen et al. (2012); however, Chen et al. (2014) found less support for it. It is possible that distance between assemblages may be less important to soil Mesostigmata, as many species are phoretic and thus are limited less by dispersal ability (Siepel 1995)

1.4 Mesostigmata and Oribatida as bioindicators

The use of soil invertebrates as bioindicators dates back to the 1950's. Taxa used for biomonitoring include mites, collembolan, spiders, nematodes and beetles(Breure et al. 2005 and references within). Mesostigmatans have been used to monitor soil quality in agricultural and forestry contexts (Koehler 1999, Minor and Norton 2004; Bedano et al. 2006), post-fire systems (Bogorodskaya et al. 2010; Kamczyc et al. 2017) and reclaimed industrial areas (Madej and Stodółka 2008, Madej and Kozub 2014). Mesostigmata have also been combined with other mite groups to create the OM/PA index (Oribatida + Mesostigmata/Prostigmata + Astigmata), where each mite group is thought to be differentially affected by land management practices (Bedano et al. 2011). The relative proportions for each mite group are calculated, then plugged into the formula [O+M/P+A] to determine that habitat's index. Bedano et al. (2011) found that natural areas had a higher index value. Differences in mite proportions within disturbed environments, stem from the varying life histories amongst mite taxa (Siepel 1994, Siepel 1995, Behan-Pelletier 1999). Ruf (1997) created a soil maturity index (based on Bongers (1990)) that groups species into two categories, "colonizers" (r-selected taxa) and “persisters” (K-selected taxa). Ruf (1998) used this maturity index on different forests in Germany and noted that highly disturbed sites had lower maturity indexes.

In contrast to soil Mesostigmata, soil Oribatida’s utility as bioindicators has been relatively well investigated. Because of the existence of oribatid-specific protocols and relatively good knowledge of local faunas in many parts of the world (Balogh and Balogh 1992, Balogh and Balogh 2002, Ruf and Beck 2005), oribatid mites are frequently used as bioindicators. A review conducted by Gergócs and Hufnagel (2017) supported Behan-Pelletier's (1999) conclusion that Oribatida are strong indicators of agricultural disturbance. They also found limited support for the use of Oribatida as bioindicators of heavy metal pollution and forest management. Currently, the Alberta Biodiversity Monitoring Institute (ABMI) uses oribatid mites as bioindicators, and identify their taxa with a key specifically developed for Albertan oribatids by Walter et al. (2014). In contrast, central Europe is one of the few regions in the world that have been well surveyed for soil Mesostigmata (see Karg 1993). However, as a high proportion of species remain undescribed for both groups, studies using species-level identification remain difficult to perform (Gulvik 2007).

1.5 Biomonitoring and Taxonomy

One impediment to the use of invertebrates as bioindicators is the lack of “traditional” taxonomic experts who use morphological features to identify species (Ebach et al. 2011). More taxonomists are becoming molecular taxonomists, in which DNA sequences are used to sort out phylogenetic relationships (Godfray 2002; Luc et al. 2010). Parataxonomy is sometimes used for groups that are poorly known or for which local taxonomic expertise is lacking. Parataxonomists use RTU’s (recognizable taxonomic units) (Oliver and Beattie 1993) to separate taxa into groups, which are sometimes referred to as morphospecies but are more properly called morphotaxa (Ward and Stanley 2004). Krell (2004) showed that parataxonomy can either over- or underestimate the number of species/morphospecies present in a habitat, making it less accurate than classic taxonomy. Ellis (1985) argued for "taxonomic sufficiency", in which identification of an organism should be done only to the level that fulfills the objective of the study. Bevilacqua et al. (2013) used this philosophy with their BestAgg approach, in which a community matrix that contains a mixture of identification levels from species to phylum, in addition to functional groups, is used to delineate environmental features (e.g. habitat types, and disturbance) within an environment. Bevilacqua et al. (2013) found that BestAgg produced similar results to species-level identification for assemblages of benthic marine macroinvertebrates. However, a similar study performed by Jiang et al. (2017) with freshwater macroinvertebrates found the BestAgg dataset to be most similar to genus-level identification. No study has used this method on a terrestrial dataset. If the application of the BestAgg method to soil taxa produces results similar to that of species-level identification, it may lead to further implementation of this method with taxonomically difficult organisms.

1.6 Thesis Objectives and Outlines

This thesis involves the use of soil invertebrate samples from 77 ABMI sites in the Boreal forest in Alberta, Canada, collected between 2010-2015. The overall goal is to catalogue the diversity of soil Mesostigmata from these sites, determine what abiotic and biotic variables structure their assemblages, and to assess the utility of Mesostigmata as bioindicators of disturbance. To my knowledge, only two studies in Western Canada have focused on the ecology of soil Mesostigmata. Díaz-Aguilar et al. (2013) found differences in Mesostigmata assemblages associated with differences in forest stand composition (coniferous vs. deciduous vs. mixed), while Díaz-Aguilar and Quideau (2013) studied trophic ecology of soil Mesostigmata. Both studies were restricted to Mesostigmata from one area near Peace River, Alberta. An informal list of Mesostigmata known from Alberta was produced by Walter and Latonas (2011). One of the main hindrances in ecological studies of invertebrates is lack of identification guides for local fauna. To help remedy this, Chapter 2 includes a list of taxa I found from the 77 ABMI sites together with an online pictorial database that is structured with an expandable taxonomic tree. Each species/morphospecies has its own dedicated page with images highlighting the important morphological features for that individual. A short commentary on related taxa found thus far in northern Alberta and list of references used for identification is found on each page.

In Chapter 3, I used multivariate statistics to determine how environmental variables structure Mesostigmata assemblages. This chapter will provide a greater understanding to what abiotic and biotic forces affect Mesostigmatan assemblage composition, including the influence of spatial distances between quadrants.

In Chapter 4, I tested the relative utility of Mesostigmata and Oribatida as bioindicators of three disturbance types: forest fire, forest harvest and linear features (seismic lines, pipelines and powerlines) for three levels of taxonomic resolution: family, genus, and species. In addition, I applied the BestAgg method described by Bevilacqua et al. (2013) to determine if individuals can be sorted and identified to a mixture of fine and coarse taxonomic levels can still provide similar results as species-level identifications.

In Chapter 5 I provided a summary of soil Mesostigmata species found in my thesis, and highlight the important environmental variables that structure soil Mesostigmata assemblages in the province. I also discussed the results and implications of testing the utility of Mesostigmata and Oribatida as a bioindicator, and provide suggestions for future researchers on Mesostigmata and Oribatida usefulness as a bioindicator. And finally, I provided my thoughts on biomonitoring of soil systems, and additional commentary on future studies in soil ecology and taxonomy.

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1.8 Tables and Figures

Table 1-1. The superorders, orders and suborders in the probably diphyletic subclass Acari, based on the classification in Krantz and Walter (2009).

Superorder	Order	Suborder
Parasitiformes	Opilioacarida	
	Holothyrida	
	Ixodida	
	Mesostigmata	Trigynaspida
		Sejida
		Monogynaspida
Acariformes	Trombidiformes	Sphaerolichida
		Prostigmata
	Sarcoptiformes	Endeostigmata
		Oribatida

2 Chapter 2: Pictorial Database of Soil Mesostigmata of Alberta

2.1 Introduction

Soil systems contain an extremely diverse assemblage of taxa from every known terrestrial phylum (Giller 1996; Coleman et al. 2004), with a great many undescribed species; in fact, André et al. (2002) estimated that only 10% of species have been described. This is in part because there are few taxonomic experts who work on these groups. Taxonomy (specifically morphological taxonomy) is recruiting fewer taxonomists in the developed world (de Carvalho et al. 2005), which is partly due to the lack of funding opportunities within it (Ebach et al. 2011). More researchers are relying on molecular data to identify organisms (Luc et al. 2010). This eases identification, but other than presence/absence of particular genetic entities in particular habitats, little information on the organism's ecology is learned. However, knowledge about their ecology is needed more than ever, as we are becoming increasingly aware of the vital nature these organisms play in belowground ecosystem function. Biodiversity Ecosystem Function (BEF) is the relationship species have in governing environmental processes. Originally, BEF concentrated on aboveground systems (e.g. Tilman et al. 1997); however, recent studies have focused on the relationship of belowground BEF. Wagg et al. (2014) found that decreased belowground biodiversity can lower aboveground diversity and impact ecosystem processes such as net productivity of flora and litter decomposition.

As fewer researchers are becoming experts in morphological taxonomy, researchers have begun using coarse taxonomy (genus-and family-level identifications) in lieu of species-level identification to quantify diversity, as it requires less expertise. This approach has been successful in quantifying diversity with various taxa like ants (Groc et al. 2010), beetles (Rosser and Eggleton 2012), and aquatic invertebrates (Jiang et al. 2013; Jiang et al. 2017). Even further removed from classical species-level taxonomy is parataxonomy, which involves identifying individuals based on easily recognizable features, such as color and body size, which may not always correlate well with actual taxonomic placement (Oliver and Beattie 1993; Basset et al. 2004). For coarse taxonomy or parataxonomy to operate efficiently, it is still necessary to have taxonomists create resources to aid untrained researchers. Pictorial keys or image databases are good tools for non-experts, because relevant morphology is clearly illustrated rather than being described in words. Examples of these include online interactive keys to pseudoscorpions Buddle (2010) and nasal mites (Knee and Proctor 2010), and the AntWeb database (AntWeb 2017).

Mites (Arachnida: Acariformes, Parasitiformes) are extremely diverse, with over 55,000 described species (Walter and Proctor 2013) and true species richness believed to be around 1,000,000 (Krantz 2009). The Parasitiformes contains four orders of mites: Opilioacarida, Holothyrida, Ixodida, and Mesostigmata (Klompen et al. 2007). Out of the four orders, Mesostigmata is the most diverse with 11,000 species described in over 70 families (Walter and Proctor 2013). Mesostigmata occupy a variety of niches, including predators in soil and in vertebrate and invertebrate nests, and parasites of vertebrates and invertebrates (Dowling and OConnor 2010). Mesostigmata has three suborders, Trigynaspida, Sejida, and Monogynaspida. Trigynaspid mites inhabit temperate and tropical regions, and are generally associated with reptiles and mammals (Lindquist et al. 2009). Sejida, the most species-poor suborder, has a much larger global distribution than Trigynaspida, and are often found in woody habitats (Lekveishvili and Klompen 2004; Lekveishvili and Klompen 2006; Walter and Proctor 2013). Monogynaspida is the most species-rich suborder with two main cohorts, Gamasina and Uropodina (Walter and Proctor 2013).

The objective of this part of my thesis work was to produce a publicly available pictorial database containing every species/morphospecies of Mesostigmata that I identified from soil samples collected in the boreal forest in northern Alberta. This database provides information on important morphological features for identification, notes on related taxa sampled in northern Alberta, and references to the primary literature used for identification. Currently, the only soil mesofauna group that has been well studied in Alberta is oribatid mites (Arachnida: Acariformes). Oribatid mites are one of the focal groups sampled by the Alberta Biodiversity Monitoring Institute (ABMI) due to their abundance and diversity in belowground communities. Taxonomic keys and illustrations of these mites can be found in Walter and Latonas (2011) and Walter et al. (2014). I did not create a key to the Mesostigmata I identified in my M.Sc. research, as many species (and potential genera in Uropodina) remain undescribed; instead, I constructed a pictorial database that contains an extensive image collection to aid future researchers in their identifications of soil Mesostigmata from boreal Alberta. The database can be readily expanded to include new mesostigmatan taxa from Alberta, which are likely to be found in other regions and habitat types that I did not focus on in my thesis.

2.2 Methods

2.2.1 Sampling Technique

Samples for this study were collected by the Alberta Biodiversity Monitoring Institute (ABMI) and provided by the Royal Alberta Museum (RAM) in Edmonton, Alberta. Information on ABMI and its sampling protocol can be found at (http://www.abmi.ca/home/publications/1-50/46.html) (ABMI 2012), and unless otherwise stated in these methods, are identical to the sampling methodology described below. ABMI's project is structured on a grid of 1656 one-hectare sites, spaced 20 km apart throughout Alberta, Canada. Additional off-grid sites are sometimes sampled to acquire information on a particularly unique environment or to assess abundance of rare biota. For terrestrial sites, ABMI employs spatially randomized sampling methodology across its entire sampling grid, aimed at collecting data from each site on a 5-year rotation. Each terrestrial site is split into 4 four quadrants: NE, NW SE, SW Each terrestrial site is split into 4 four quadrants: NE, NW SE, SW. Organic and mineral soil samples are collected in the outer corners of each quadrant, 9.3 m diagonally outside of the one-hectare site, 80 m away from site center in the NE (45°), NW (315°), SE (135°), and SW (225°) direction. 500 mL of both organic and mineral soil samples is collected; each sample is composed of four subsamples, spaced 1-2 meters apart from one another. If 500 mL of organic and mineral soil are not collected from the four subsamples, additional subsamples are collected until 500 mL is reached. Soil samples are then shipped in coolers to the RAM within seven days of collection, and are processed by laboratory technicians and taxonomists. Organic soil samples are placed in a Tullgren funnel with an incandescent light bulb as the light source, there, soil invertebrates are extracted into containers of 95% ethanol over a period of 7 days. Mineral soil samples are sent out for analysis (e.g., calculate pH of soil).

At the RAM, soil invertebrates are sorted into two size categories, 50-300 µm and > 300 µm. ABMI only identifies adult Oribatida that are greater than 300µm in size, oribatids < 300 µm, juvenile oribatids, and all non-oribatid invertebrates are placed into vials and stored as residuals at the RAM. For my study, I took adult mesostigmatid mites from both the 50-300 µm and > 300 µm residuals. All specimens were sorted with the aid of a dissecting microscope and placed in lactic acid overnight, to be slide-mounted the next day. I used PVA (#6371A-PVA Medium and #6371NS1-PVA/Phenol free medium) from Bioquip products (Rancho, Dominguez, California) as slide-mounting media. Glass slides (catalogue number 12-550-A3) and coverslips (catalogue number 12-545-83) from Fisherbrand were used for slide making. Labels for slides detailed ABMI site and quadrant, size category (50-300 µm or > 300 µm) family, genus and species of the individual, what side the mite is on (more than 1 mite, L and R, one mite, NA), sex of the mite (M/F) and slide box and slide location. Nymphs and larval mites were encoded with n and l, respectively. Each mite received its own label, meaning that some slides received two labels. Slides were initially stored in the Proctor Lab, at the University of Alberta, but after the project's completion, were moved to the RAM's reference collection. For identification, I examined slide-mounted mites with a Leica DMLB compound scope with DIC microscopy and magnification capacity up to 800x. Literature used for identifications partially came from unpublished keys acquired at the Acarology Summer Program at The Ohio State University, in addition to many published works (Trägårdh 1942; Evans 1955; Krantz 1961; Lindquist 1961; Hurlbutt 1963; Evans and Till 1966; Chant and Hansell 1971; Halašková 1977; Hirschmann et al. 1984; Wagrowska-Adamczyk and Hirschmann 1984; Karg 1993; Halliday 1997a; Halliday

1997b; Makarova 2000; Makarova 2003; Mašán 2003; Christian and Karg 2006; Chant and McMurtry 2007; Gwiazdowicz and Halliday 2008; Lindquist et al. 2009; Díaz-Aguilar and Ujvári 2010; Kontschán 2010; Lindquist and Moraza 2010; Denmark and Evans 2011; Lindquist and Makarova 2011; Gwiazdowicz and Marchenko 2012; Joharchi et al. 2013; Mašán and Halliday 2013; Walter 2013; Hajizadeh et al. 2014; Ramroodi et al. 2014; Sikora 2014; Kontschán 2015; Narita et al. 2015; Kazemi et al. 2016; Mašán et al. 2016; Narita and De Moraes 2016; Vatankhah et al. 2016; Makarova and Huhta 2017).

2.2.2 Image Acquisition and Manipulation and Website Creation

Images were taken with a Leica MC170 HD camera attached to the compound scope via the Leica LAS EZ 3.0 program. Images were of important morphological features, examples include setae type and length, sternal and ventrianal/anal shield and male spermatodactyl/spermatotreme. Images were edited in GIMP (GNU Image Manipulation Program) (The Gimp Team 1997-2015). The usual manipulation protocol involved removing visual artifacts (e.g. soil particles), reattaching separated limbs and repairing split shields, and applying a contrast mask. Contrast masking consists of 6 steps: 1) duplicate the original image for editing purposes, 2) desaturate the image, 3) apply a gaussian blur, 4) overlay the edited image onto the original image, 5) adjust contrast and brightness, and 6) sharpen image to highlight edges of its idiosoma. Arrows or boxes were occasionally added to highlight morphological features. All images were labeled with a letter to match the description on the webpage with the image.

After GIMP processing, images were uploaded to the website https://mesostigmataofalberta.wordpress.com. The website was created via WordPress (WordPress Foundation 2017). Each species/morphospecies was given its own page.

Each page contains three sections: 1) images of important morphological features; 2) information on related taxa (in the context of the species/morphospecies found in northern Alberta) and 3) primary literature used for identification. The primary literature used was in the form of "in-text" citations. These in-text citations are linked to the references where full citations are listed. Species pages are connected to the taxonomy page, which groups species/morphospecies by their taxonomic rank (Suborder, Cohort, Family, and Genus). Each species/morphospecies listed in the taxonomy page is connected via hyperlink to its individual page.

Additional pages were added to improve functionality of the website, and to provide more information on mesostigmatid mite morphology and terminology. A 'Welcome' page was also added; it contains information on ABMI sites sampled, authorship and preferred citation format. Information about ABMI and the RAM can be found in the 'About' page. An 'Updates' page was made to notify users of any changes to species pages. This connects to the 'Contact' page, which allows users to message the lead author (Matthew Meehan) by email. Information on Mesostigmata morphology and terminology are found on the 'Glossary' page. Finally, a 'Thank you' page was made to acknowledge other acarologists who helped with the identifications of individuals.

2.2.3 Screenshots of Web Pages for Thesis

Screenshots were taken of every part of the website and displayed four at a time on the following pages. Screenshots for the Welcome, Updates, Contact, About and Thank you pages are displayed first. These pages will subsequently be called the "Base Pages". Screenshots containing all glossary terms, and the taxonomic tree are next shown. After that, species pages appear in the order shown on the taxonomic tree. Finally, screenshots of the reference section are displayed.

2.3 Results

I identified soil mesostigmatid mites from 2 suborders, 3 cohorts, 21 families, 46 genera and 109 species/morphospecies (Table 2-1). For adults, I found an average of 5.19 ± 2.85 (mean ± SD) species and 13.40 ± 11.78 individuals per quadrant.

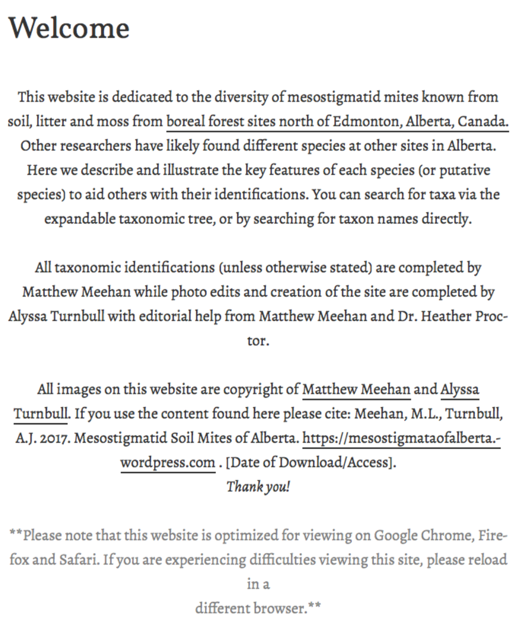
2.4 Website Content

A total of 118 webpages were made, screenshots of each page can be seen below. The website can be found at https://mesostigmataofalberta.wordpress.com. The template of how screenshots will be presented is on the next page. To view images of species/morphospecies please use the website. Screenshots of the website were taken to fulfill the requirements for my MSc. thesis, and should not be used in place of the website. At this time (Jan 2018), all species/morphospecies with the exception of one (*Zercon* sp. 2) can be found on the website.

Template: Screenshots of species/morphospecies pages are to be viewed in a particular order, starting with the top left (1), than bottom left (2), followed by the top right (3), then bottom right (4).

1	3
2	4

2.4.1 Base Pages



Welcome

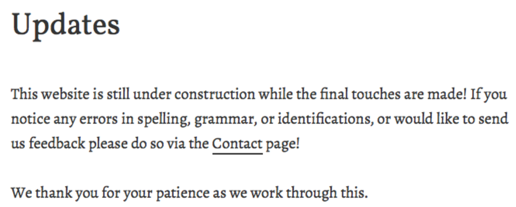
This website is dedicated to the diversity of mesostigmatid mites known from soil, litter and moss from boreal forest sites north of Edmonton, Alberta, Canada. Other researchers have likely found different species at other sites in Alberta. Here we describe and illustrate the key features of each species (or putative species) to aid others with their identifications. You can search for taxa via the expandable taxonomic tree, or by searching for taxon names directly.

All taxonomic identifications (unless otherwise stated) are completed by Matthew Meehan while photo edits and creation of the site are completed by Alyssa Turnbull with editorial help from Matthew Meehan and Dr. Heather Proctor.

All images on this website are copyright of Matthew Meehan and Alyssa Turnbull. If you use the content found here please cite: Meehan, M.L., Turnbull, A.J. 2017. Mesostigmatid Soil Mites of Alberta. https://mesostigmataofalberta.wordpress.com . [Date of Download/Access].

Thank you!

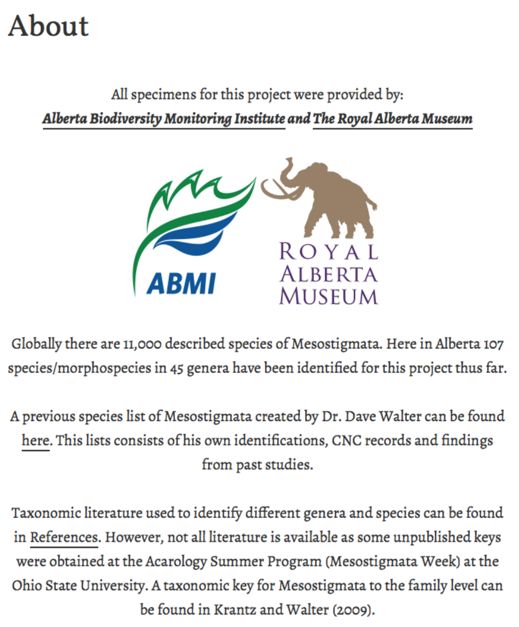
**Please note that this website is optimized for viewing on Google Chrome, Firefox and Safari. If you are experiencing difficulties viewing this site, please reload in a
different browser.**



Updates

This website is still under construction while the final touches are made! If you notice any errors in spelling, grammar, or identifications, or would like to send us feedback please do so via the Contact page!

We thank you for your patience as we work through this.



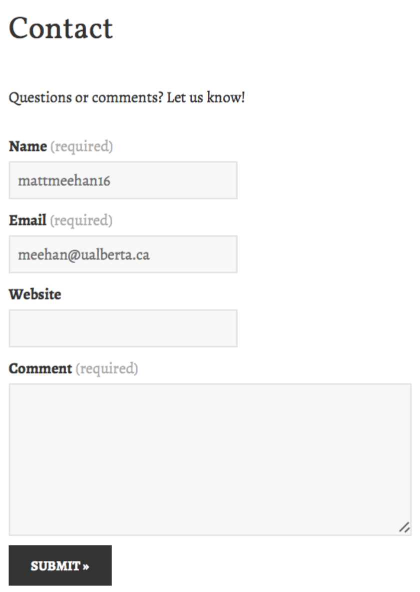
About

All specimens for this project were provided by:
Alberta Biodiversity Monitoring Institute and The Royal Alberta Museum

Globally there are 11,000 described species of Mesostigmata. Here in Alberta 107 species/morphospecies in 45 genera have been identified for this project thus far.

A previous species list of Mesostigmata created by Dr. Dave Walter can be found here. This lists consists of his own identifications, CNC records and findings from past studies.

Taxonomic literature used to identify different genera and species can be found in References. However, not all literature is available as some unpublished keys were obtained at the Acarology Summer Program (Mesostigmata Week) at the Ohio State University. A taxonomic key for Mesostigmata to the family level can be found in Krantz and Walter (2009).



Contact

Questions or comments? Let us know!

Name (required)
mattmeehan16

Email (required)
meehan@ualberta.ca

Website

Comment (required)

Thank you

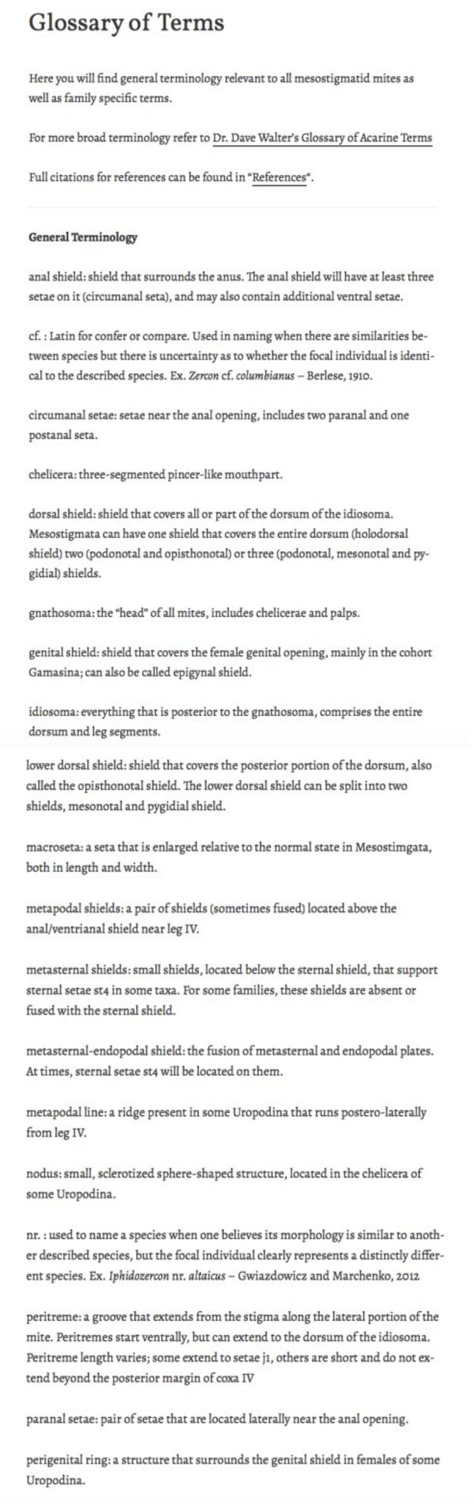
This research was supported by an NSERC Discovery Grant to HP and an Alberta Conservation Association Biodiversity Grant to MM and HP.
The completion of this website would not have been possible without the Acarology Summer Program at Ohio State University and correspondence with fellow Acarologists.

Thank You,

Dr. Fred Beaulieu
Dr. Ashley Dowling
Dr. Bruce Halliday
Dr. Hans Klompen
Dr. Wayne Knee
Dr. Gerry Krantz
Dr. Evert Lindquist
Dr. Owen Seeman
Dr. Dave Walter

For your help with the identifications for this website.

2.4.2 Glossary



Glossary of Terms

Here you will find general terminology relevant to all mesostigmatid mites as well as family specific terms.

For more broad terminology refer to Dr. Dave Walter's Glossary of Acarine Terms

Full citations for references can be found in "References".

General Terminology

anal shield: shield that surrounds the anus. The anal shield will have at least three setae on it (circumanal seta), and may also contain additional ventral setae.

cf. : Latin for confer or compare. Used in naming when there are similarities between species but there is uncertainty as to whether the focal individual is identical to the described species. Ex. *Zercon* cf. *columbianus* – Berlese, 1910.

circumanal setae: setae near the anal opening, includes two paranal and one postanal seta.

chelicera: three-segmented pincer-like mouthpart.

dorsal shield: shield that covers all or part of the dorsum of the idiosoma. Mesostigmata can have one shield that covers the entire dorsum (holodorsal shield) two (podonotal and opisthonotal) or three (podonotal, mesonotal and pygidial) shields.

gnathosoma: the "head" of all mites, includes chelicerae and palps.

genital shield: shield that covers the female genital opening, mainly in the cohort Gamasina; can also be called epigynal shield.

idiosoma: everything that is posterior to the gnathosoma, comprises the entire dorsum and leg segments.

lower dorsal shield: shield that covers the posterior portion of the dorsum, also called the opisthonotal shield. The lower dorsal shield can be split into two shields, mesonotal and pygidial shield.

macroseta: a seta that is enlarged relative to the normal state in Mesostimgata, both in length and width.

metapodal shields: a pair of shields (sometimes fused) located above the anal/ventrianal shield near leg IV.

metasternal shields: small shields, located below the sternal shield, that support sternal setae st4 in some taxa. For some families, these shields are absent or fused with the sternal shield.

metasternal-endopodal shield: the fusion of metasternal and endopodal plates. At times, sternal setae st4 will be located on them.

metapodal line: a ridge present in some Uropodina that runs postero-laterally from leg IV.

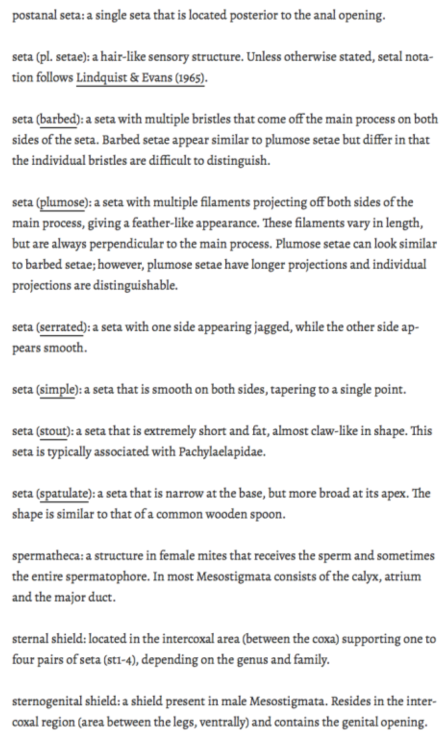
nodus: small, sclerotized sphere-shaped structure, located in the chelicera of some Uropodina.

nr. : used to name a species when one believes its morphology is similar to another described species, but the focal individual clearly represents a distinctly different species. Ex. *Iphidozercon* nr. *altaicus* – Gwiazdowicz and Marchenko, 2012

peritreme: a groove that extends from the stigma along the lateral portion of the mite. Peritremes start ventrally, but can extend to the dorsum of the idiosoma. Peritreme length varies; some extend to setae j1, others are short and do not extend beyond the posterior margin of coxa IV

paranal setae: pair of setae that are located laterally near the anal opening.

perigenital ring: a structure that surrounds the genital shield in females of some Uropodina.



postanal seta: a single seta that is located posterior to the anal opening.

seta (pl. setae): a hair-like sensory structure. Unless otherwise stated, setal notation follows Lindquist & Evans (1965).

seta (barbed): a seta with multiple bristles that come off the main process on both sides of the seta. Barbed setae appear similar to plumose setae but differ in that the individual bristles are difficult to distinguish.

seta (plumose): a seta with multiple filaments projecting off both sides of the main process, giving a feather-like appearance. These filaments vary in length, but are always perpendicular to the main process. Plumose setae can look similar to barbed setae; however, plumose setae have longer projections and individual projections are distinguishable.

seta (serrated): a seta with one side appearing jagged, while the other side appears smooth.

seta (simple): a seta that is smooth on both sides, tapering to a single point.

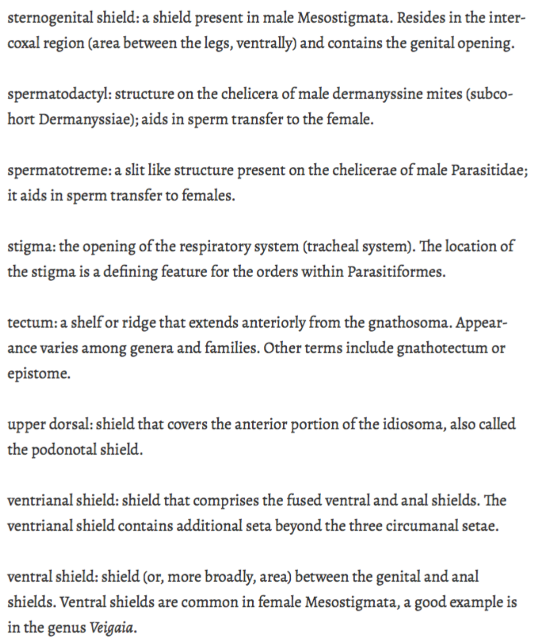
seta (stout): a seta that is extremely short and fat, almost claw-like in shape. This seta is typically associated with Pachylaelapidae.

seta (spatulate): a seta that is narrow at the base, but more broad at its apex. The shape is similar to that of a common wooden spoon.

spermatheca: a structure in female mites that receives the sperm and sometimes the entire spermatophore. In most Mesostigmata consists of the calyx, atrium and the major duct.

sternal shield: located in the intercoxal area (between the coxa) supporting one to four pairs of seta (st1-4), depending on the genus and family.

sternogenital shield: a shield present in male Mesostigmata. Resides in the intercoxal region (area between the legs, ventrally) and contains the genital opening.



sternogenital shield: a shield present in male Mesostigmata. Resides in the intercoxal region (area between the legs, ventrally) and contains the genital opening.

spermatodactyl: structure on the chelicera of male dermanyssine mites (subcohort Dermanyssiae); aids in sperm transfer to the female.

spermatotreme: a slit like structure present on the chelicerae of male Parasitidae; it aids in sperm transfer to females.

stigma: the opening of the respiratory system (tracheal system). The location of the stigma is a defining feature for the orders within Parasitiformes.

tectum: a shelf or ridge that extends anteriorly from the gnathosoma. Appearance varies among genera and families. Other terms include gnathotectum or epistome.

upper dorsal: shield that covers the anterior portion of the idiosoma, also called the podonotal shield.

ventrianal shield: shield that comprises the fused ventral and anal shields. The ventrianal shield contains additional seta beyond the three circumanal setae.

ventral shield: shield (or, more broadly, area) between the genital and anal shields. Ventral shields are common in female Mesostigmata, a good example is in the genus *Veigaia*.

Terminology Specific to the Zerconidae

Zerconidae
Note: citations are provided for morphology, if terminology of a structure is credited to an author(s).

inner dilation: a small, circular projection out of the peritreme, near the stigma.

posterodorsal cavities:well-developed scars that can be sclerotized, located posteriorly on the opisthonotal shield. Examples can be seen in *Zercon*.

tectum (*Zercon*-type): a single, slender anteromedial process, which is divided into two to four tines (Ujvári 2011).

tectum (*Parazercon*-type): four anterior processes (with the two center processes being the longest) that taper apically (Ujvári 2011).

tectum (*Prozercon*-type): a single, apically tapering anteromedially process (Ujvári 2011).

peritremal setae: setae located on peritremal shield. Numbers vary from one to three (r1, r2, and r3). Only one genus has a single seta on its shield (r3 seta, *Monozercon* – Blaszak, 1984), and others have two or three. Typically, the r1 seta is extremely hard to see as it is under leg 1. Due to the location, we were unable to include photos of this seta in the gallery of images on this website.

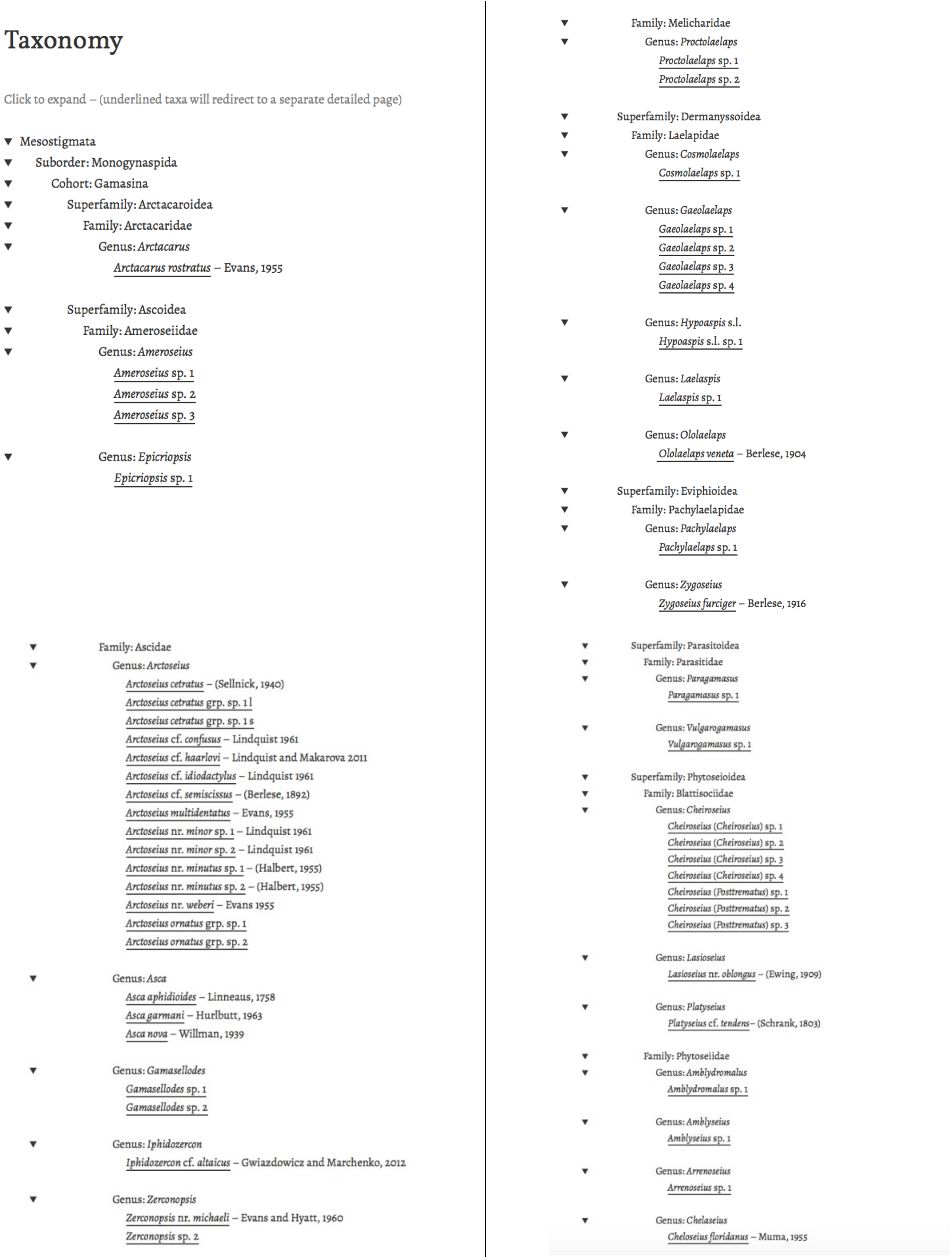
2.4.3 Taxonomic Tree (Closed)

Taxonomy

Click to expand – (underlined taxa will redirect to a separate detailed page)

- ▼ Mesostigmata
  - ▼ Suborder: Monogynaspida
    - ▶ Cohort: Gamasina
    - ▶ Cohort: Microgyniina
    - ▶ Cohort: Uropodina s.s.
  - ▶ Suborder: Sejida

2.4.4 Taxonomic Tree (Open)



Taxonomy

Click to expand – (underlined taxa will redirect to a separate detailed page)

- ▼ Mesostigmata
  - ▼ Suborder: Monogynaspida
    - ▼ Cohort: Gamasina
      - ▼ Superfamily: Arctacaroidea
        - ▼ Family: Arctacaridae
          - ▼ Genus: *Arctacarus*
            - *Arctacarus rostratus* – Evans, 1955
      - ▼ Superfamily: Ascoidea
        - ▼ Family: Ameroseiidae
          - ▼ Genus: *Ameroseius*
            - *Ameroseius* sp. 1
            - *Ameroseius* sp. 2
            - *Ameroseius* sp. 3
          - ▼ Genus: *Epicriopsis*
            - *Epicriopsis* sp. 1
        - ▼ Family: Ascidae
          - ▼ Genus: *Arctoseius*
            - *Arctoseius cetratus* – (Sellnick, 1940)
            - *Arctoseius cetratus* grp. sp. 1 l
            - *Arctoseius cetratus* grp. sp. 1 s
            - *Arctoseius* cf. *confusus* – Lindquist 1961
            - *Arctoseius* cf. *haarlovi* – Lindquist and Makarova 2011
            - *Arctoseius* cf. *idiodactylus* – Lindquist 1961
            - *Arctoseius* cf. *semiscissus* – (Berlese, 1892)
            - *Arctoseius multidentatus* – Evans, 1955
            - *Arctoseius* nr. *minor* sp. 1 – Lindquist 1961
            - *Arctoseius* nr. *minor* sp. 2 – Lindquist 1961
            - *Arctoseius* nr. *minutus* sp. 1 – (Halbert, 1955)
            - *Arctoseius* nr. *minutus* sp. 2 – (Halbert, 1955)
            - *Arctoseius* nr. *weberi* – Evans 1955
            - *Arctoseius ornatus* grp. sp. 1
            - *Arctoseius ornatus* grp. sp. 2
          - ▼ Genus: *Asca*
            - *Asca aphidioides* – Linneaus, 1758
            - *Asca garmani* – Hurlbutt, 1963
            - *Asca nova* – Willman, 1939
          - ▼ Genus: *Gamasellodes*
            - *Gamasellodes* sp. 1
            - *Gamasellodes* sp. 2
          - ▼ Genus: *Iphidozercon*
            - *Iphidozercon* cf. *altaicus* – Gwiazdowicz and Marchenko, 2012
          - ▼ Genus: *Zerconopsis*
            - *Zerconopsis* nr. *michaeli* – Evans and Hyatt, 1960
            - *Zerconopsis* sp. 2
        - ▼ Family: Melicharidae
          - ▼ Genus: *Proctolaelaps*
            - *Proctolaelaps* sp. 1
            - *Proctolaelaps* sp. 2
      - ▼ Superfamily: Dermanyssoidea
        - ▼ Family: Laelapidae
          - ▼ Genus: *Cosmolaelaps*
            - *Cosmolaelaps* sp. 1
          - ▼ Genus: *Gaeolaelaps*
            - *Gaeolaelaps* sp. 1
            - *Gaeolaelaps* sp. 2
            - *Gaeolaelaps* sp. 3
            - *Gaeolaelaps* sp. 4
          - ▼ Genus: *Hypoaspis* s.l.
            - *Hypoaspis* s.l. sp. 1
          - ▼ Genus: *Laelaspis*
            - *Laelaspis* sp. 1
          - ▼ Genus: *Ololaelaps*
            - *Ololaelaps veneta* – Berlese, 1904
      - ▼ Superfamily: Eviphioidea
        - ▼ Family: Pachylaelapidae
          - ▼ Genus: *Pachylaelaps*
            - *Pachylaelaps* sp. 1
          - ▼ Genus: *Zygoseius*
            - *Zygoseius furciger* – Berlese, 1916
      - ▼ Superfamily: Parasitoidea
        - ▼ Family: Parasitidae
          - ▼ Genus: *Paragamasus*
            - *Paragamasus* sp. 1
          - ▼ Genus: *Vulgarogamasus*
            - *Vulgarogamasus* sp. 1
      - ▼ Superfamily: Phytoseioidea
        - ▼ Family: Blattisociidae
          - ▼ Genus: *Cheiroseius*
            - *Cheiroseius* (*Cheiroseius*) sp. 1
            - *Cheiroseius* (*Cheiroseius*) sp. 2
            - *Cheiroseius* (*Cheiroseius*) sp. 3
            - *Cheiroseius* (*Cheiroseius*) sp. 4
            - *Cheiroseius* (*Posttrematus*) sp. 1
            - *Cheiroseius* (*Posttrematus*) sp. 2
            - *Cheiroseius* (*Posttrematus*) sp. 3
          - ▼ Genus: *Lasioseius*
            - *Lasioseius* nr. *oblongus* – (Ewing, 1909)
          - ▼ Genus: *Platyseius*
            - *Platyseius* cf. *tendens*– (Schrank, 1803)
        - ▼ Family: Phytoseiidae
          - ▼ Genus: *Amblydromalus*
            - *Amblydromalus* sp. 1
          - ▼ Genus: *Amblyseius*
            - *Amblyseius* sp. 1
          - ▼ Genus: *Arrenoseius*
            - *Arrenoseius* sp. 1
          - ▼ Genus: *Chelaseius*
            - *Cheloseius floridanus* – Muma, 1955

- ▼ Genus: *Neoseiulus*
  - *Neoseiulus* sp. 1

- ▼ Genus: *Proprioseiopsis*
  - *Proprioseiopsis* sp. 1
  - *Proprioseiopsis* sp. 2

- ▼ Superfamily: Rhodocaroidea
  - ▼ Family: Digamasellidae
    - ▼ Genus: *Dendrolaelaps*
      - *Dendrolaelaps* sp. 1
      - *Dendrolaelaps* sp. 2
      - *Dendrolaelaps* sp. 3
      - *Dendrolaelaps* sp. 4
      - *Dendrolaelaps* sp. 6
      - *Dendrolaelaps* sp. 7
      - *Dendrolaelaps* sp. 8
      - *Dendrolaelaps* sp. 9
      - *Dendrolaelaps* sp. 10
      - *Dendrolaelaps* sp. 11
      - *Dendrolaelaps* sp. 13
      - *Dendrolaelaps* sp. 14
      - *Dendrolaelaps* sp. 15

  - ▼ Family: Halolaelapidae
    - ▼ Genus: *Halodarcia*
      - *Halodarcia* sp. 1

    - ▼ Genus: nr. *Saprosecans*
      - nr. *Saprosceans* sp. 1

  - ▼ Family: Ologamasidae
    - ▼ Genus: *Gamasellus*
      - *Gamasellus* sp. 1
      - *Gamasellus* sp. 2
      - *Gamasellus* sp. 3

- ▼ Superfamily: Zerconoidea
  - ▼ Family: Zerconidae
    - ▼ Genus: *Boreozercon*
      - *Boreozercon emendi* – Díaz-Aguilar and Ujvári, 2010

    - ▼ Genus: *Mixozercon*
      - *Mixozercon borealis* – Díaz-Aguilar and Ujvári, 2010
      - *Mixozercon jasoniana* – Díaz-Aguilar and Ujvári, 2010

    - ▼ Genus: *Parazercon*
      - *Parazercon radiatus* – Berlese, 1910

    - ▼ Genus: *Rafaskas*
      - *Rafaskas* sp. 1

    - ▼ Genus: *Skeironozercon*
      - *Skeironozercon embersoni* – Halašková, 1977
      - *Skeironozercon tricavus* – Blaszak, 1982

    - ▼ Genus: *Zercon*
      - *Zercon alaskaensis* – Sellnick, 1958
      - *Zercon* cf. *columbianus* – Berlese, 1910
      - *Zercon michaeli* – Halašková, 1977
      - *Zercon nr. lindquisti* – Halašková, 1977
      - *Zercon oregonus* – Sikora, 2014
      - *Zercon* sp. 1

- ▼ Cohort: Microgyniina
  - ▼ Superfamily: Microgynioidea
    - ▼ Family: Microgyniidae
      - ▼ Genus: *Microgynium*
        - *Microgynium incisum* – Krantz, 1961
        - *Microgynium* sp. 1

- ▼ Cohort: Uropodina s.s.
  - ▼ Family: Dinychidae
    - ▼ Genus: *Dinychus*
      - *Dinychus* sp. 1
      - *Dinychus* sp. 2
      - *Dinychus* sp. 3
      - *Dinychus* sp. 4
      - *Dinychus* sp. 5
      - *Dinychus* sp. 6
      - *Dinychus* sp. 7
      - *Dinychus* sp. 8

    - ▼ Genus: *Urodiaspis*
      - *Urodiaspis* sp. 1

  - ▼ Family: Dithinozerconidae
    - ▼ Genus: *Iphidinychus*
      - *Iphidinychus* sp. 1
      - *Iphidinychus* sp. 2

  - ▼ Family: Oplitidae
    - ▼ Genus: Unknown
      - sp. 1

  - ▼ Family: Trachydidae
    - ▼ Genus: *Trachytes*
      - *Trachytes* sp. 1

  - ▼ Family: Trematuridae
    - ▼ Genus: cf. *Trichouropoda*
      - cf. *Trichouropoda* s.l. sp. 1

- ▼ Suborder: Sejida
  - ▼ Superfamily: Sejoida
    - ▼ Family: Sejidae
      - ▼ Genus: *Sejus*
        - *Sejus* cf. *americanus* – (Banks, 1902)
        - *Sejus* sp. 2

2.4.5 Suborder: Monogynaspida

2.4.5.1 Cohort: Gamasina

2.4.5.1.1 Arctacaroidea

2.4.5.1.1.1 Arctacaridae

Arctacarus rostratus Evans, 1955

Morphological Characteristics

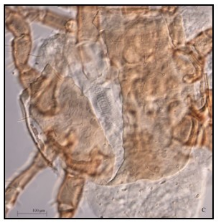
No males illustrated as no males have yet been found

(click images to enlarge)

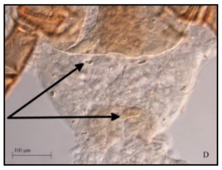
(A) Full body dorsal.

(B) Full body ventral.

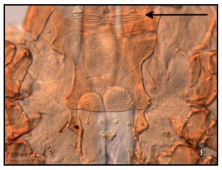
(C) Dorsal shield only covers half the body (past leg 4).



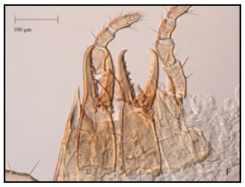
(D) Lower half of idiosoma covered with setae and mesonotal and pygidial scutella (arrows).



(E) Sternal shield with distinctive small sclerites located in the presternal area (arrow).



(F) Chelicerae.



Related Taxa

Thus far in this project I have found no others species within this genus in Alberta.

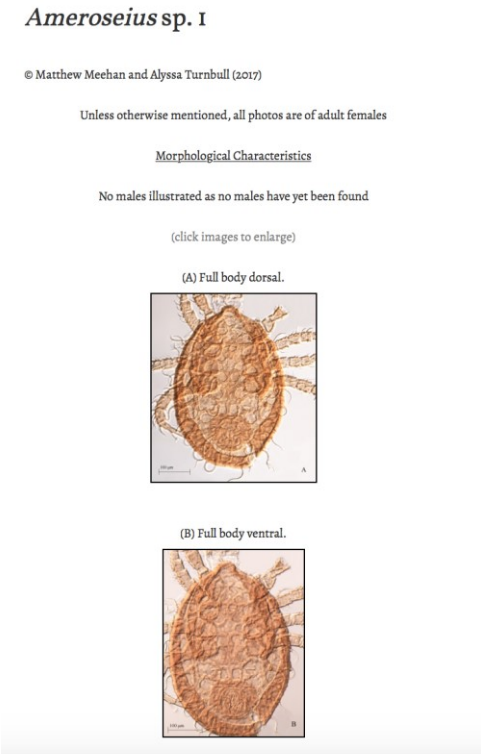
Literature Used for Identification

Evans 1955

Makarova 2003

2.4.5.1.2 Ascoidea

2.4.5.1.2.1 Ameroseiidae



Ameroseius sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

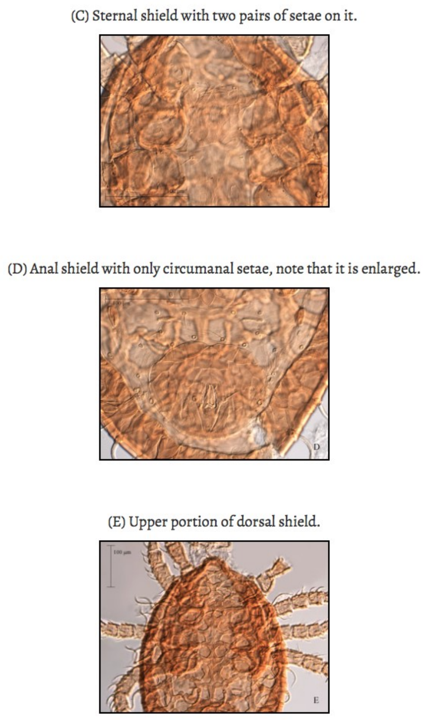
Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

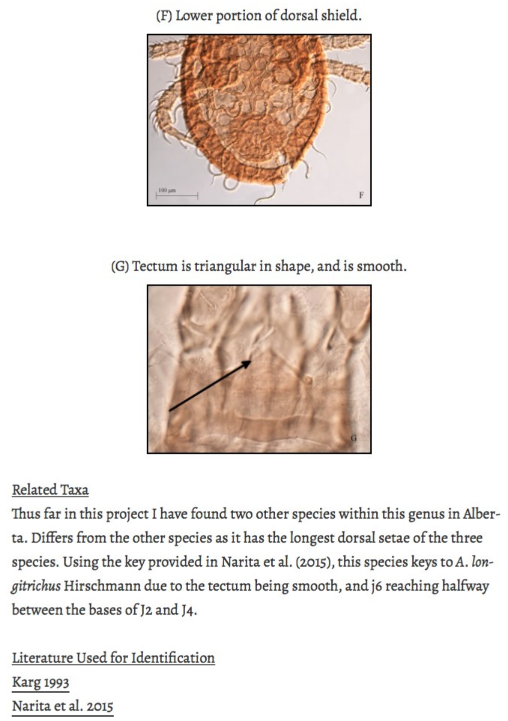
(B) Full body ventral.



(C) Sternal shield with two pairs of setae on it.

(D) Anal shield with only circumanal setae, note that it is enlarged.

(E) Upper portion of dorsal shield.



(F) Lower portion of dorsal shield.

(G) Tectum is triangular in shape, and is smooth.

Related Taxa

Thus far in this project I have found two other species within this genus in Alberta. Differs from the other species as it has the longest dorsal setae of the three species. Using the key provided in Narita et al. (2015), this species keys to *A. longitrichus* Hirschmann due to the tectum being smooth, and j6 reaching halfway between the bases of J2 and J4.

Literature Used for Identification

Karg 1993

Narita et al. 2015

Ameroseius sp. 2

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

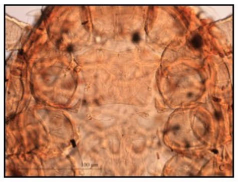
No males illustrated as no males have yet been found

(click images to enlarge)

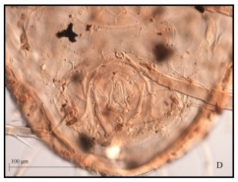
(A) Full body dorsal.

(B) Full body ventral.

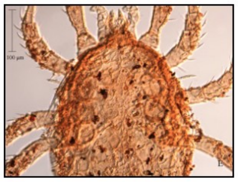
(C) Sternal shield with two pairs of setae on it.



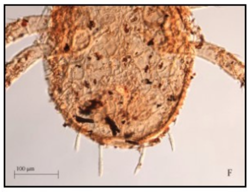
(D) Ventrianal shield with only circumanal setae.



(E) Upper portion of dorsal shield.



(F) Lower portion of dorsal shield.



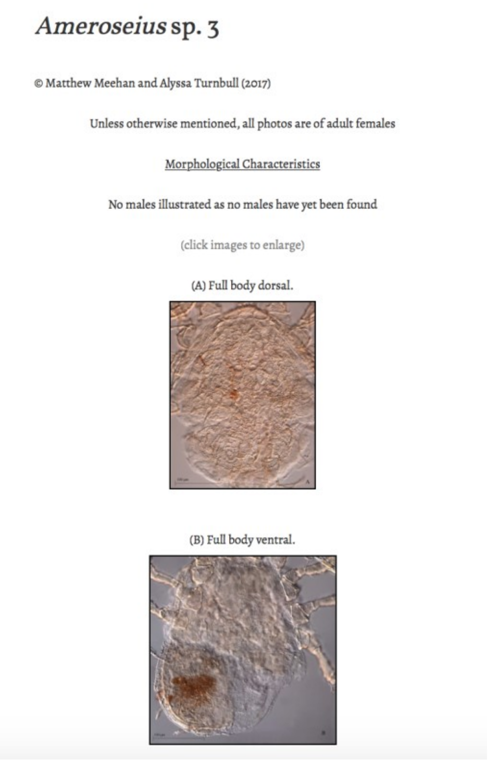
Related Taxa

Thus far in this project I have found two other species within this genus in Alberta. *Ameroseius* sp. 2 differs from the other species in having serrated dorsal setae. Using the key provided in Narita et al. (2015), this species keys to *A. sculptilis* Berlese due to the anal shield having ridges and pit-like depressions.

Literature Used for Identification

Karg 1993

Narita et al. 2015



Ameroseius sp. 3

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

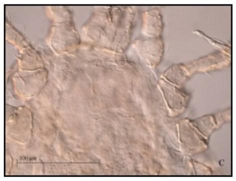
No males illustrated as no males have yet been found

(click images to enlarge)

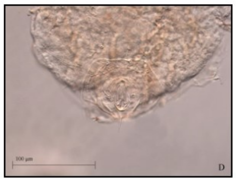
(A) Full body dorsal.

(B) Full body ventral.

(C) Sternal shield with two pairs of setae on it.



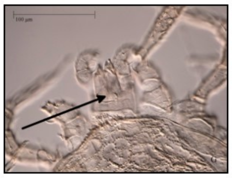
(D) Ventrianal shield with 2 pairs of setae (not including paranal setae).



(E) Upper portion of dorsal shield.

(F) Lower portion of dorsal shield.

(G) Tectum is triangular in shape, and is smooth (arrow).



Related Taxa

Thus far in this project I have found two other species within this genus in Alberta. *Ameroseius* sp. 3 differs from the other two species as the dorsal setae are plumose (feather-like) and it has a beaded ornamentation on dorsal shield. Using the key provided in Narita et al. (2015), this species keys to *A. fimetorum* Karg; however, *Ameroseius* sp. 3 dorsal setae are plumose, and not all j/J setae reach the next setal base.

Literature Used for Identification

Karg 1993

Narita et al. 2015

Epicriopsis sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

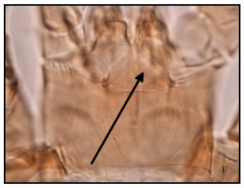
(B) Full body ventral.

(C) Extremely long leg I.

(D) Only one pair of setae on sternal shield.

(E) Circular tubercules on the anterior portion of dorsal shield.

(F) Tectum (arrow).



Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. Using the key provided in Narita and De Moraes (2016), this species keys out to *E. walteri* Halliday; however, in *Epicriopsis* sp. 1 the dorsal setae are longer, the dorsal shield lacks a pair of incisions on the posterolateral margins, and it has one pair rather than two pairs of setae on the sternal shield.

Literature Used for Identification

Halliday 1997

Karg 1993

Narita and De Moraes 2016

2.4.5.1.2.2 Ascidae

Arctoseius cetratus (Sellnick, 1940)

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

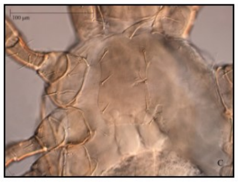
No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

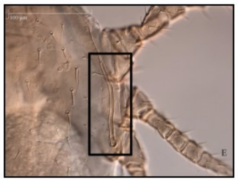
(B) Full body ventral.

(C) Sternal shield with three pairs of setae, the shield is rectangular in shape and lightly sclerotized.



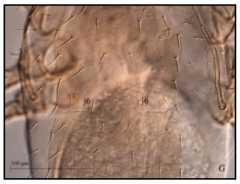
(D) Genital shield.

(E) Peritremes extend to midline of coxa II.

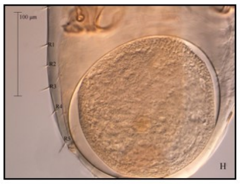


(F) Biramous (two-tined) tectum (arrow).

(G) Dorsal shield incisions reaching level of j6.



(H) Post marginal row of R-setae with five pairs (R1-5).



(I) Dorsal shield setae are uniform in length.

Related Taxa

Thus far in this project I have found 15 other species within this genus in Alberta. *Arctoseius cetratus* is in the *cetratus* group, which is characterized by short peritremes, a biramous tectum, and a rectangular sternal shield.

Literature Used for Identification

Keum et al. 2015
Makarova 2000
Makarova and Huhta 2017
Mašán 2014

Arctoseius cetratus grp. sp. 1 l

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

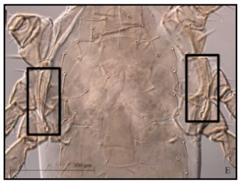
(A) Full body dorsal.

(B) Full body ventral.

(C) Sternal shield with three pairs of setae present.

(D) Anal shield.

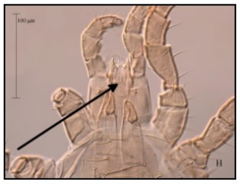
(E) Peritremes extend to anterior leg III/posterior leg II.



(F) Dorsal slit extends past z6, towards j6.

(G) S and Z series setae are long.

(H) Biramous (two-tined) tectum (arrow).



Related taxa

Thus far in this project I have found 15 other species within this genus in Alberta. *Arctoseius cetratus* grp. sp. 1 l is in the *cetratus* group, which is characterized by short peritremes, a biramous tectum, and a rectangular sternal shield. *Arctoseius cetratus* grp. sp. 1 l differs from *Arctoseius cetratus* (Sellnick) as the dorsal setae are generally longer.

Literature used for identification

Makarova 2000

Mašán 2014

Arctoseius cetratus grp. sp. 1 s

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

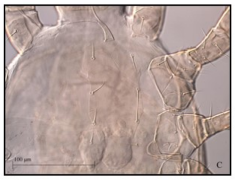
No males illustrated as no males have yet been found

(click images to enlarge)

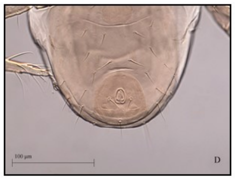
(A) Full body dorsal.

(B) Full body ventral.

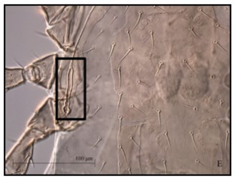
(C) Sternal shield with three pairs of setae present.



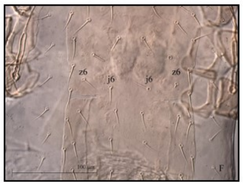
(D) Anal shield.



(E) Peritreme extends to midline/anterior leg III.



(F) Dorsal slit extends past z6, towards j6.



(G) Dorsal setae reach next setal base.

(H) Biramous (two-tined) tectum (arrow).

Related taxa

Thus far in this project I have found 15 other species within this genus in Alberta. *Arctoseius cetratus* grp. sp. 1 s is in the *cetratus* group, which is characterized by short peritremes, a biramous tectum, and a rectangular sternal shield. *Arctoseius cetratus* grp. sp. 1 looks similar to *Arctoseius cetratus* (Sellnick); however, the peritremes are shorter than those of *Arctoseius cetratus*.

Literature used for identification

Makarova 2000

Mašán 2014

Arctoseius cf. *confusus* Lindquist 1961

Unless otherwise mentioned, all photos are of adult females

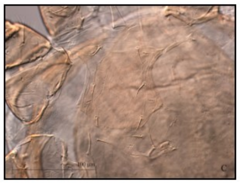
Morphological Characteristics

(click images to enlarge)

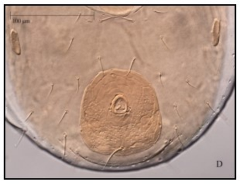
(A) Full body dorsal.

(B) Full body ventral.

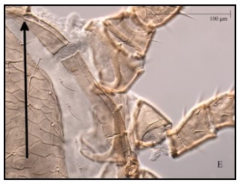
(C) Sternal shield with three pairs of setae.



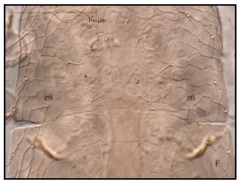
(D) Anal shield.



(E) Peritreme extends to leg I (arrow).



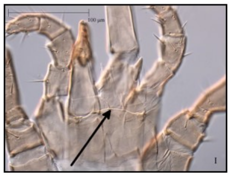
(F) Dorsal slits extend to z6.



(G) All dorsal setae are short (except Z5).

(H) Z5 setae are long.

(I) Triramous (three-tined) tectum (arrow).



(J) Male chelicerae.

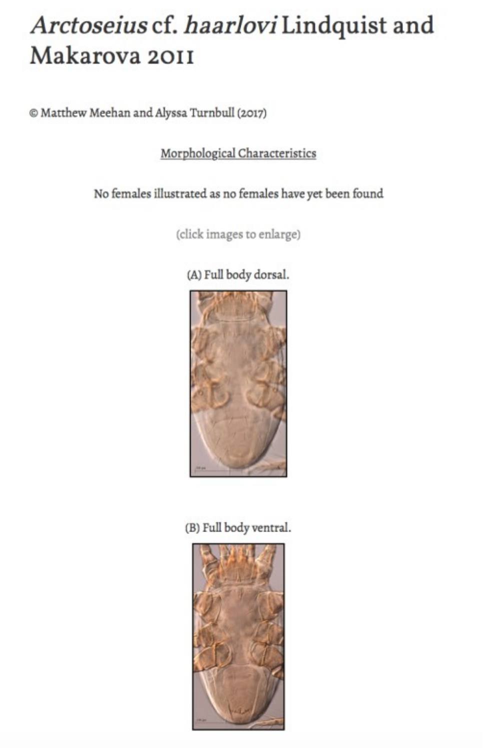
Related taxa

Thus far in this project I have found 15 other species within this genus in Alberta. Using the key provided in Makarova (2000), this species keys to *Arctoseius confusus* Lindquist, based on the reticulation on its sternal shield and for short dorsal setae (except for Z5). Since the anal shield is not as round as indicated in Lindquist (1961) (though anal shields can vary considerably, as mentioned by Lindquist (1961) for *A. idiodactylus*), I am conservatively calling it *Arctoseius* cf. *confusus*.

Literature used for identification

Lindquist 1961

Makarova 2000



Arctoseius cf. *haarlovi* Lindquist and Makarova 2011

© Matthew Meehan and Alyssa Turnbull (2017)

Morphological Characteristics

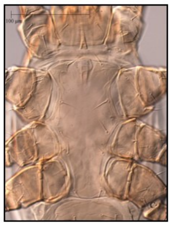
No females illustrated as no females have yet been found

(click images to enlarge)

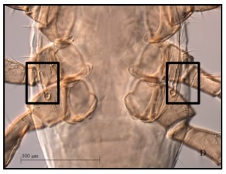
(A) Full body dorsal.

(B) Full body ventral.

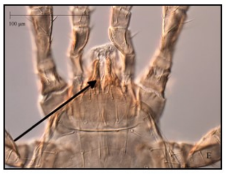
(C) Male sternitigenitial shield.



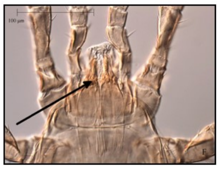
(D) Peritremes are extremely short, only extend to midline leg III.



(E) Triamous (three-tined) tectum (arrow).



(F) Male chelicera (arrow).



(G) Incision on dorsal shield extends to z6.

Related Taxa

Thus far in this project I have found 15 other species within this genus in Alberta. *Arctoseius* cf. *haarlovi* is in the *cetratus* group, which is characterized by short peritremes, a biramous tectum, and a rectangular sternal shield. *Arctoseius* cf. *haarlovi* has extremely short peritremes, similar to *Arctoseius haarlovi* Lindquist and Makarova 2011; however, given the diversity of *Arctoseius* (both in Alberta and globally) and that *Arctoseius haarlovi* Lindquist and Makarova was first described in a circumpolar region in Russia, a vastly different location than examined here, I am conservatively calling it *Arctoseius* cf. *haarlovi*

Literature Used for Identification

Lindquist and Makarova 2011

Makarova 2000

Arctoseius cf. *idiodactylus* Lindquist 1961

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

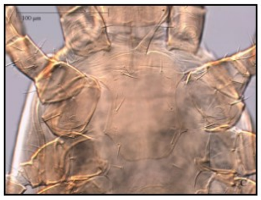
No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

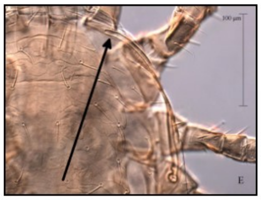
(B) Full body ventral.

(C) Sclerotized sternal shield with three pairs of setae.

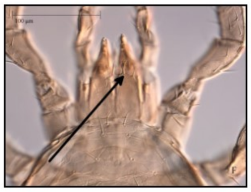


(D) Genital shield.

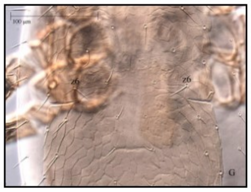
(E) Peritremes extend to midline/anterior of coxa I (arrow).



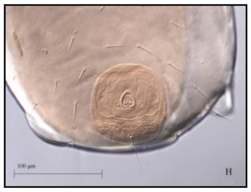
(F) Triamous (three-tined) tectum (arrow).



(G) Dorsal incisions extend to level of z6.



(H) Anal shield is longer than wide, and has straight lateral margins.



(I) Z5 setae are long.

Related Taxa

Thus far in this project I have found 15 other species within this genus in Alberta. *Arctoseius* cf. *idiodactylus* has flattened lateral margins on its anal shield, and is not round like *Arctoseius idiodactylus* Lindquist. Using drawings from Lindquist (1961) no other differences could be detected, as such, I am conservatively calling it *Arctoseius* cf. *idiodactylus*.

Literature Used for Identification

Lindquist 1961
Makarova 2000
Makarova and Huhta 2017

Arctoseius cf. *semiscissus* (Berlese, 1892)

Unless otherwise mentioned, all photos are of adult females

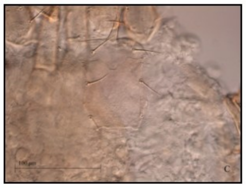
Morphological Characteristics

(click images to enlarge)

(A) Full body dorsal.

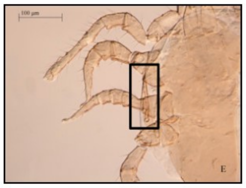
(B) Full body ventral.

(C) Sternal shield with two pairs of setae, with one addition pair of setae in the presternal area.



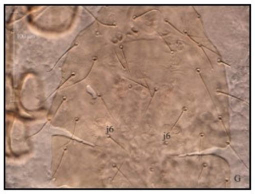
(D) Genital shield.

(E) Peritremes extend to midline of coxa II.

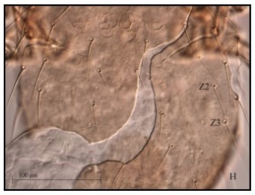


(F) Biramous (two-tined) tectum (arrow).

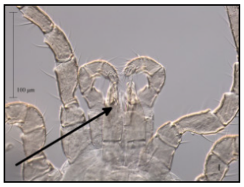
(G) Dorsal shield incisions reaching level of j6.



(H) All dorsal shield setae are long, Z2 reaches the base of Z3.



(I) Chelicera of male (arrow).



Related Taxa

Thus far in this project I have found 15 other species within this genus in Alberta. *Arctoseius* cf. *semiscissus* is in the *cetratus* group, which is characterized by short peritremes, a biramous tectum, and a rectangular sternal shield. Using multiple keys (Makarova 2000, Makarova and Huhta 2017 and Mašán 2014) these individuals were keyed to *A. semiscissus* (Berlese); however, with st1 not on the sternal shield, and with no drawings for comparison, it is conservatively called *Arctoseius* cf. *semiscissus*.

Literature Used for Identification

Makarova 2000

Makarova and Huhta 2017

Mašán 2014

Arctoseius multidentatus Evans, 1955

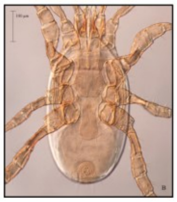
Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

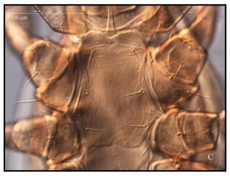
(click images to enlarge)

(A) Full body dorsal.

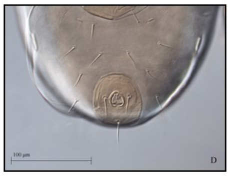
(B) Full body ventral.



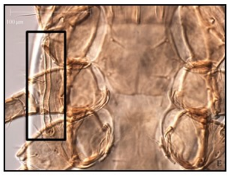
(C) Sternal shield with three pairs of setae present.



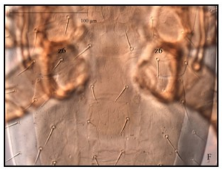
(D) Anal shield, all circumanal setae are subequal.



(E) Peritreme extends to posterior edge of leg II.



(F) Dorsal slits extend to z6.



(G) Dorsal setae do not reach next setal base.

(H) Tarsus II-IV setae are acicular (III-IV pictured here).

(I) Triramous (three-tined) tectum.

(J) Male chelicerae.

Related taxa

Thus far in this project I have found 15 other species within this genus in Alberta. *Arctoseius multidentatus* is in the *multidentatus* group as a result of having short peritremes, a narrow dorsal shield and circumanal setae being subequal. Tarsus II-IV setae are acicular, which differentiates it from *Arctoseius koltchaki* Makarova and Lindquist 2013 (so far not found in Alberta).

Literature used for identification

Evans 1955

Makarova 2000

Makarova and Lindquist 2013

Arctoseius nr. *minor* sp. 1
Lindquist 1961

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

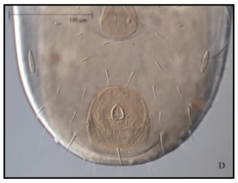
(click images to enlarge)

(A) Full body dorsal.

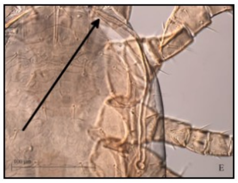
(B) Full body ventral.

(C) Sternal shield with three pairs of setae.

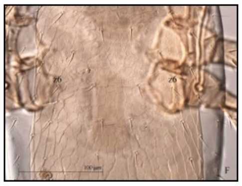
(D) Anal shield has straight edges.



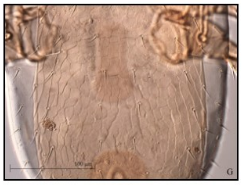
(E) Peritreme ends at anterior leg I (arrow).



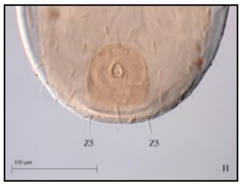
(F) Dorsal slits extend to z6.



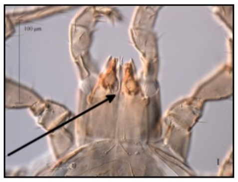
(G) Dorsal setae are short.



(H) Z5 setae are short.



(I) Triramous (three-tined) tectum (arrow).



(J) Male chelicerae.

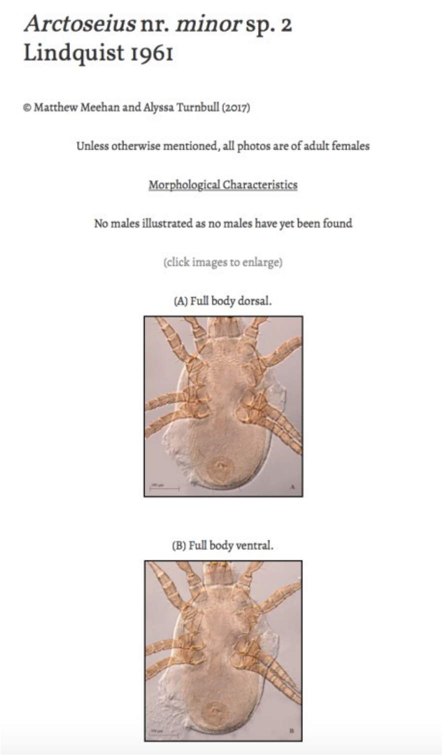
Related taxa

Thus far in this project I have found 15 other species within this genus in Alberta. Using the key provided in Makarova (2000), this species keys to *Arctoseius minor* Lindquist as all dorsal setae (including Z5) are short, and it has long peritremes. As this species has faint reticulation over the entire dorsal shield, and straight edges on anal shield (not round), it was not considered *Arctoseius minor*.

Literature Used for Identification

Lindquist 1961

Makarova 2000



Arctoseius nr. *minor* sp. 2 Lindquist 1961

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

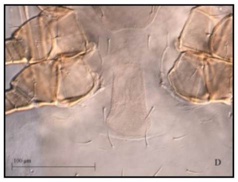
(click images to enlarge)

(A) Full body dorsal.

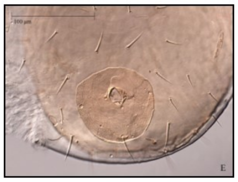
(B) Full body ventral.

(C) Sternal shield with three pairs of setae.

(D) Genital shield, note the granulation.



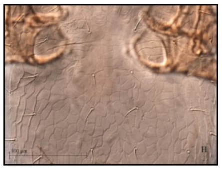
(E) Anal shield, note the pores on the outer edges.



(F) Peritreme ends anterior leg I (arrow).

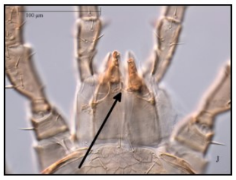
(G) Dorsal slit ends near z6.

(H) Dorsal setae are short, including Z5.



(I) Z5 are short.

(J) Triramous (three-tined) tectum (arrow).



Related taxa

Thus far in this project I have found 15 other species within this genus in Alberta. Using the key provided in Makarova (2000), this species keys to *Arctoseius minor* Lindquist or *Arctoseius babenkoi* Makarova. *Arctoseius* nr. *minor* 2 has granulation on the genital shield, extremely faint reticulation on the entire sternal shield, and two large pores on the anal shield. This combination of characters makes this species unique.

Literature used for identification

Lindquist 1961

Makarova 2000

Arctoseius nr. *minutus* sp. 1 (Halbert, 1955)

Unless otherwise mentioned, all photos are of adult females

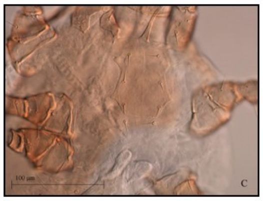
Morphological Characteristics

(click images to enlarge)

(A) Full body dorsal.

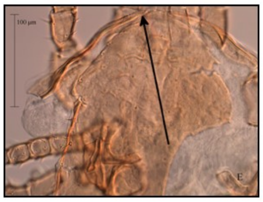
(B) Full body ventral.

(C) Sclerotized sternal shield with three pairs of setae.

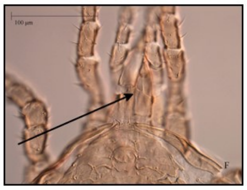


(D) Genital shield.

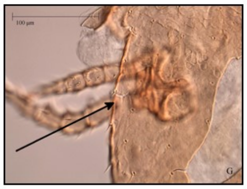
(E) Peritremes extend to top of dorsum (arrow).



(F) Triamous (three-tined) tectum (arrow).

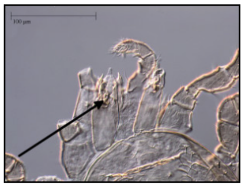


(G) Dorsal slit faint and jagged (not straight), may not be present in some individuals (arrow).



(H) Dorsal setae are needle-like.

(I) Chelicera of male (arrow).



Related Taxa

Thus far in this project I have found 15 other species within this genus in Alberta. Using the key provided in Makarova and Huhta (2017), this species keys to *A. minutus* (Halbert). *Arctoseius* nr. *minutus* sp. 1 has jagged dorsal incisions, scale like ornamentation on the upper dorsal shield, the lower dorsal shield is smooth, and all dorsal setae are needlelike. *Arctoseius* nr. *minutus* sp. 2 (Halbert) has different dorsal ornamentation than *Arctoseius* nr. *minutus* sp. 1, which differentiates the species. This species is not considered to be *A. minutus* due to the absence of lateral angular extensions on the sternal shield.

Literature Used for Identification

Makarova 2000
Makarova and Huhta 2017

Arctoseius nr. *minutus* sp. 2 (Halbert, 1955)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

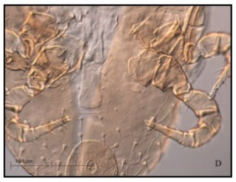
(click images to enlarge)

(A) Full body dorsal.

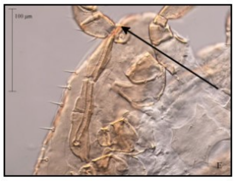
(B) Full body ventral.

(C) Sclerotized sternal shield with three pairs of setae.

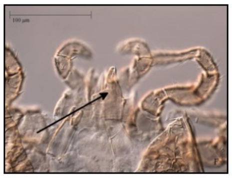
(D) Genital shield.



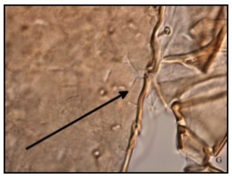
(E) Peritremes extend to top of dorsum (arrow).



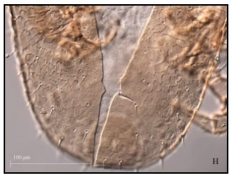
(F) Triamous (three-tined) tectum (arrow).



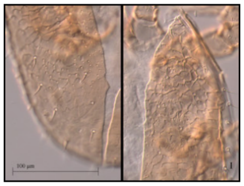
(G) Dorsal slit faint and jagged (not straight), may not be present in some individuals (arrow).



(H) Dorsal setae are needle-like.



(I) Upper dorsal shield with scale like ornamentation, while lower dorsal shield is punctate.



Related Taxa

Thus far in this project I have found 15 other species within this genus in Alberta. Using the key provided in Makarova and Huhta (2017), this species keys to *A. minutus* (Halbert). *Arctoseius* nr. *minutus* sp. 2 has jagged dorsal incisions, scale like ornamentation on the upper dorsal shield, lower dorsal shield is punctate, and all dorsal setae are needlelike. *Arctoseius* nr. *minutus* sp. 2 has different dorsal ornamentation than *Arctoseius* nr. *minutus* sp. 1 (Halbert), which differentiates the species. This species is not considered to be *A. minutus* due to the absence of lateral angular extensions on the sternal shield.

Literature Used for Identification

Makarova 2000

Makarova and Huhta 2017

Arctoseius nr. *weberi* Evans 1955

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

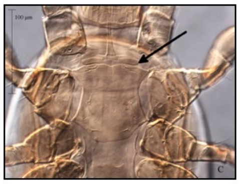
No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

(B) Full body ventral.

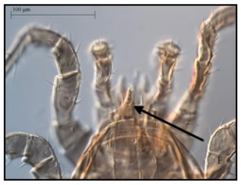
(C) Sclerotized sternal shield with three pairs of setae, with sclerotized presternal shields (arrow).



(D) Genital shield.

(E) Peritremes extend to midline of coxa I (arrows).

(F) Triramous (three-tined) tectum (arrow).



Related Taxa

Thus far in this project I have found 15 other species within this genus in Alberta. The sclerotized presternal shields separate *Arctoseius* nr. *weberi* from all other species/morphospecies. *Arctoseius* nr. *weberi* differs from *A. weberi* Evans due to little reticulation on the sternal shield, and shape of the genital and anal shield.

Literature Used for Identification

Lindquist 1961

Makarova 2000

Makarova and Huhta 2017

Arctoseius ornatus grp. sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

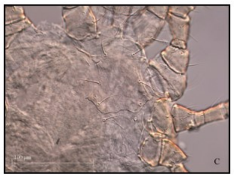
No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

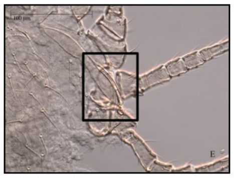
(B) Full body ventral.

(C) Sternal shield with three pairs of setae.



(D) Anal shield.

(E) Peritreme extends to posterior/midline leg II.



(F) No dorsal slit.

(G) Dorsal setae are long, reach (and at times go past) next setal base.

(H) Tectum (two-tined pictured here).

Related taxa

Thus far in this project I have found 15 other species within this genus in Alberta. This morphospecies is interesting as it fits multiple species groups in *Arctoseius*. Using the key provided in Makarova (2000), it fits into the *cetratus/multidentatus* group, as it has short peritremes. In addition,it has a biramous (two tined) tectum, and only 6 setae were observed on tibia IV, placing it again in the *cetratus* group. However, as it contains such characters, including: non-rectangular sternal shield, no dorsal slits, wide dorsal shield, and long setae, I believe it is best placed in the *ornatus* group (Makarova 2000). Further analysis of this mite may lead to a different identification of it, but for now, I have it placed in this group.

Literature used for identification

Makarova 2000

Arctoseius ornatus grp. sp. 2

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

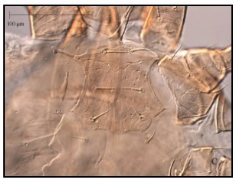
No males illustrated as no males have yet been found

(click images to enlarge)

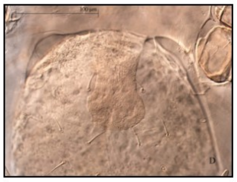
(A) Full body dorsal.

(B) Full body ventral.

(C) Sternal shield with three pairs of setae.

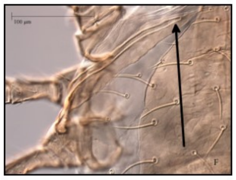


(D) Genital shield, extremely convex.

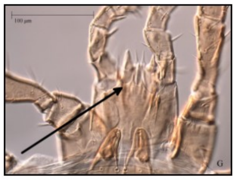


(E) Anal shield.

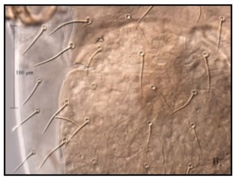
(F) Peritremes extend to posterior of leg I (arrow).



(G) Triramous (three-tined) tectum (arrow).



(H) Dorsal shield incisions reaching level of z6.



Related Taxa

Thus far in this project I have found 15 other species within this genus in Alberta. Using the key provided in Makarova, this species keys to *ornatus* group by having long Z5, J3 and J4 setae.

Literature Used for Identification

Evans 1955

Makarova 2000

Asca aphidioides (Linneaus, 1758)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

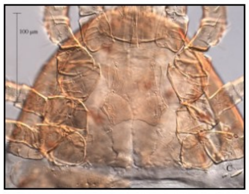
No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

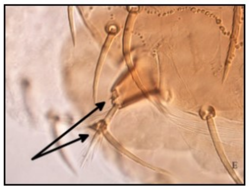
(B) Full body ventral.

(C) Sternal shield with three setae, one additional pair located on soft cuticle.



(D) Ventrianal shield.

(E) Posterolateral tubercules bearing two setae (one is prominent while the other is minute, arrows).



(F) Lower dorsal shield, note the polygonal network of minute protuberances on shield.

Related Taxa

Thus far in this project I have found two other species within this genus in Alberta, *Asca garmani* Hurlbutt and *Asca nova* Willman. *Asca aphidioides* is most similar looking to *Asca garmani*; however, it differs by having minute protuberances on the dorsal shield. Hurlbutt (1963) states that there could be a second seta on the posterolateral tubercles; however, they are so small that even under oil immersion they are not always able to be visualized.

Literature Used for Identification

Hurlbutt 1963

Asca garmani Hurlbutt, 1963

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

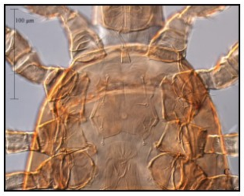
No males illustrated as no males have yet been found

(click images to enlarge)

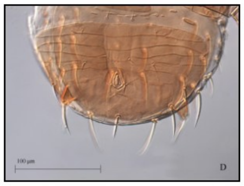
(A) Full body dorsal.

(B) Full body ventral.

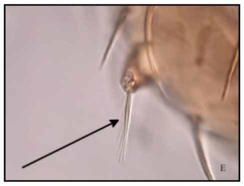
(C) Sternal shield with three pairs of setae, one additional pair located on soft cuticle.



(D) Ventrianal shield.



(E) Posterolateral tubercules bearing one seta.



(F) Lower dorsal shield, note the polygonal network of minute protuberances on shield.

Related Taxa

Thus far in this project I have found two other species within this genus in Alberta, *Asca garmani* Hurlbutt and *Asca nova* Willman. *Asca aphidioides* is most similar looking to *Asca garmani*; however, it differs by having minute protuberances on the dorsal shield. Hurlbutt (1963) states that there could be a second seta on the posterolateral tubercles; however, they are so small that even under oil immersion they are not always able to be visualized.

Literature Used for Identification

Hurlbutt 1963

Asca nova Willman, 1939

Unless otherwise mentioned, all photos are of adult females

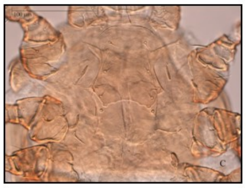
Morphological Characteristics

(click images to enlarge)

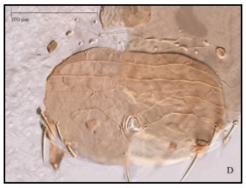
(A) Full body dorsal.

(B) Full body ventral.

(C) Sternal shield with three pairs of setae, one additional pair located on soft cuticle.



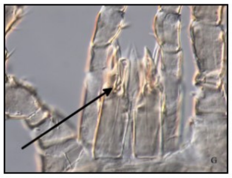
(D) Ventrianal shield.



(E) Posterolateral tubercules bearing two setae (both setae are prominent, arrow).

(F) Lower dorsal shield.

(G) Chelicera of male (arrow).



Related Taxa
Thus far in this project I have found two other species within this genus in Alberta, *Asca garmani* Hurlbutt and *Asca aphidioides* (Linneaus). *Asca nova* has two prominent setae on each posterolateral tubercule, not one. This differentiates it from *Asca garmani* and *Asca aphidioides*.

Literature Used for Identification
Hurlbutt 1963

Gamasellodes sp. 1

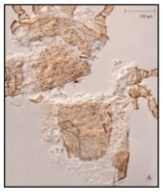
Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

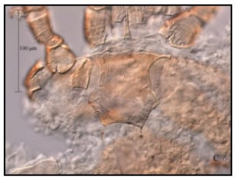
(click images to enlarge)

(A) Full body dorsal.



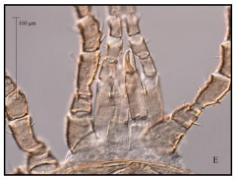
(B) Full body ventral.

(C) Sternal shield with two pairs of setae.

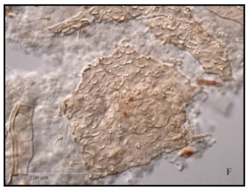


(D) Peritremes extend to j1 (arrow).

(E) Chelicera.



(F) Upper and lower dorsal shield have bumpy ornamentation with spike-like setae.



Related Taxa

Thus far in this project I have found one other species within this genus in Alberta. st1 being off the sternal shield in *Gamasellodes* sp. 1 is unlike the diagnosis for the genus provided by Walter (2003). As such, this identification may change in the future.

Literature Used for Identification

Karg 1993

Walter 2003

Gamasellodes sp. 2

Unless otherwise mentioned, all photos are of adult females

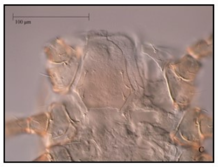
Morphological Characteristics

(click images to enlarge)

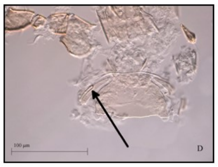
(A) Full body dorsal.

(B) Full body ventral.

(C) Sternal shield with three pairs of setae.



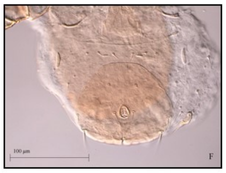
(D) Peritremes extend to j1 (arrow).



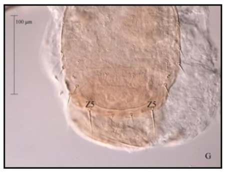
(E) Chelicera.

(E) Chelicera.

(F) Ventrianal shield.



(G) Long Z5 setae.



Related taxa

Thus far in this project I have found one other species within this genus in Alberta. This mite is peculiar as it has drastic setae reductions on genu and tibia IV having only 7 and 6 instead of 10 and 9, suggesting possible placement in Digamasellidae; however, these reductions are not seen on other legs. As st4 is off the sternal shield, it was placed in Ascidae. It is definitely a rhodacarid-looking mite, but I did not consider it *Protogamasellus* due to the absence of a transverse line across the dorsal shield. Further analysis needs to be done to accurately identify this mite, for now, it is placed in *Gamasellodes*.

Literature cited

Lindquist and Evans 1965

Zerconopsis nr. *michaeli* Evans and Hyatt, 1960

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

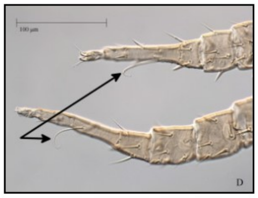
(click images to enlarge)

(A) Full body dorsal.

(B) Full body ventral.

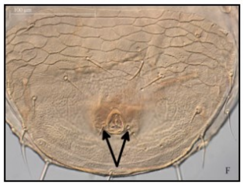
(C) Genital shield with one pair of setae adjacent to shield, not on it.

(D) Tarsus II-IV each with two elongated dorso-proximal setae (arrows, one seta on each tarsus pictured here).



(E1, E2 and E3) Dorsum with three pairs of setae that are spatulate: s4, Z3, and Z5.

(F) Ventrianal shield with 6 pairs of setae (not including paranal pair, arrows).



(G) Chelicera of female *Zerconopsis* nr. *michaeli*.

(H) Chelicera of male *Zerconopsis* nr. *michaeli* (arrow).

Related Taxa

Thus far in this project I have found one other species within this genus in Alberta, *Zerconopsis* sp. 2. Using the key provided by Karg (1993), this species keys out to *Z. michaeli* Evans and Hyatt. *Zerconopsis* nr. *michaeli* is larger on average than *Z. michaeli*, also *Z.* nr. *michaeli* has 6 pairs of setae on ventrianal shield, *Z. michaeli* only has 5. Lastly, *Zerconopsis* nr. *michaeli* has a smooth dorsal shield, while *Zerconopsis* sp. 2 has thick ridge-like structures on dorsal shield.

Literature Used for Identification

Karg 1993

Zerconopsis sp. 2

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

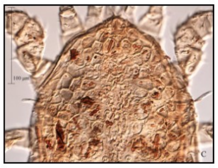
No males illustrated as no males have yet been found

(click images to enlarge)

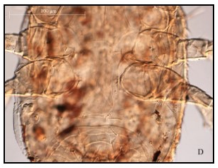
(A) Full body dorsal.

(B) Full body ventral.

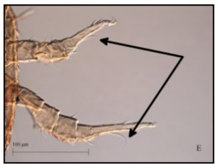
(C) Dorsal shield is not smooth, has thick ridge-like ornamentation.



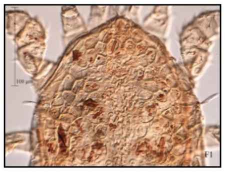
(D) Genital shield with one pair of setae adjacent to shield, not on it.

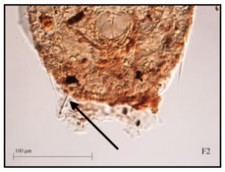


(E) Tarsus II-IV each with two elongated dorso-proximal setae (arrows, one seta on each tarsus pictured here).

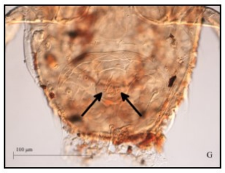


(F1 and F2) Dorsum with two pairs of setae that are spatulate: s4 and Z5 (arrow). Dorsum was covered with debris, hard to tell if any other setae were spatulate.

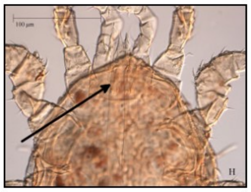




(G) Ventrianal shield with 3 pairs of setae (not including paranal pair, arrows).



(H) Chelicera of female *Zerconopsis* sp. 2 (arrow).



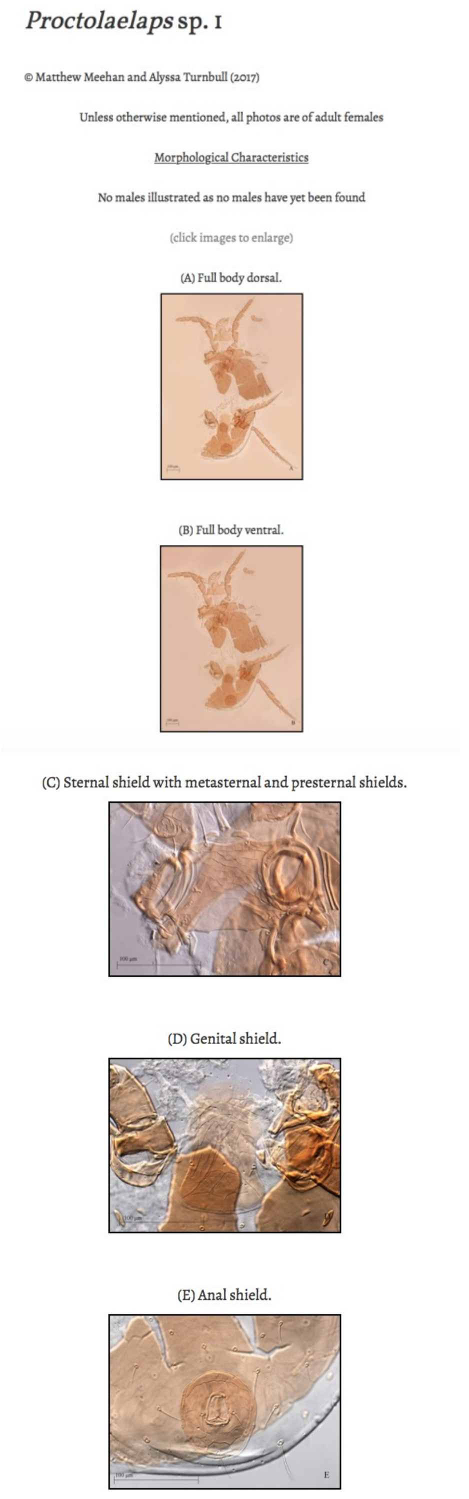
Related Taxa

Thus far in this project I have found one other species within this genus in Alberta, *Zerconopsis* nr. *michaeli* Evans and Hyatt. *Zerconopsis* sp. 2 differs from *Zerconopsis* nr. *michaeli* as it has fewer pairs of setae present on ventrianal shield. *Zerconopsis* sp. 2 has thick ridge-like structures on dorsal shield, while *Zerconopsis* nr. *michaeli* has a smooth dorsal shield.

Literature Used for Identification

Karg 1993

2.4.5.1.2.3 Melicharidae



Proctolaelaps sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

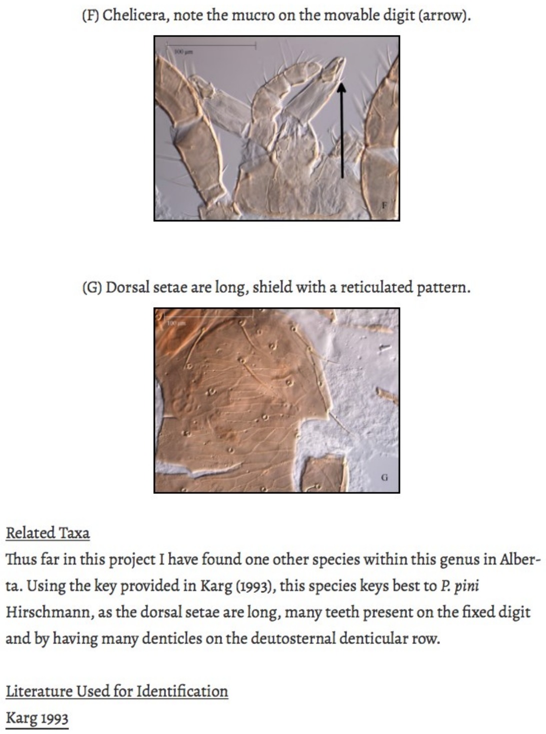
(A) Full body dorsal.

(B) Full body ventral.

(C) Sternal shield with metasternal and presternal shields.

(D) Genital shield.

(E) Anal shield.



(F) Chelicera, note the mucro on the movable digit (arrow).

(G) Dorsal setae are long, shield with a reticulated pattern.

Related Taxa

Thus far in this project I have found one other species within this genus in Alberta. Using the key provided in Karg (1993), this species keys best to *P. pini* Hirschmann, as the dorsal setae are long, many teeth present on the fixed digit and by having many denticles on the deutosternal denticular row.

Literature Used for Identification

Karg 1993

Proctolaelaps sp. 2

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

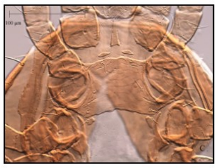
No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

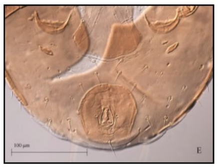
(B) Full body ventral.

(C) Sternal shield, with metasternal and presternal shields.

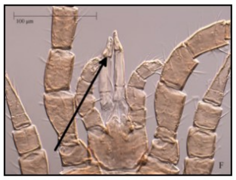


(D) Genital shield.

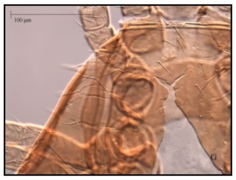
(E) Anal shield.



(F) Chelicera, without a mucro on the movable digit (arrow).



(G) Dorsal setae are not as long as *Proctolaelaps* sp. 1, shield without a reticulation pattern.



Related Taxa
One other species has been found in this genus thus far in Alberta. Using the key provided in Karg (1993), this species keys to *P. jüradeus* (Schweizer), due to having short dorsal shield setae, and for the anal opening being less than 1/4 the size of the anal shield.

Literature Used for Identification
Karg 1993

2.4.5.1.3 Dermanyssoidea

2.4.5.1.3.1 Laelapidae

Cosmolaelaps sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

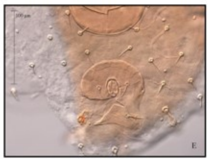
(A) Full body dorsal.

(B) Full body ventral.

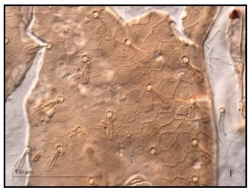
(C) Sternal shield, note the obvious poroids on the shield (arrows).

(D) Genital shield.

(E) Anal shield is subtriangular.



(F) Setae on dorsal shield are paddle shaped.



(G) Corniculi are normal in length (arrows).

Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. Using the key provided in Karg (1993) this species keys to the *claviger*-group, as dorsal setae are paddle shaped.

Literature Used for Identification

Karg 1993

Ramroodi et al. 2014

Gaeolaelaps sp. 1

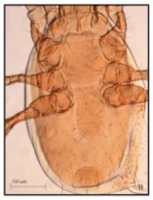
Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

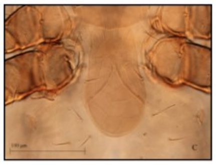
(click images to enlarge)

(A) Full body dorsal.

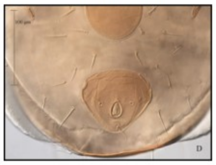
(B) Full body ventral.



(C) Genital shield.

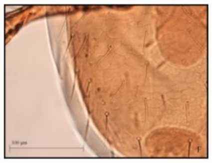


(D) Anal shield is subtriangular (guitar pick shape).

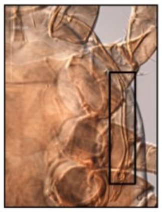


(E) Reticulation on posterior portion of dorsal shield, fades away in the anterior portion.

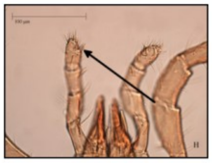
(F) Dorsal setae are long, tips of setae close to or reaching next setal base.



(G) Peritremes extend to mid-level of leg II.

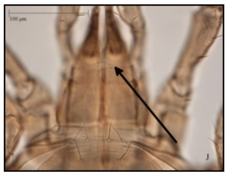


(H) Palp tarsus claw is two-tined (arrow).



(I) Chelicera of female *Gaeolaelaps* sp. 1 (arrow).

(J) Tectum (arrow).



(K) Chelicerae of male *Gaeolaelaps* sp. 1.

Related Taxa

Thus far in this project I have found three other species within this genus in Alberta. *Gaeolaelaps* sp. 1 has longer dorsal setae than the other species found thus far. Using the key provided by Vatankhah et al. (2016), this species keys out to *G. similisetae* (Karg) as it has 39 pairs of setae, two tined palp tarsal claw, a slightly convex genital shield and Z5 as the longest dorsal seta.

Literature Used for Identification

Karg 1993

Vatankhah et al. 2016

Gaeolaelaps sp. 2

Unless otherwise mentioned, all photos are of adult females

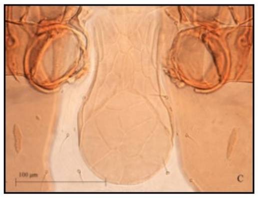
Morphological Characteristics

(click images to enlarge)

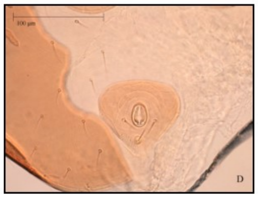
(A) Full body dorsal.

(B) Full body ventral.

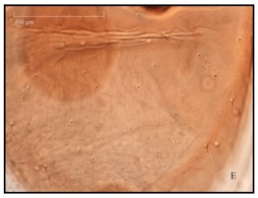
(C) Genital shield.



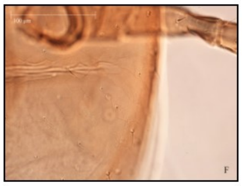
(D) Anal shield is subtriangular (guitar pick shape).



(E) Light reticulation on dorsal shield.

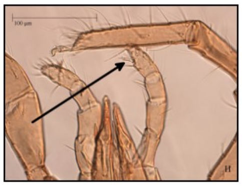


(F) Dorsal setae are short, tips do not reach next setal base.

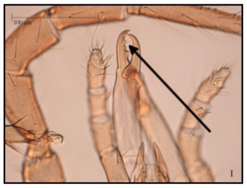


(G) Peritremes extend to coxa I.

(H) Palp tarsus claw is two-tined (arrow).



(I) Female chelicera of *Gaeolaelaps* sp. 2, note the presence of pilus dentilis (arrow).



(J) Tectum (arrow).

(K) Male chelicera.

Related Taxa

Thus far in this project I have found three other species within this genus in Alberta. *Gaeolaelaps* sp. 2 is distinguishable in having the longest peritremes and the shortest dorsal setae. Using the key provided by Karg 1993, this species keys out to *G. praesternalis* (Willmann); however, this species may belong to the genus *Androlaelaps* due to having a pilus dentilis and a smooth tectum. I placed in *Gaeolaelaps* as some species have a pilus dentilis and genu IV having 9 setae total.

Literature Used for Identification

Karg 1993

Gaeolaelaps sp. 3

Unless otherwise mentioned, all photos are of adult females

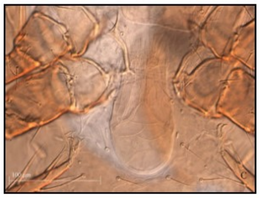
Morphological Characteristics

(click images to enlarge)

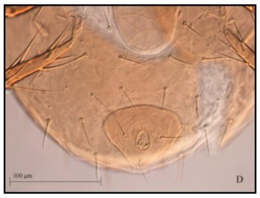
(A) Full body dorsal.

(B) Full body ventral.

(C) Genital shield.

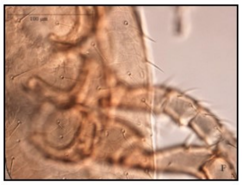


(D) Anal shield is subtriangular (guitar pick shape).



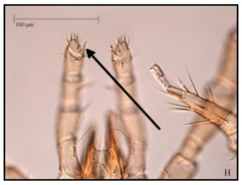
(E) Reticulation on dorsal shield.

(F) Dorsal setae are short, do not reach next setal base.

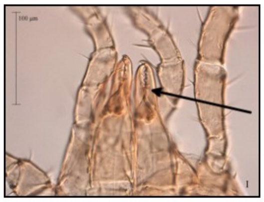


(G) Peritremes extend to midline/anterior of leg II.

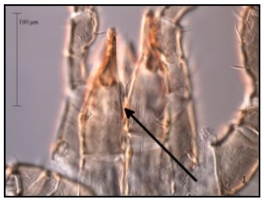
(H) Palp tarsus claw is two-tined (arrow).



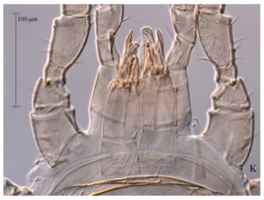
(I) Chelicera of female (arrow).



(J) Tectum (arrow).



(K) Chelicera of male.



Related Taxa

Thus far in this project I have found three other species within this genus in Alberta. *Gaeolaelaps* sp. 3 peritremes extend to anterior of leg II, making them among the longest peritremes in short peritreme group of *Gaeolaelaps*. Only two species within this short peritreme group, globally, have been noted to have peritremes of this size: *G. macra* (Karg) and *G. oribuculatus* Nemati & Mohseni (Vatankhah et al. 2016).

Literature Used for Identification

Karg 1993
Vatankhah et al. 2016

Gaeolaelaps sp. 4

Morphological Characteristics

No males illustrated as no males have yet been found

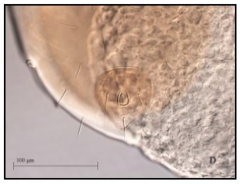
(click images to enlarge)

(A) Full body dorsal.

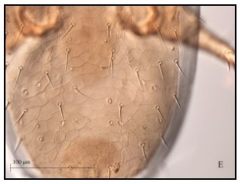
(B) Full body ventral.

(C) Genital shield.

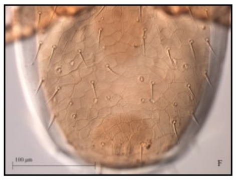
(D) Anal shield is subtriangular (guitar pick shape).



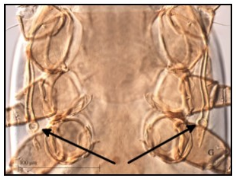
(E) Reticulation on dorsal shield.



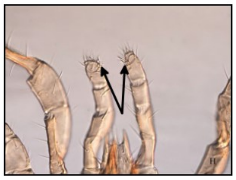
(F) Dorsal setae are short, do not reach next setal base.



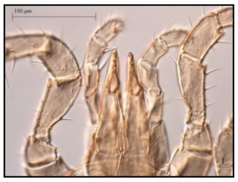
(G) Peritremes extend to posterior of leg II.



(H) Palp tarsus claw is two-tined.



(I) Chelicera of female.



(J) Tectum (arrow).

Related Taxa

Thus far in this project I have found three other species within this genus in Alberta. *Gaeolaelaps* sp. 4 looks similar to *Gaeolaelaps* sp. 3; however, this morphospecies has shorter peritremes. Using the key provided in Vatankhah et al. (2016) this species keys to *G. latopuga* (Karg), as it has an extra pair of setae in between z2 and z4.

Literature Used for Identification

Karg 1993

Vatankhah et al. 2016

Hypoaspis s.l. sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

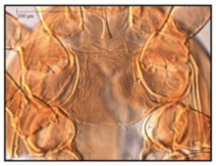
No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

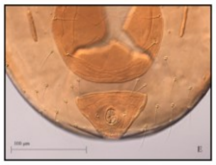
(B) Full body ventral.

(C) Sternal shield with three pairs of long setae.

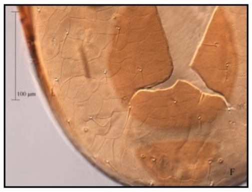


(D) Genitiventral shield, lateral edges expanded to near midline leg IV. Pairs of setae on shield are near lateral edge.

(E) Triangular anal shield.



(F) Dorsal shield with reticulation, setae are simple.



Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. Due to the difficulty of placing this mite into a genus, it has been placed into *Hypoaspis* s.l.. *Hypoaspis* s.l. is a broad taxon that encompasses many subgenera and genera (depending on the source, some subgenera are elevated to genera), including *Alloparasitus*, *Gaeolaelaps* and *Cosmolaelaps* (Karg, 1993).

Literature Used for Identification

Karg 1993

Laelaspis sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

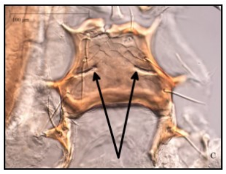
No males illustrated as no males have yet been found

(click images to enlarge)

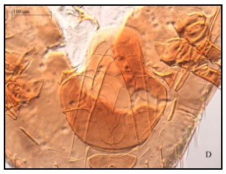
(A) Full body dorsal.

(B) Full body ventral.

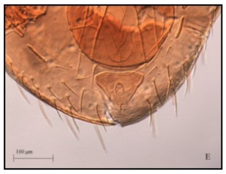
(C) Sternal shield with three pairs of long setae, one additional pair is on endopodal elements, attached to sternal shield. Third poroid on sternal shield expanded (arrows).



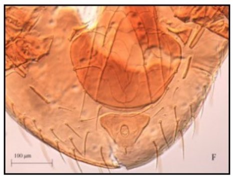
(D) Genitiventral shield, lateral margins extending to the outer margins of leg IV.



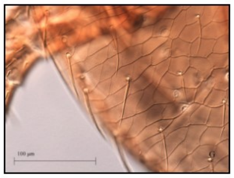
(E) Triangular anal shield.



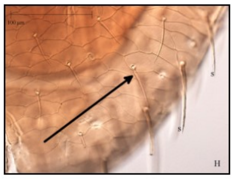
(F) Soft cuticle by anal shield is hypertrichous.



(G) Dorsal shield with reticulation.



(H) Dorsal setae long, some are serrated (s), while other are needle-shaped and have a knob like process (arrow).



Related Taxa

Thus far in this project I have found no others species within this genus in Alberta. Using the key provided in Joharchi et al. (2012) this species keys best to *L.volgini* Shereef and Afifi due to having long dorsal setae, Z5 being 2 to 3 times larger than J5, having a rounded genitiventral shield, and having the shields width extend almost to the coxae of legs IV.

Literature Used for Identification

Joharchi et al. 2012

Ololaelaps veneta (Berlese, 1904)

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

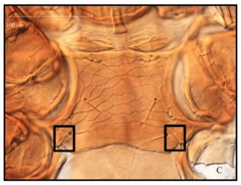
No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

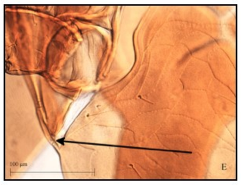
(B) Full body ventral.

(C) Sternal shield with four pairs of setae, fourth pair are on the lower corners of the shield near the endopodal shield.



(D) Hologastric (genitiventrianal) shield covering the genital, ventral and anal area. Six pairs of setae (not including paranal setae, box) on hologastric shield.

(E) Peritremal and hologastric shield are fused together (arrow).



Related Taxa

Thus far in this project I have found no others species within this genus in Alberta.

Literature Used for Identification

Evans and Till 1966

Karg 1993

2.4.5.1.4 Eviphioidea

2.4.5.1.4.1 Pachylaelapidae

Pachylaelaps sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

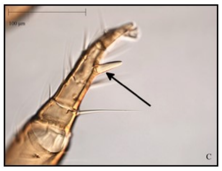
No males illustrated as no males have yet been found

(click images to enlarge)

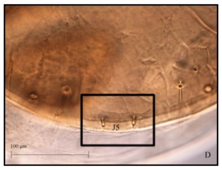
(A) Full body dorsal.

(B) Full body ventral.

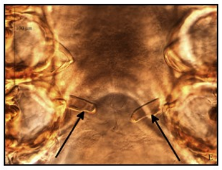
(C) Two stout, spur-like setae on tarsus II (arrow, one shown here).



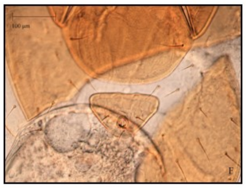
(D) Minute J5 setae on dorsal shield.



(E) Sperm induction systems are short, stout and extremely sclerotized (arrows).



(F) Anal shield is widely separated from genitiventral shield.



Related Taxa

Thus far in this project I have found no others species within this genus in Alberta. This species keys out to *P. insularis* (Berlese 1920), using the dichotomous key provided in Mašán et al. (2016). However, *Pachylaelaps* sp. 1, has fewer setae on lateromarginal and ventral soft integument than *P. insularis*.

Literature Used for Identification

Karg 1993

Mašán and Halliday 2013

Mašán et al. 2016

Zygoseius furciger Berlese, 1916

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

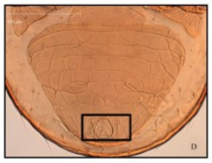
(click images to enlarge)

(A) Full body dorsal.

(B) Full body ventral.

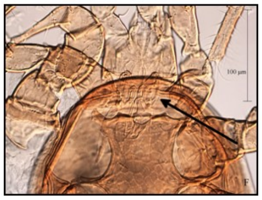
(C) Sternal shield with three pairs of setae, and one pair on metasternal-endopodal shield.

(D) Ventrianal shield with five pairs of setae (not including paranal setae, box).



(E) Tectum (arrow).

(F) Chelicera of male *Zygoseius furciger* (arrow).



Related Taxa
Thus far in this project I have found no others species within this genus in Alberta.

Literature Used for Identification
Halliday 1997

2.4.5.1.5 Parasitoidea

2.4.5.1.5.1 Parasitidae

Paragamasus sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

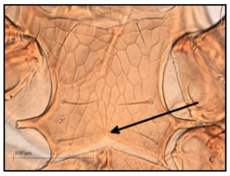
Morphological Characteristics

(click images to enlarge)

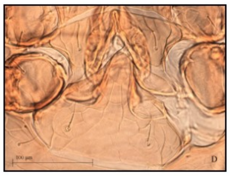
(A) Full body dorsal.

(B) Full body ventral.

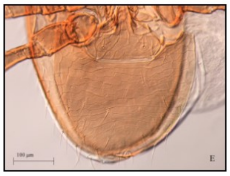
(C) Sternal shield, note that there is a small incision at the base of the sternal shield (arrow).



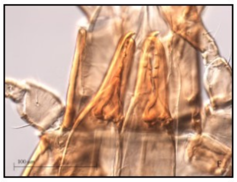
(D) Metasternal shields and genital shield.



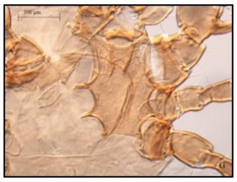
(E) Ventrianal shield.



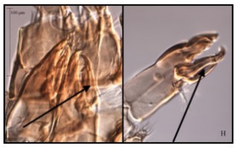
(F) Female chelicerae.



(G) Male sternal shield.



(H) Male chelicera (left) from this collection, note the spermatotreme (arrows), only present in male Parasitidae. Chelicera of male *Paragamasus* from HP collection from Cypress Hills, SK. Spermatotreme less prominent from this collection.



(I) Large spurs on male leg II (arrow).

Related Taxa

Thus far in this project I have found no others species within this genus in Alberta. This species was identified to be *P. alpestris* (Berlese), using the dichotomous key provided in Karg (1993), due to its large idiosoma, its small incision on the sternal shield and by having long r5 setae. However, as Karg (1993) includes only central European species, it is unlikely that it is *P. alpestris*.

Literature Used for Identification

Karg 1993

Vulgarogamasus sp. 1

Morphological Characteristics

No females illustrated as no females have yet been found

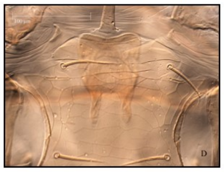
(click images to enlarge)

(A) Full body dorsal (male).

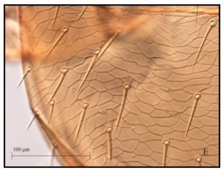
(B) Full body ventral (male).

(C) Male holoventral shield.

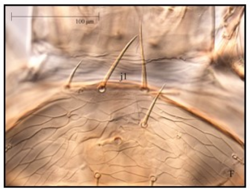
(D) Male genital opening.



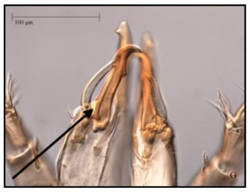
(E) Dorsal shield with long setae and a reticulation pattern (male).



(F) j1 slightly serrated (male).



(G) Chelicera of male, note the spermatotreme (arrow).



Related Taxa

Thus far in this project I have found no others species within this genus in Alberta. Identification to genus was performed by Dr. Hans Klompen from The Ohio State University.

Literature Used for Identification

No primary literature was consulted.

2.4.5.1.6 Phytoseioidea

2.4.5.1.6.1 Blattisociidae

Cheiroseius (*Cheiroseius*) sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

(B) Full body ventral.

(C) Sternal shield with three pairs of setae, and one pair of setae on metasternal shields.

(D) Ventrianal shield with 5 pairs of setae (including paranal pair).

(E) Post-stigmatic extension of peritreme, is extremely short (arrow).

(F) Tarsus of leg I is elongate, leg I is similar in length with idiosoma.

(G) Dorsal shield has wavy, scale like pattern.

Related Taxa

Thus far in this project I have found six other species within this genus in Alberta. As defined in Karg (1993), this species is in the subgenus *Cheiroseius*, based on it having a short post-stigmatic extension. Three other species were found within this subgenus. Using Karg (1993), this species keys to *Cheiroseius borealis* (Berlese). *Cheiroseius* (*Cheiroseius*) sp. 1 main morphological difference from the other three species identified to this subgenus, is having 5 pairs of setae on ventrianal shield, and not 4.

Literature Used for Identification

Karg 1993

Lindquist and Moraza 2010

Cheiroseius (*Cheiroseius*) sp. 2

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

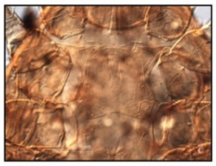
No males illustrated as no males have yet been found

(click images to enlarge)

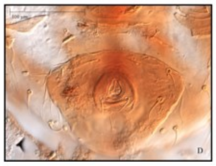
(A) Full body dorsal.

(B) Full body ventral.

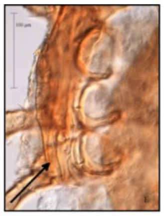
(C) Sternal shield with three pairs of setae, and one pair of setae on metasternal shields.



(D) Ventrianal shield with 4 pairs of setae (including paranal pair).

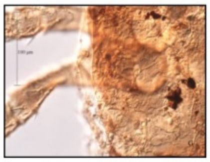


(E) Post-stigmatic extension of peritrme extends to posterior leg IV (arrow).



(F) Tarsus of leg I is elongate, leg I is similar in length with idiosoma.

(G) Dorsal shield has a faint scale-like pattern.



Related Taxa

Thus far in this project I have found six other species within this genus in Alberta. As defined in Karg (1993), this species is in the subgenus Cheiroseius, based on it having a short post-stigmatic extension. Three other species were found within this subgenus. Using Karg (1993), this species keys to *Cheiroseius bryophilus* Karg. This species looks most similar to *Cheiroseius* (*Cheiroseius*) sp. 4; however, *Cheiroseius* (*Cheiroseius*) sp. 2 has longer post-stigmatic extensions than *Cheiroseius* (*Cheiroseius*) sp. 4.

Literature Used for Identification

Karg 1993
Lindquist and Moraza 2010

Cheiroseius (*Cheiroseius*) sp. 3

Unless otherwise mentioned, all photos are of adult females

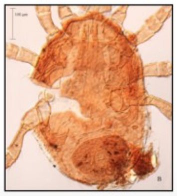
Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

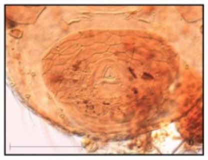
(A) Full body dorsal.

(B) Full body ventral.



(C) Sternal shield with three pairs of setae, and one pair of setae on metasternal shields.

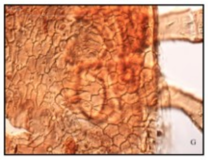
(D) Ventrianal shield with 4 pairs of setae (including paranal pair).



(E) Post-stigmatic extension extension of peritreme extends to posterior margin of leg IV (arrow).

(F) Tarsus of leg I is elongate, leg I is similar in length to idiosoma.

(G) Dorsal shield has scaly, net-like pattern.



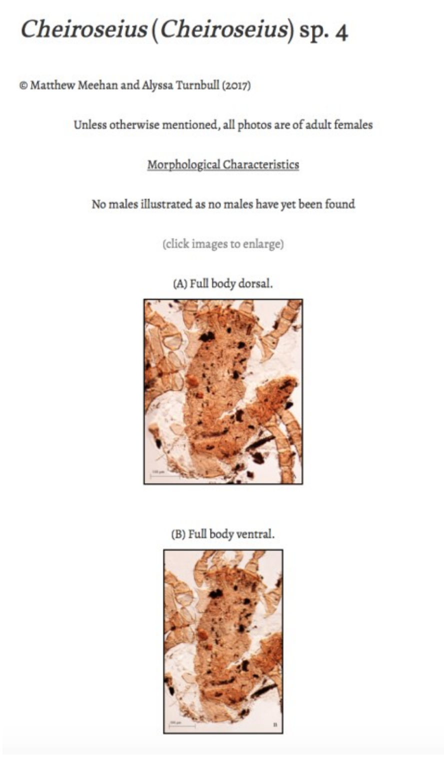
Related Taxa

Thus far in this project I have found six other species within this genus in Alberta. As defined in Karg (1993), this species is in the subgenus Cheiroseius, based on its having a short post-stigmatic extension. Three other species were found within this subgenus. Using Karg (1993), this species keys to *Cheiroseius dungeri* Karg; however, it shares similar traits with *C. bryophilus* Karg as well. *Cheiroseius* (*Cheiroseius*) sp. 3 has a scaly, net-like pattern on its dorsal shield, differentiating itself from *Cheiroseius* (*Cheiroseius*) sp. 2 and *Cheiroseius* (*Cheiroseius*) sp. 4

Literature Used for Identification

Karg 1993

Lindquist and Moraza 2010



Cheiroseius (*Cheiroseius*) sp. 4

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

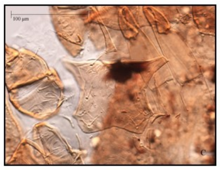
No males illustrated as no males have yet been found

(click images to enlarge)

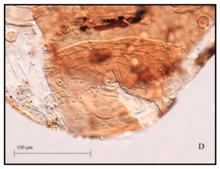
(A) Full body dorsal.

(B) Full body ventral.

(C) Sternal shield with three pairs of setae, and one pair of setae on metasternal shields.

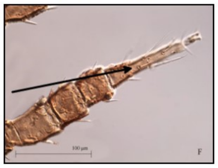


(D) Ventrianal shield with 4 pairs of setae (including paranal pair).



(E) Post-stigmatic extension extension of peritreme extends to midline of leg IV (arrow).

(F) Tarsus of leg I is elongate (arrow), leg I shorter than idiosoma.



(G) Dorsal shield has a scale-like pattern.

Related Taxa

Thus far in this project I have found six other species within this genus in Alberta. As defined in Karg (1993), this species is in the subgenus Cheiroseius, based on its having a short post-stigmatic extension. Three other species were found within this subgenus. Only one individual was found of this morphospecies. Due to the debris on the dorsal shield, and the shield being split, it was difficult to determine what species this keys to. This species looks most similar to *Cheiroseius* (*Cheiroseius*) sp. 2; however, *Cheiroseius* (*Cheiroseius*) sp. 4 has shorter post-stigmatic extensions than *Cheiroseius* (*Cheiroseius*) sp. 2.

Literature Used for Identification

Karg 1993

Lindquist and Moraza 2010

Cheiroseius (*Posttrematus*) sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

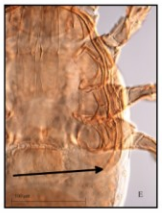
(A) Full body dorsal.

(B) Full body ventral.

(C) Sternal shield with three pairs of setae, and one pair of setae on metasternal shields.

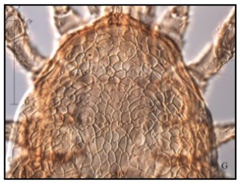
(D) Ventrianal shield with 4 pairs of setae (including paranal pair).

(E) Post-stigmatic extension extension of peritreme extends beyond posterior margin of leg IV and curls behind it (arrow) (arrow).

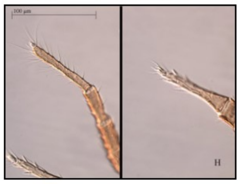


(F) Tarsus of leg I is elongate; leg I is shorter than idiosoma.

(G) Dorsal shield has scaly, net-like pattern.



(H) Claws on tarsus 1 (left) are smaller than those on tarsi II, III, and IV.



Related Taxa

Thus far in this project I have found six other species within this genus in Alberta. As defined in Karg (1993), this species is in the subgenus Posttrematus based on it having a long post-stigmatic extension. Two other species were found within this subgenus. Using Karg (1993), this species keys to *Cheiroseius cassiteridium* (Evans and Hyatt). *Cheiroseius* (*Posttrematus*) sp. 1 differs from the other two species I found in this subgenus, as tarsus I is longer than tibia I (Fig. H, left panel)

Literature Used for Identification

Karg 1993

Lindquist and Moraza 2010

Cheiroseius (*Posttrematus*) sp. 2

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

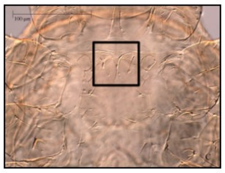
No males illustrated as no males have yet been found

(click images to enlarge)

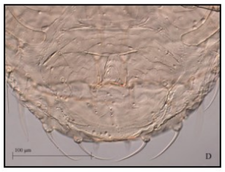
(A) Full body dorsal.

(B) Full body ventral.

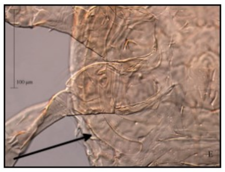
(C) Sternal shield with three pairs of setae, and one pair of setae on metasternal shields. Note the m shaped impression on the shield.



(D) Ventrianal shield with 4 pairs of setae (including paranal pair).

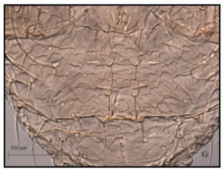


(E) Post-stigmatic extension extension of peritreme extends beyond posterior margin of leg IV and curls behind it (arrow).

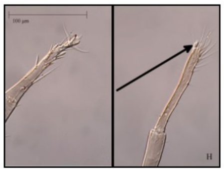


(F) Tarsus of leg I is shorter than tibia; leg I is longer than idiosoma.

(G) Dorsal shield has scaly pattern.



(H) Claws on tarsus 1 (right, arrow) are smaller than those on tarsi II, III, and IV.

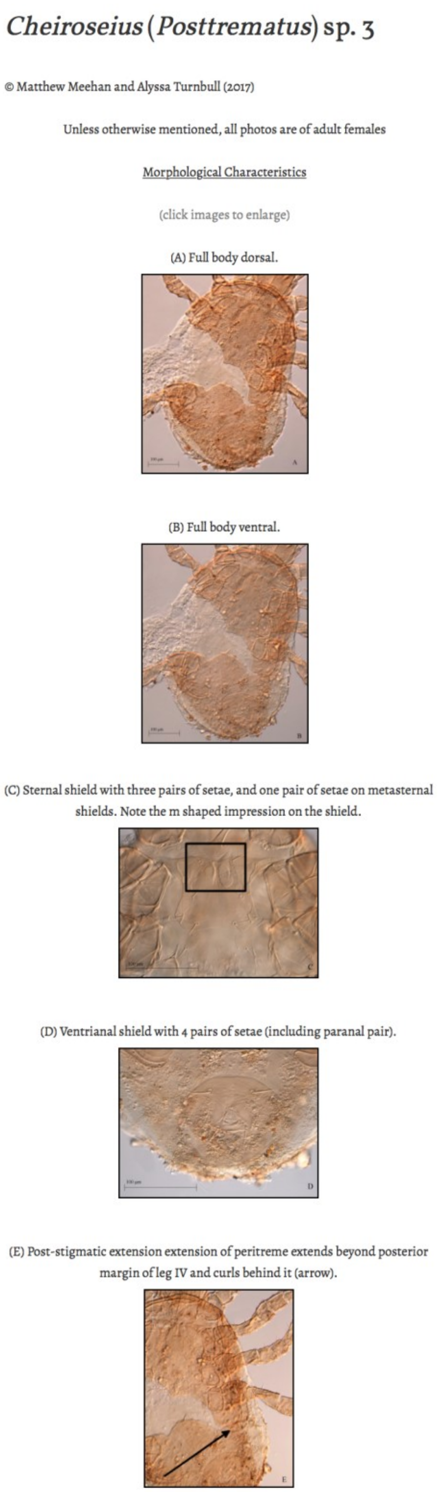


Related Taxa

Thus far in this project I have found six other species within this genus in Alberta. As defined in Karg (1993), this species is in the subgenus Posttrematus based on it having a long post-stigmatic extension. Two other species were found within this subgenus. Using Karg (1993), this species keys to *Cheiroseius mutilus* (Berlese). *Cheiroseius*(*Posttrematus*) sp. 2 differs from *Cheiroseius* (*Posttrematus*) sp. 3 due to the ornamentation on the dorsal shield and having longer dorsal setae.

Literature Used for Identification

Karg 1993
Lindquist and Moraza 2010



Cheiroseius (*Posttrematus*) sp. 3

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

(click images to enlarge)

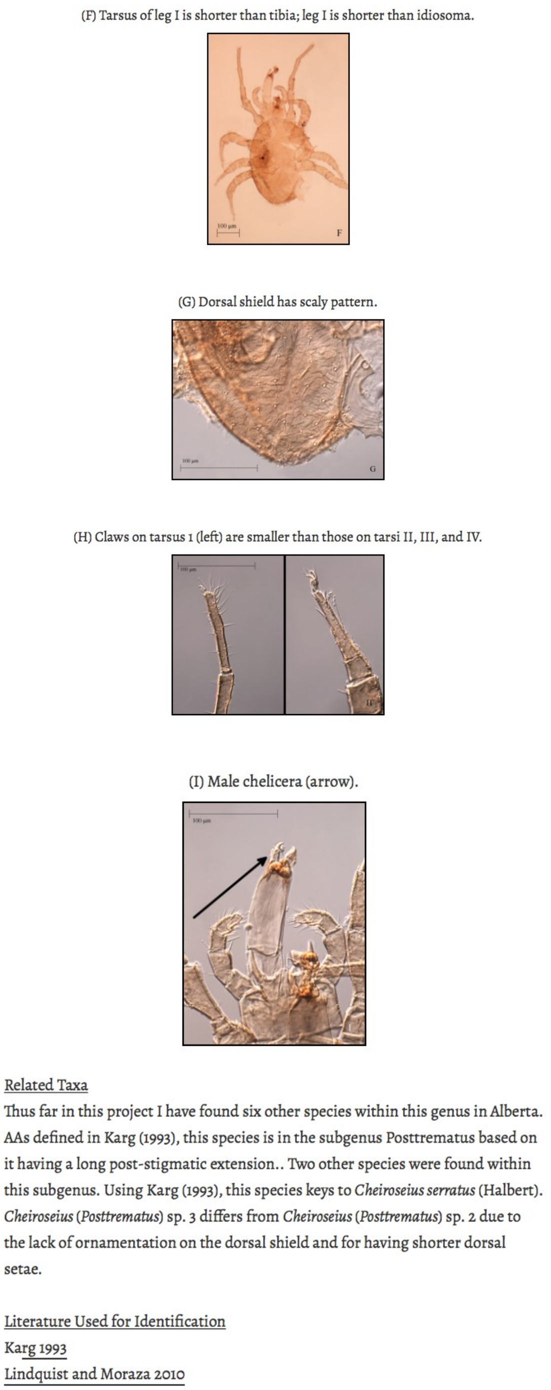
(A) Full body dorsal.

(B) Full body ventral.

(C) Sternal shield with three pairs of setae, and one pair of setae on metasternal shields. Note the m shaped impression on the shield.

(D) Ventrianal shield with 4 pairs of setae (including paranal pair).

(E) Post-stigmatic extension extension of peritreme extends beyond posterior margin of leg IV and curls behind it (arrow).



(F) Tarsus of leg I is shorter than tibia; leg I is shorter than idiosoma.

(G) Dorsal shield has scaly pattern.

(H) Claws on tarsus 1 (left) are smaller than those on tarsi II, III, and IV.

(I) Male chelicera (arrow).

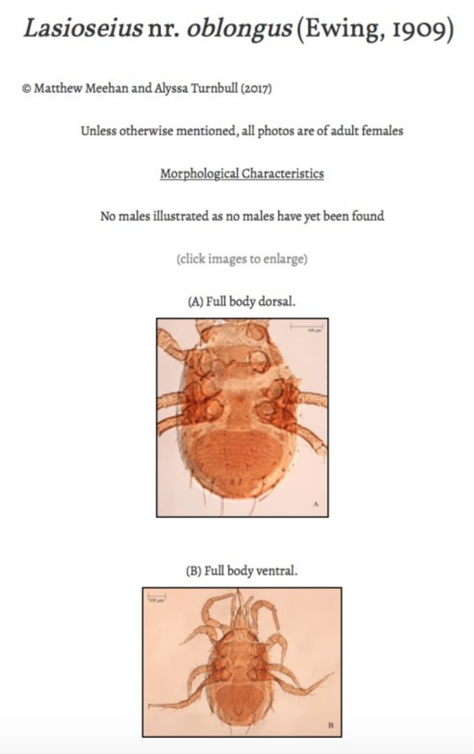
Related Taxa

Thus far in this project I have found six other species within this genus in Alberta. AAs defined in Karg (1993), this species is in the subgenus Posttrematus based on it having a long post-stigmatic extension.. Two other species were found within this subgenus. Using Karg (1993), this species keys to *Cheiroseius serratus* (Halbert). *Cheiroseius* (*Posttrematus*) sp. 3 differs from *Cheiroseius* (*Posttrematus*) sp. 2 due to the lack of ornamentation on the dorsal shield and for having shorter dorsal setae.

Literature Used for Identification

Karg 1993

Lindquist and Moraza 2010



Lasioseius nr. *oblongus* (Ewing, 1909)

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

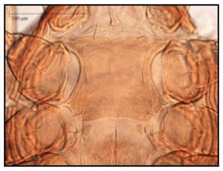
Morphological Characteristics

No males illustrated as no males have yet been found

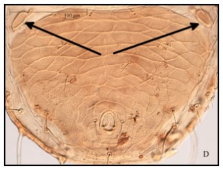
(click images to enlarge)

(A) Full body dorsal.

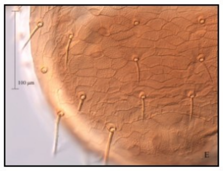
(B) Full body ventral.



(C) Sternal shield with three pairs of setae, and one pair of setae on metasternal shields. Note the punctuated ornamentation on the shield.



(D) Ventrianal shield with six pairs of setae (not including paranal setae), note the free round metapodal plates (arrows).



(E) Dorsal shield has long setae and a reticulated pattern.

(F) Fixed digit of the chelicera has many teeth.

Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. Using the key provided in Christian and Karg (2006), this species keys to *Lasioseius oblongus* (Ewing).Similarities between the two species include presence of all J setae, and having punctuated ornamentation on the sternal shield. However, *Lasioseius oblongus* has shorter dorsal setae than *Lasioseius* nr. *oblongus*.

Literature Used for Identification

Christian and Karg 2006

Lindquist and Moraza 2010

Platyseius cf. *tendens* (Schrank, 1803)

Unless otherwise mentioned, all photos are of adult females

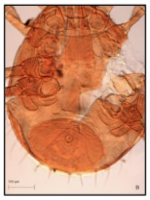
Morphological Characteristics

No males illustrated as no males have yet been found

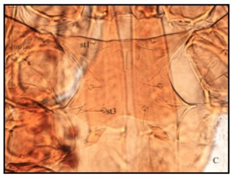
(click images to enlarge)

(A) Full body dorsal.

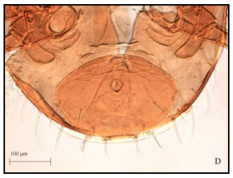
(B) Full body ventral.



(C) Sternal shield with three pairs of setae, and one pair of setae on metasternal shields. Note that st1 is distinctly shorter than st3.



(D) Ventrianal shield with 6 pairs of setae (including paranal pair).



(E) Peritremal shield.

(F) Posterior dorsal shield with only two pairs of J series setae, J4 and J5.

Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. Using the key provided in Kazemi et al. 2016, this species keys to *Platyseius tendens* (Schrank). Because I couldn't find a description or illustrations of *Platyseius tendens*, I am conservatively calling it *Platyseius* cf. *tendens*.

Literature Used for Identification

Kazemi et al. 2016

Lindquist and Moraza 2010

2.4.5.1.6.2 Phytoseiidae

Amblydromalus sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

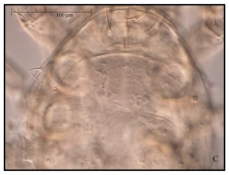
No males illustrated as no males have yet been found

(click images to enlarge)

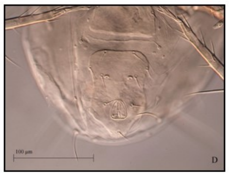
(A) Full body dorsal.

(B) Full body ventral.

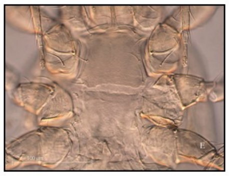
(C) Dorsal shield with no reticulation.



(D) Ventrianal shield with three pairs of preanal setae (not including paranal setae)and with no striation. Ventrianal shield is vase-shaped .

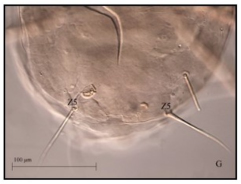


(E) Sternal shield with three pairs of setae, and one pair on metasternal shields.



(F) Macrosetae are present on legs II-IV (arrow).

(G) Z5 setae are not longer than the distance between Z5 setal bases.



Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. A vase-shaped ventrianal shield is a rare characteristic, shared only with *Typhlodromalus*.

Literature Used for Identification

Chant and McMurtry 2007

Denmark and Evans 2011

Amblyseius sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

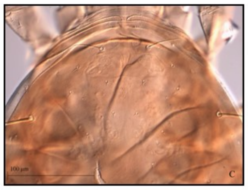
No males illustrated as no males have yet been found

(click images to enlarge)

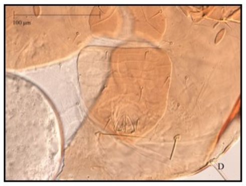
(A) Full body dorsal.

(B) Full body ventral.

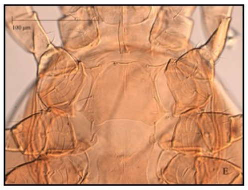
(C) Dorsal shield with no reticulation.



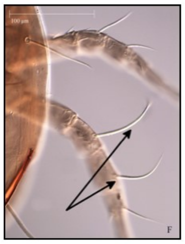
(D) Ventrianal shield with three pairs of preanal setae (not including paranal setae) and with heavy striation.



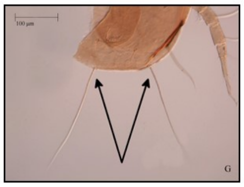
(E) Sternal shield with three pairs of setae, and one pair on metasternal shields.



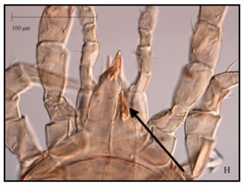
(F) Macrosetae are present on legs II-III (arrows).



(G) Z5 setae are longer than the distance between Z5 setal bases (arrows).



(H) Chelicerae (arrow) are not exceptionally large (compared to *Chelaseius*).



Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. I was not able to identify it to species as the spermatheca was not visible. *Ambylseius* looks similar to *Chelaseius*; however, *Chelaseius* has much larger chelicera than *Amblyseius*.

Literature Used for Identification

Chant and Hansell 1971
Chant and McMurtry 2007
Denmark and Evans 2011

Arrenoseius sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

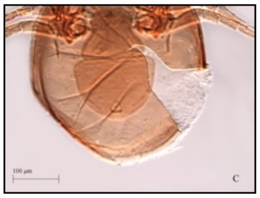
No males illustrated as no males have yet been found

(click images to enlarge)

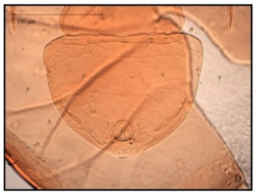
(A) Full body dorsal.

(B) Full body ventral.

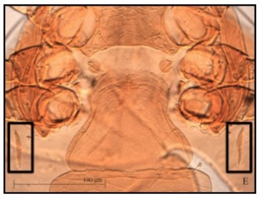
(C) Lower dorsal shield.



(D) Ventrianal shield with three pairs of setae on it (not including paranal setae)



(E) Metapodal shields are relatively small, in comparison to *Pararrenoseius*.



Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. However, 20 species have been identified globally. One other species has been found in North America, *A. palustris* (Chant).

Literature Used for Identification

Chant and McMurtry 2007

Denmark and Evans 2011

Chelaseius floridanus (Muma, 1955)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

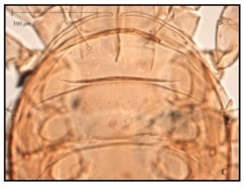
No males illustrated as no males have yet been found

(click images to enlarge)

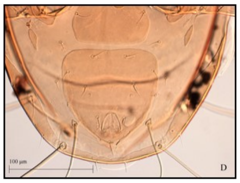
(A) Full body dorsal.

(B) Full body ventral.

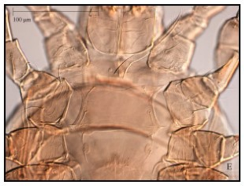
(C) Dorsal shield with no reticulation.



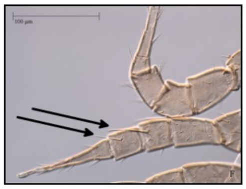
(D) Ventrianal shield with three pairs of preanal setae (not including paranal setae) with no striation.



(E) Sternal shield with three pairs of setae, and one pair on metasternal shields.

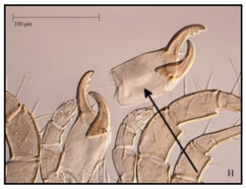


(F) Macrosetae are present on legs II-III (arrows).



(G) Z5 setae (arrows) are longer than the distance between Z5 setal bases.

(H) Chelicerae are large in comparison to *Amblyseius* (arrow).



Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. Three other species have been documented within North Amerca: *C. vicinus* (Muma), *C. tundra* (Chant and Hansell), and *C. schusterellus* (Athias-Henriot). Morphologically, *C. floridanus* is most similar to *C. tundra* and *C. schusterellus*. *Chelaseius floridanus* can be differentiated from both species of these species by having S4 at least 5x longer than z2.

Literature Used for Identification

Chant and Hansell 1971
Chant and McMurtry 2007
Denmark and Evans 2011

Neoseiulus sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

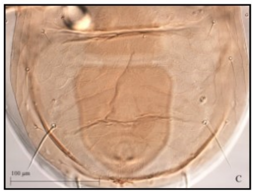
No males illustrated as no males have yet been found

(click images to enlarge)

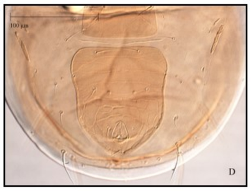
(A) Full body dorsal.

(B) Full body ventral.

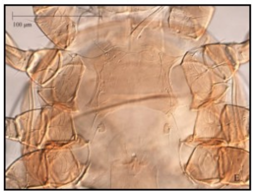
(C) Dorsal shield with light reticulation.



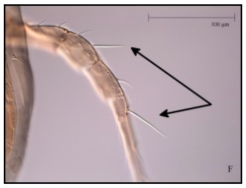
(D) Ventrianal shield with three pairs of preanal setae (not including paranal setae), and with heavy striation



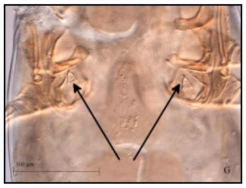
(E) Sternal shield with three pairs of setae, and one pair on metasternal shields.



(F) Leg IV with two macrosetae (arrows).



(G) Spermathecae are saccular (arrows).



Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. Using the key provided in Denmark and Evans (2011), this species keys out to *N. arcticus* (Chant and Hansell) or *N. inornatus* (Schuster and Pritchard). *Neoseiulus* sp. 1 dorsal setae lengths partially match both descriptions.

Literature Used for Identification

Chant and Hansell 1971
Chant and McMurtry 2007
Denmark and Evans 2011

Proprioseiopsis sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

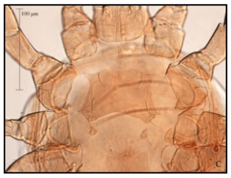
No males illustrated as no males have yet been found

(click images to enlarge)

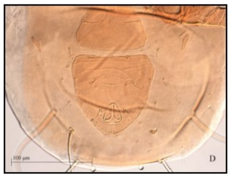
(A) Full body dorsal.

(B) Full body ventral.

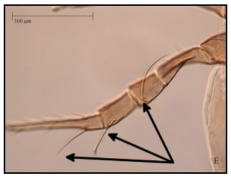
(C) Sternal shield with three pairs of setae, one pair on metasternal shields.



(D) Ventrianal shield with three pairs of preanal setae (not including paranal setae).

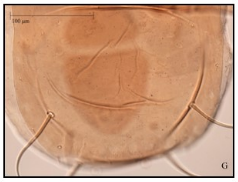


(E) Leg IV with three macrosetae (arrows).



(F) Dorsum with elongate s4, Z4 and Z5.

(G) No J2 or J4 setae.



Related Taxa

Thus far in this project I have found one other species within this genus in Alberta, *Proprioseiopsis* sp. 2. *Proprioseiopsis* sp. 1 differs from *Proprioseiopsis* sp. 2 by having less striation on sternal and ventrianal shields.

Literature Used for Identification

Chant and McMurtry 2007

Denmark and Evans 2011

Proprioseiopsis sp. 2

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

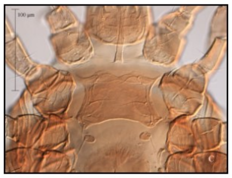
No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

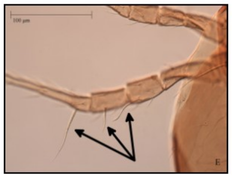
(B) Full body ventral.

(C) Sternal shield with three pairs of setae, one pair on metasternal shields.



(D) Ventrianal shield with three pairs of preanal setae (not including paranal setae).

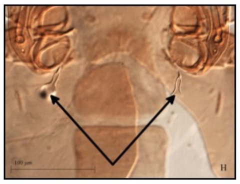
(E) Leg IV with three macrosetae (arrows).



(F) Dorsum with elongate s4, Z4 and Z5.

(G) No J2 or J4 setae.

(H) Saccular spermathecae (arrows).



Related Taxa

Thus far in this project I have found one other species within this genus in Alberta, *Proprioseiopsis* sp. 1. *Proprioseiopsis* sp. 2 differs from *Proprioseiopsis* sp. 1 by having more striation on sternal and ventrianal shields. Using the key provided in Denmark and Evans (2011), this species keys best to *P. borealis* (Chant and Hansell).

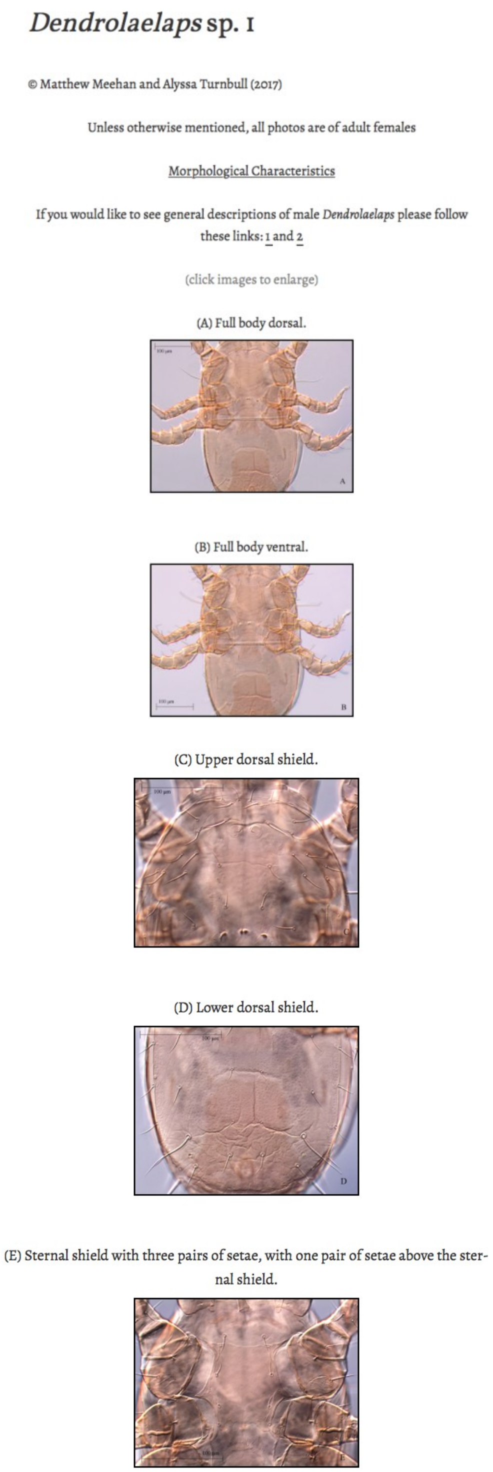
Literature Used for Identification

Chant and McMurtry 2007

Denmark and Evans 2011

2.4.5.1.7 Rhodocaroidae

2.4.5.1.7.1 Digamasellidae



Dendrolaelaps sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

(click images to enlarge)

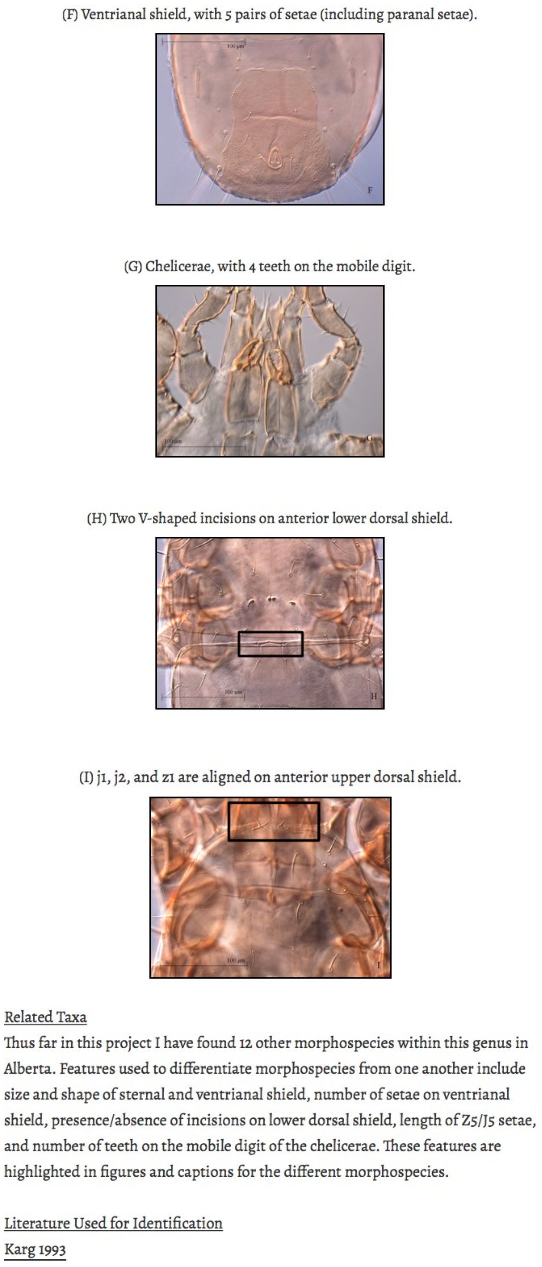
(A) Full body dorsal.

(B) Full body ventral.

(C) Upper dorsal shield.

(D) Lower dorsal shield.

(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.



(F) Ventrianal shield, with 5 pairs of setae (including paranal setae).

(G) Chelicerae, with 4 teeth on the mobile digit.

(H) Two V-shaped incisions on anterior lower dorsal shield.

(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.

Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993

Dendrolaelaps sp. 2

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

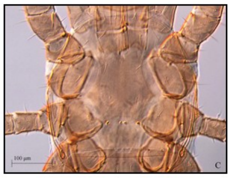
If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

(click images to enlarge)

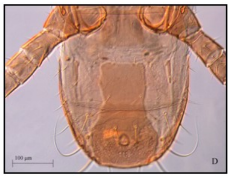
(A) Full body dorsal.

(B) Full body ventral.

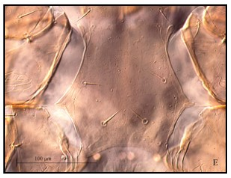
(C) Upper dorsal shield.



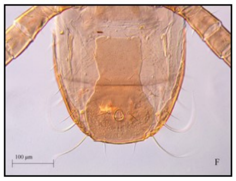
(D) Lower dorsal shield.



(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.

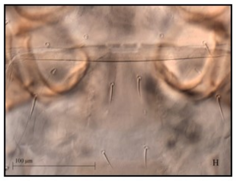


(F) Ventrianal shield, with 5 pairs of setae (including paranal setae).

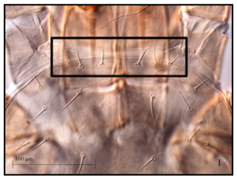


(G) Chelicerae, with 5 or more teeth on the mobile digit.

(H) No v forming structures on anterior lower dorsal shield.



(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.



Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993

Dendrolaelaps sp. 3

Unless otherwise mentioned, all photos are of adult females

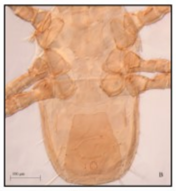
Morphological Characteristics

If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

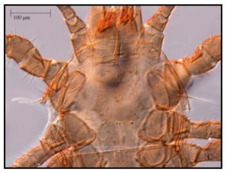
(click images to enlarge)

(A) Full body dorsal.

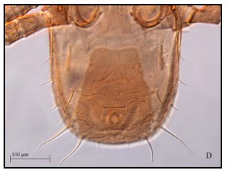
(B) Full body ventral.



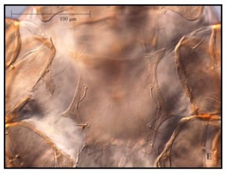
(C) Upper dorsal shield.



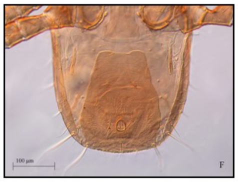
(D) Lower dorsal shield.



(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.

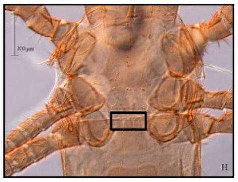


(F) Ventrianal shield, with 5 pairs of setae (including paranal setae).

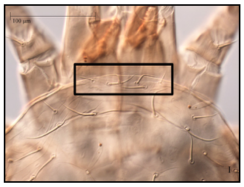


(G) Chelicerae, with 4 teeth on the mobile digit.

(H) Two V-shaped incisions on anterior lower dorsal shield.



(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.



Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993

Dendrolaelaps sp. 4

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

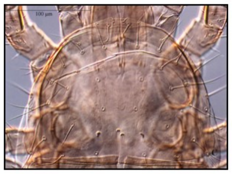
If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

(click images to enlarge)

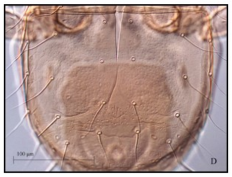
(A) Full body dorsal.

(B) Full body ventral.

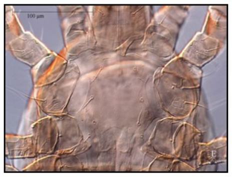
(C) Upper dorsal shield.



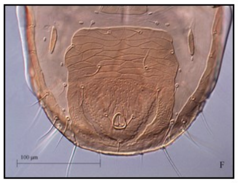
(D) Lower dorsal shield.



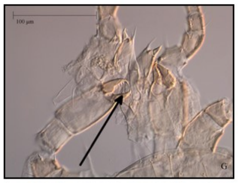
(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.



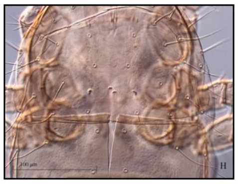
(F) Ventrianal shield, with 5 pairs of setae (including paranal setae).



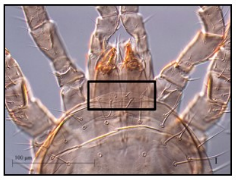
(G) Chelicera, with 4 teeth on the mobile digit (arrow).



(H) No v forming structures on anterior lower dorsal shield.



(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.

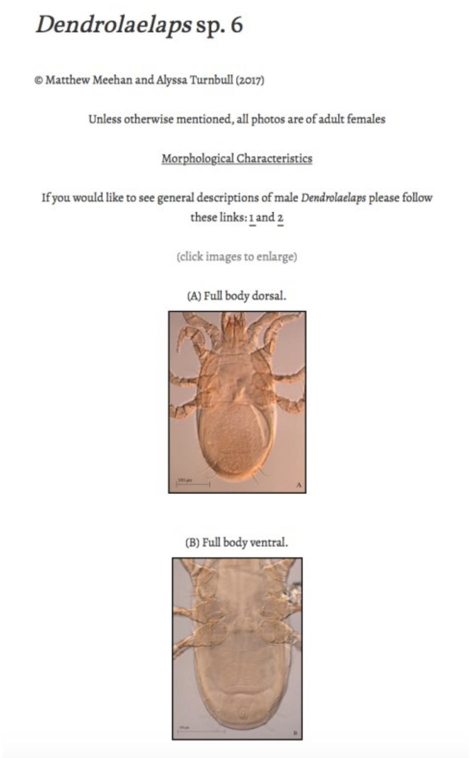


Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993



Dendrolaelaps sp. 6

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

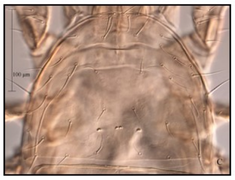
If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

(click images to enlarge)

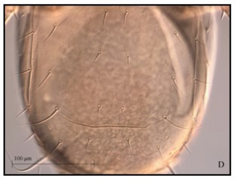
(A) Full body dorsal.

(B) Full body ventral.

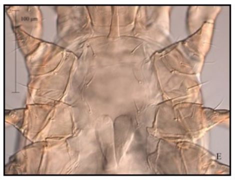
(C) Upper dorsal shield.



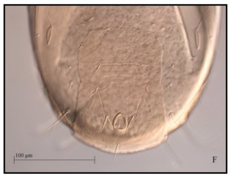
(D) Lower dorsal shield.



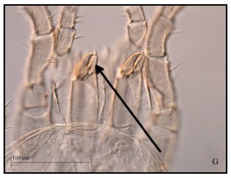
(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.



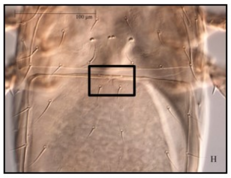
(F) Ventrianal shield, with 5 pairs of setae (including paranal setae), first pair setae on the border of the shield.



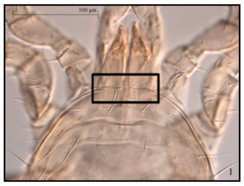
(G) Chelicera, with 4 teeth on the mobile digit (arrow).



(H) A single Y-shaped incision on anterior lower dorsal shield.



(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.



Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993

Dendrolaelaps sp. 7

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

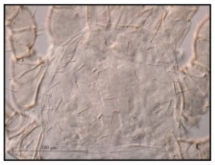
If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

(click images to enlarge)

(A) Full body dorsal.

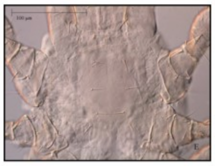
(B) Full body ventral.

(C) Upper dorsal shield.

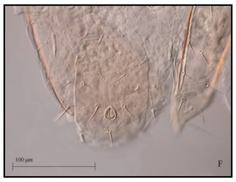


(D) Lower dorsal shield.

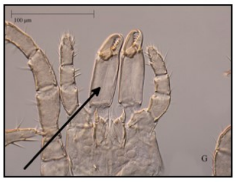
(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.



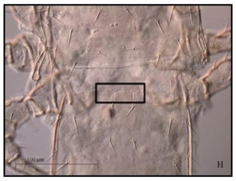
(F) Ventrianal shield, with 4 pairs of setae (including paranal setae).



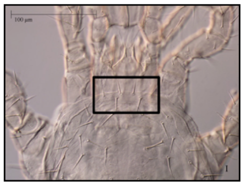
(G) Chelicera (arrow), with 4 teeth on the mobile digit.



(H) Two V-shaped incisions on anterior lower dorsal shield.



(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.



Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993

Dendrolaelaps sp. 8

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

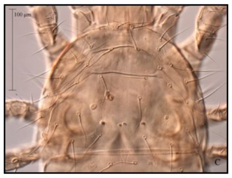
If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

(click images to enlarge)

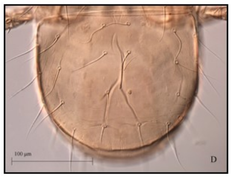
(A) Full body dorsal.

(B) Full body ventral.

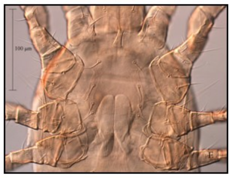
(C) Upper dorsal shield.



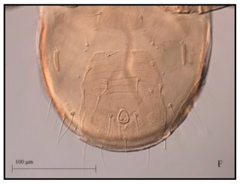
(D) Lower dorsal shield.



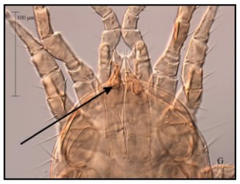
(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.



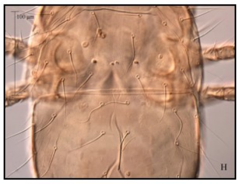
(F) Ventrianal shield, with 6 pairs of setae (including paranal setae).



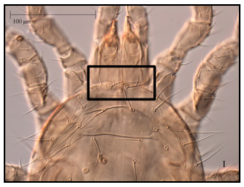
(G) Chelicera (arrow), with 3-4 teeth on the mobile digit.



(H) No v forming structures on anterior lower dorsal shield.



(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.



Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993

Dendrolaelaps sp. 9

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

(click images to enlarge)

(A) Full body dorsal.

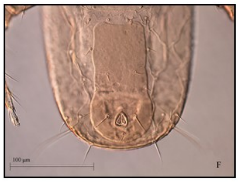
(B) Full body ventral.

(C) Upper dorsal shield.

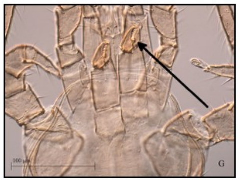
(D) Lower dorsal shield.

(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.

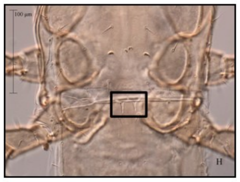
(F) Ventrianal shield, with 3 pairs of setae (including paranal setae).



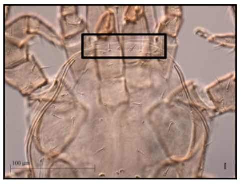
(G) Chelicera, with 4 teeth on the mobile digit (arrow).



(H) Two V-shaped incisions on anterior lower dorsal shield.



(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.



Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993

Dendrolaelaps sp. 11

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Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

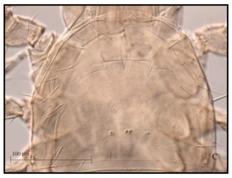
If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

(click images to enlarge)

(A) Full body dorsal.

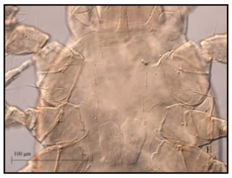
(B) Full body ventral.

(C) Upper dorsal shield.



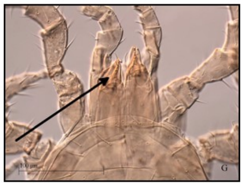
(D) Lower dorsal shield.

(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.



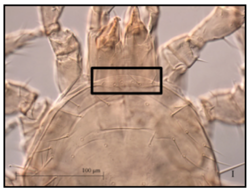
(F) Ventrianal shield, with 4 pairs of setae (including paranal setae).

(G) Chelicera, with 4 teeth on the mobile digit (arrow).



(H) A single Y-shaped incision on anterior lower dorsal shield.

(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.



Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993

Dendrolaelaps sp. 13

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

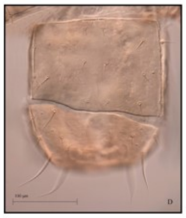
(click images to enlarge)

(A) Full body dorsal.

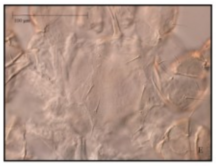
(B) Full body ventral.

(C) Upper dorsal shield.

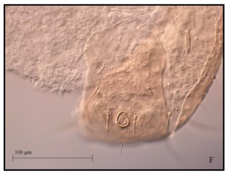
(D) Lower dorsal shield.



(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.



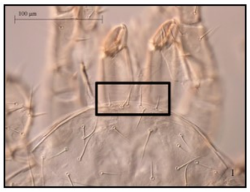
(F) Ventrianal shield, with 4 pairs of setae (including paranal setae), with one pair of setae near the border of the shield.



(G) Chelicerae, with 3-4 teeth on the mobile digit.

(H) A single Y-shaped incision on anterior lower dorsal shield.

(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.

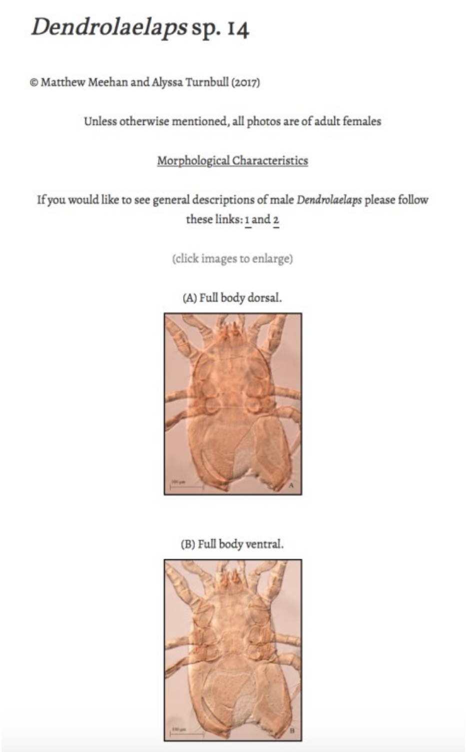


Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993



Dendrolaelaps sp. 14

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

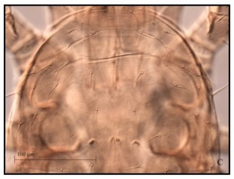
If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

(click images to enlarge)

(A) Full body dorsal.

(B) Full body ventral.

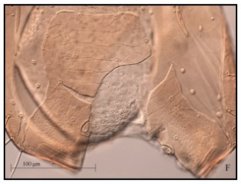
(C) Upper dorsal shield.



(D) Lower dorsal shield.

(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.

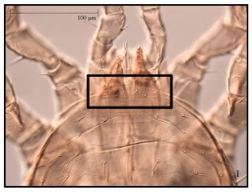
(F) Ventrianal shield, with 5 pairs of setae (including paranal setae).



(G) Chelicerae.

(H) No v forming structures on anterior lower dorsal shield.

(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.



Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993

Dendrolaelaps sp. 15

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

If you would like to see general descriptions of male *Dendrolaelaps* please follow these links: 1 and 2

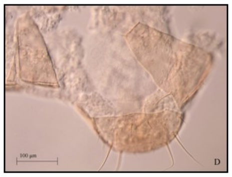
(click images to enlarge)

(A) Full body dorsal.

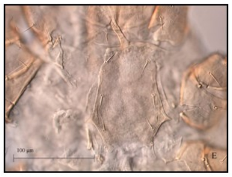
(B) Full body ventral.

(C) Upper dorsal shield.

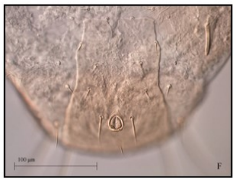
(D) Lower dorsal shield.



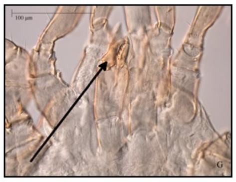
(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.



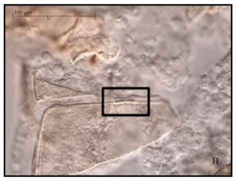
(F) Ventrianal shield, with 5 pairs of setae (including paranal setae).



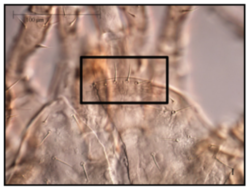
(G) Chelicera, with 4 teeth on the mobile digit (arrow).



(H) Two V-shaped incisions on anterior lower dorsal shield.



(I) j1, j2, and z1 are aligned on anterior upper dorsal shield.



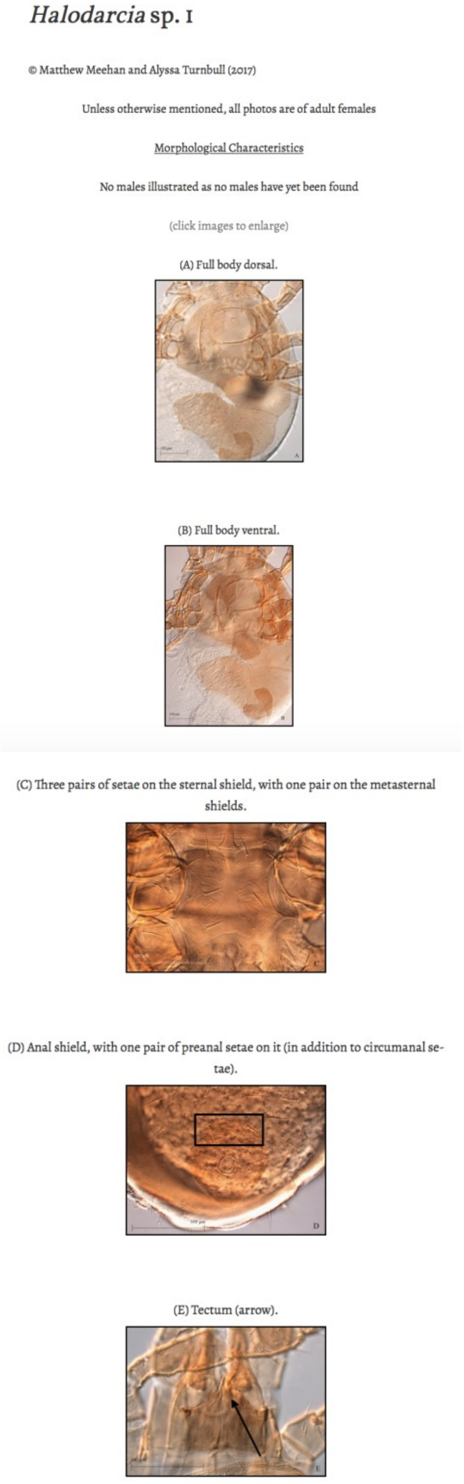
Related Taxa

Thus far in this project I have found 12 other morphospecies within this genus in Alberta. Features used to differentiate morphospecies from one another include size and shape of sternal and ventrianal shield, number of setae on ventrianal shield, presence/absence of incisions on lower dorsal shield, length of Z5/J5 setae, and number of teeth on the mobile digit of the chelicerae. These features are highlighted in figures and captions for the different morphospecies.

Literature Used for Identification

Karg 1993

2.4.5.1.7.2 Halolaelapidae



Halodarcia sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

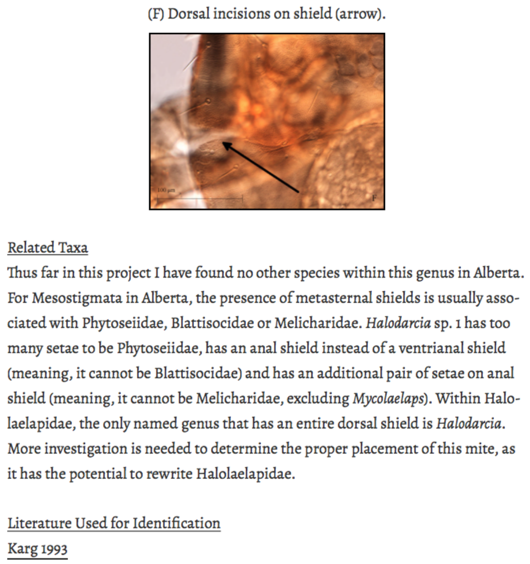
(A) Full body dorsal.

(B) Full body ventral.

(C) Three pairs of setae on the sternal shield, with one pair on the metasternal shields.

(D) Anal shield, with one pair of preanal setae on it (in addition to circumanal setae).

(E) Tectum (arrow).



(F) Dorsal incisions on shield (arrow).

Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. For Mesostigmata in Alberta, the presence of metasternal shields is usually associated with Phytoseiidae, Blattisocidae or Melicharidae. *Halodarcia* sp. 1 has too many setae to be Phytoseiidae, has an anal shield instead of a ventrianal shield (meaning, it cannot be Blattisocidae) and has an additional pair of setae on anal shield (meaning, it cannot be Melicharidae, excluding *Mycolaelaps*). Within Halolaelapidae, the only named genus that has an entire dorsal shield is *Halodarcia*. More investigation is needed to determine the proper placement of this mite, as it has the potential to rewrite Halolaelapidae.

Literature Used for Identification

Karg 1993

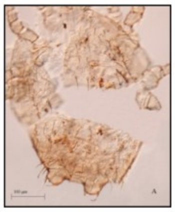
nr. *Saprosecans* sp. 1

Morphological Characteristics

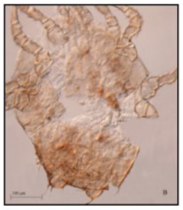
No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

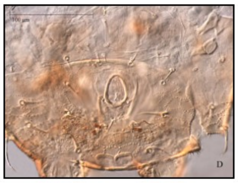


(B) Full body ventral.

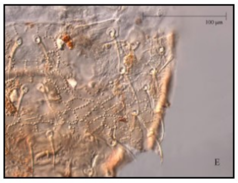


(C) Sternal shield with three pairs of setae, and one pair on metasternal shields.

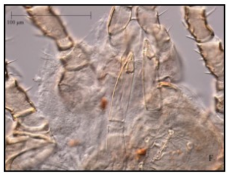
(D) Ventrianal shield, note the large anal opening.



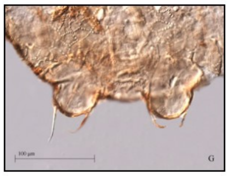
(E) Dorsal shield with long setae and a distinct beaded ornamentation.



(F) Chelicerae.



(G) Round posterior horns located on the dorsal shield.



Related Taxa
Thus far in this project I have found no other species within this genus in Alberta. This mite is unique in that it has posterior horns, a characteristic only shared with the genus *Asca*, and many species within the family Sejidae. This mite was determined to not be *Saprosceans* as it does not have mesonotal and pygidial shields.

Literature Used for Identification
The Mesostigmata key in Krantz and Walter (2009) was used for family-level identification, and taxonomic literature acquired at the The Ohio State Acarology Summer Program were used for genus-level identification.

2.4.5.1.7.3 Ologamasidae

Gamasellus sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

(click images to enlarge)

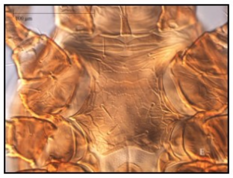
(A) Full body dorsal.

(B) Full body ventral.

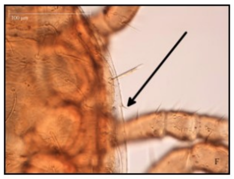
(C) Podonotal shield.

(D) Opisthonotal shield.

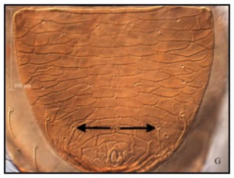
(E) Sternal shield with four pairs of setae.



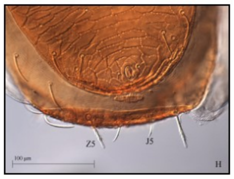
(F) r3 is short (arrow).



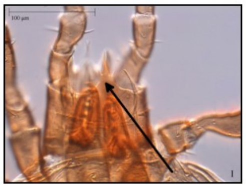
(G) Ventrianal shield, note that JV3 is simple (arrows).



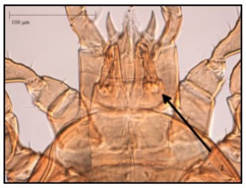
(H) Z5 and J5 on opisthonotal shield, Z5 is plumose while J5 is simple.



(I) Tectum (arrow).



(J) Male chelicera (arrow) of Gamasellus sp. 1.



Related Taxa

Thus far in this project I have found two other species within this genus in Alberta, *Gamasellus* sp. 2 and *Gamasellus* sp. 3. The short r3 and simple JV3 of *Gamasellus* sp. 1 differentiates it from *Gamasellus* sp. 2, which has a long r3 and plumose JV3. *Gamasellus* sp. 1 can be differentiated from *Gamasellus* sp. 3 by having a simple J5 rather than a plumose one.

Literature Used for Identification

Karg 1993

Gamasellus sp. 2

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

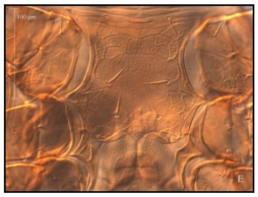
(A) Full body dorsal.

(B) Full body ventral.

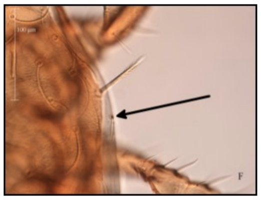
(C) Podonotal shield.

(D) Opisthonotal shield.

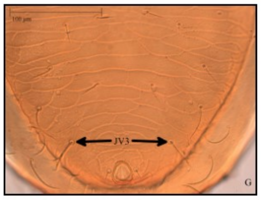
(E) Sternal shield with four pairs of setae.



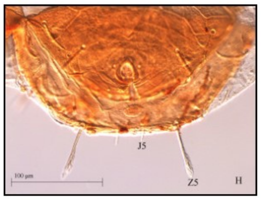
(F) r3 is long.



(G) Ventrianal shield, note that JV3 is plumose.



(H) Z5 and J5 on opisthonotal shield, Z5 is plumose while J5 is simple.



(I) Tectum.

Related Taxa

Thus far in this project I have found two other species within this genus in Alberta, *Gamasellus* sp. 1 and *Gamasellus* sp. 3. The long r2 and plumose JV3 of *Gamasellus* sp. 2 differentiates it from *Gamasellus* sp. 1 which has a short r3 and simple JV3. *Gamasellus* sp. 2 can be differentiated from *Gamasellus* sp. 3 by having a simple J5 rather than a plumose one.

Literature Used for Identification

Karg 1993

Gamasellus sp. 3

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

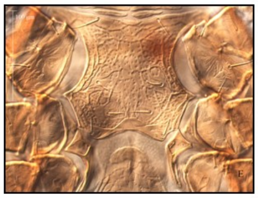
(A) Full body dorsal.

(B) Full body ventral.

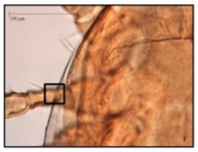
(C) Podonotal shield, note that z5 is plumose.

(D) Opisthonotal shield.

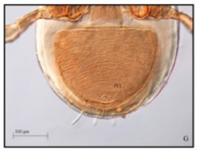
(E) Sternal shield with four pairs of setae (st1-4).



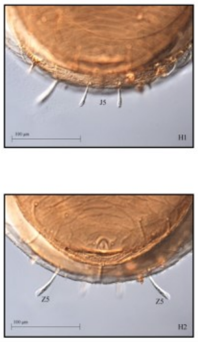
(F) r3 is extremely short (box).



(G) Ventrianal shield, note that JV3 is simple.



(H1 and H2) Z5 and J5 on opisthonotal shield, Z5 and J5 are both plumose.



(I) Tectum.

Related Taxa

Thus far in this project I have found two other species within this genus in Alberta, *Gamasellus* sp. 1 and *Gamasellus* sp. 2. J5 being plumose differentiates *Gamasellus* sp. 3 from *Gamasellus* sp. 1 and *Gamasellus* sp. 2, as they have a simple J5.

Literature Used for Identification

Karg 1993

2.4.5.1.7.4 Rhodacaridae

Rhodacarellus sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

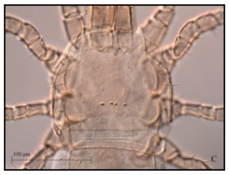
Morphological Characteristics

(click images to enlarge)

(A) Full body dorsal.

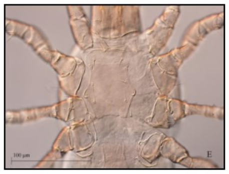
(B) Full body ventral.

(C) Upper dorsal shield.



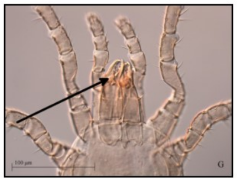
(D) Lower dorsal shield.

(E) Sternal shield with three pairs of setae, with one pair of setae above the sternal shield.

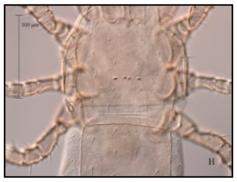


(F) Ventrianal shield, with 6 pairs of setae (including paranal setae).

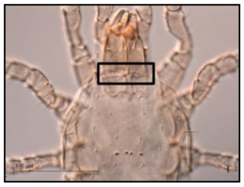
(G) Chelicera, with 3 teeth on the mobile digit (arrow).



(H) No v forming structures on anterior lower dorsal shield.



(I) j1, z1, and s1 are aligned on anterior upper dorsal shield.



Related Taxa

Thus far in this project I have found no others species within this genus in Alberta.

Literature Used for Identification

Karg 1993

2.4.5.1.8 Zerconoidea

2.4.5.1.8.1 Zerconidae

Boreozercon emendi Díaz-Aguilar and Ujvári, 2010

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

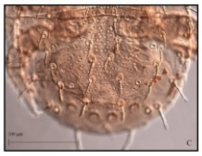
No males illustrated as no males have yet been found

(click images to enlarge)

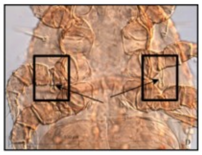
(A) Full body dorsal view.

(B) Full body ventral view.

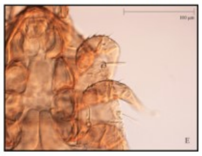
(C) All setae on opisthonotal shield are plumose (feather like).



(D) Peritremes are short without a bend, and with one inner dilation (arrows).

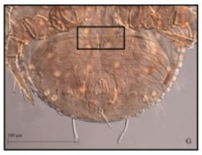


(E) Two setae (r1 and r3) on peritremal shield (r1 not visible).



(F) Peritremal shield is not fused with ventrianal shield, but does extend past leg IV.

(G) Ventrianal shield with only one pair of setae present (JV1) along anterior border.



(H) *Zercon*-type tectum (arrow).

Related Taxa

No other species have been found thus far in Alberta for this genus. This genus differs from others as it lacks adgenital pores, similar to *Mixozercon*.

Literature Used for Identification

Sikora 2014

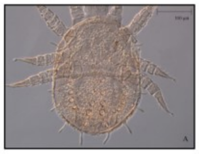
Mixozercon borealis Díaz-Aguilar and Ujvári, 2010

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

(click images to enlarge)

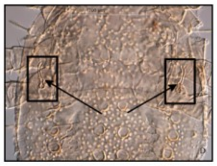
(A) Full body dorsal view.



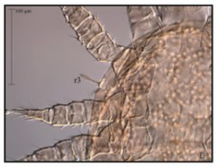
(B) Full body ventral view.

(C) Setae on opisthonotal shield vary in length and type.

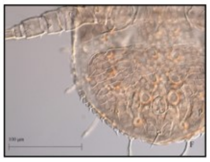
(D) Peritremes are short with an inner dilation (arrows) and no bend.



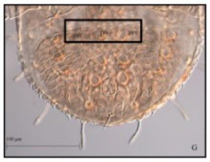
(E) Two setae (r1, r3) on peritremal shield (r1 not visible).



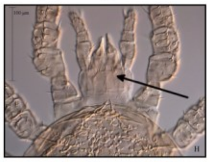
(F) Peritremal shield is not connected to ventrianal shield, peritremal shield does not extend past coxa IV.



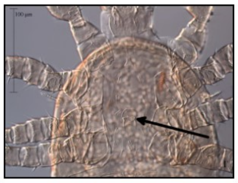
(G) Ventrianal shield with two pairs of setae present (JV1 and ZV1) along anterior border.



(H) *Zercon*-type tectum.



(I) Male genital opening located ventrally, between legs II and III (arrow).



Related Taxa

Two species have thus far been found in Alberta within this genus (*M. borealis* and *M. jasoniana* Díaz-Aguilar and Ujvári). *M. borealis* J1 and Z1 setae are simple, not plumose. *Mixozercon borealis* left lateral section of peritremal shield does not extend past coxa IV, while in *M. jasoniana* the peritremal shield does extend past coxa IV. Missing adgenital pores, similar to *Skeironozercon*.

Literature Used for Identification

Díaz-Aguilar and Ujvári 2010

Mixozercon jasoniana Díaz-Aguilar and Ujvári, 2010

© Matthew Meehan and Alyssa Turnbull

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

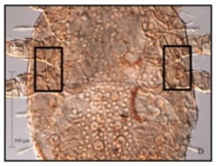
(click images to enlarge)

(A) Full body dorsal view.

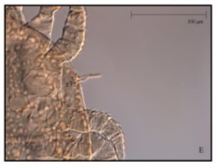
(B) Full body ventral view.

(C) Setae on opisthonotal shield vary in type and length, note that J1 and Z1 are plumose (see related taxa).

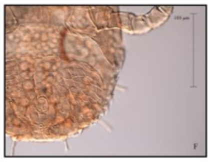
(D) Peritremes are short with no bend.



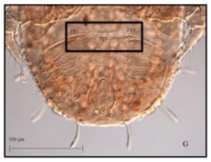
(E) Two setae (r1, r3) on peritremal shield (r1 not visible).



(F) Peritremal shield is not connected to ventrianal shield. Peritremal shield extends past coxa IV.

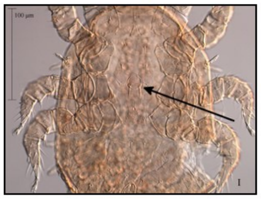


(G) Ventrianal shield with two pairs of setae present (JV1 and ZV1) along anterior border.



(H) *Zercon*-type tectum (arrow).

(I) Male genital opening located ventrally, in between legs II and III (arrow).



Related Taxa

Two species have thus far been found in Alberta for this genus (*M. borealis* Díaz-Aguilar and Ujvári and *M. jasoniana*). *M. jasoniana* J1 and Z1 setae are plumose, not simple. In addition, the left lateral portion of peritremal shield extends beyond coxa IV, while in *M. borealis* the peritremal shield does not extend. Missing adgenital pores, similar to *Skeironozercon*.

Literature Used for Identification

Díaz-Aguilar and Ujvári 2010

Parazercon radiatus Berlese, 1910

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

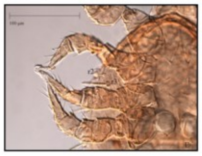
(A) Full body dorsal view.

(B) Full body ventral view.

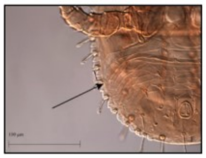
(C) All setae on opisthonotal shield are plumose (feather like).

(D) Peritremes are short without a bend.

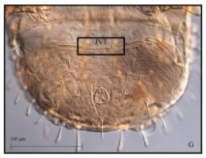
(E) Three setae (r1, r2, and r3) on peritremal shield (r1 not visible).



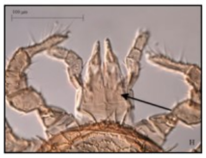
(F) Peritremal shield is fused to ventrianal shield (arrow).



(G) Ventrianal shield with only one pair of setae present (JV1) along anterior border.



(H) *Parazercon*-type tectum (arrow).



Related Taxa

No other species have yet been found in Alberta for this genus. Similar to ***Skeironozercon*** , it has three setae (r1, r2 and r3) on the peritremal shield.

Literature Used for Identification

Sikora 2014

Rafaskas sp. 1

Unless otherwise mentioned, all photos are of adult females

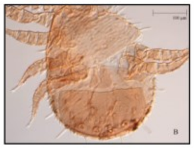
Morphological Characteristics

No males illustrated as no males have yet been found

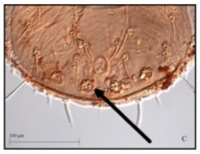
(click images to enlarge)

(A) Full body dorsal view.

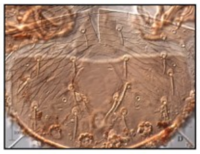
(B) Full body ventral view.



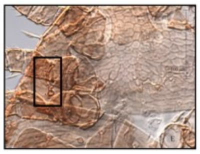
(C) Four sclerotized posterodorsal cavities (arrow).



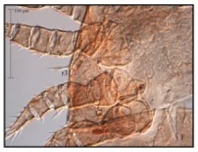
(D) Setae on opisthonotal shield vary in length and type.



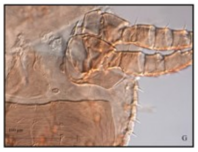
(E) Peritremes are elongate with a bend, and an inner dilation (arrow).



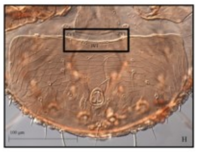
(F) Two setae (r1, r3) on peritremal shield, r3 is short, thorn like (r1 not visible).



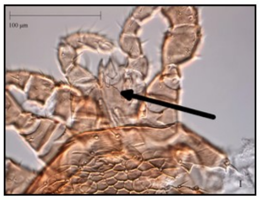
(G) Peritremal shield is not connected to ventrianal shield.



(H) Ventrianal shield with two pairs of setae present (JV1 and ZV1) along anterior border.



(I) *Zercon*-type tectum (arrow).



Related Taxa
No other species have thus far been found in Alberta for this genus. r3 on peritremal shield being thorn like, separates it from other genera found.

Literature Used for Identification
Sikora 2014

Skeironozercon embersoni
Halašková, 1977

Unless otherwise mentioned, all photos are of adult females

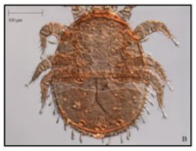
Morphological Characteristics

No males illustrated as no males have yet been found

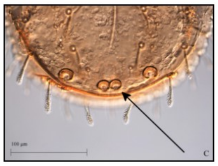
(click images to enlarge)

(A) Full body dorsal.

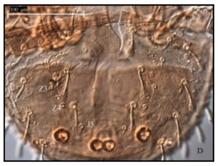
(B) Full body ventral.



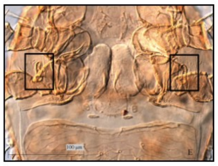
(C) *Skeironozercon embersoni* has four posterodorsal cavities, with the medial cavities joined together (arrow).



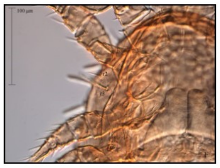
(D) J5, Z3, and Z4 on opisthonotal shield are short and smooth.



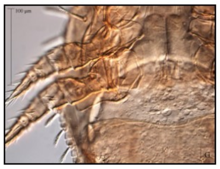
(E) Peritremes are short, without a bend.



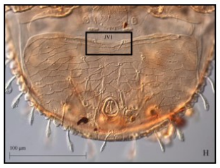
(F) Three setae (r1, r2, and r3) on peritremal shield (r1 not visible).



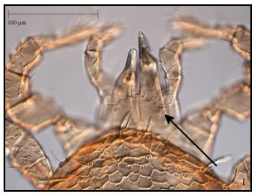
(G) Peritremal shield is not connected to ventrianal shield.



(H) Ventrianal shield with only one pair of setae present (JV1) along anterior border.



(I) *Parazercon*-type tectum (arrow).



Related Taxa

One other species has thus far been found in Alberta within the genus, *Skeironozercon tricavus* Blaszak. *Skeironozercon embersoni* differs from *S. tricavus* as the posterodorsal medial cavities are joined together and J5, Z3, and Z4 are short and smooth.

Literature Used for Identification

Sikora 2014

Skeironozercon tricavus
Blaszak, 1982

Unless otherwise mentioned, all photos are of adult females

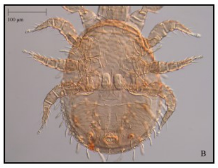
Morphological Characteristics

No males illustrated as no males have yet been found

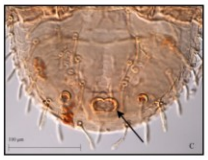
(click images to enlarge)

(A) Full body dorsal

(B) Full body ventral.



(C) *Skeironozercon tricavus* has four posterodorsal cavities, with the medial cavities almost fully fused together (arrow).



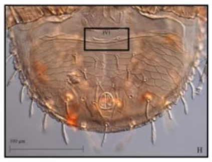
(D) J5, Z3, and Z4 on opisthonotal shield are long and plumose.

(E) Peritremes are short, without a bend.

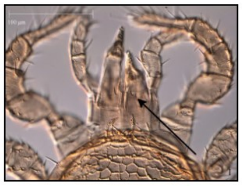
(F) Three setae (r1, r2, and r3) on peritremal shield (r1 not visible).

(G) Peritremal shield is not connected to ventrianal shield.

(H) Ventrianal shield with only one pair of setae present (JV1) along anterior border.



(I) *Parazercon*-type tectum (arrow).



Related Taxa

One other species has thus far been found in Alberta within the genus, *Skeironozercon embersoni* Halašková. *Skeironozercon tricavus* differs from *S. embersoni* as the posterodorsal medial cavities are almost fully fused together and J5, Z3, and Z4 are long and plumose.

Literature Used for Identification

Sikora 2014

Zercon alaskaensis Sellnick, 1958

Unless otherwise mentioned, all photos are of adult females

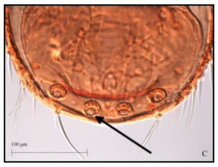
Morphological Characteristics

(click images to enlarge)

(A) Full body dorsal view.

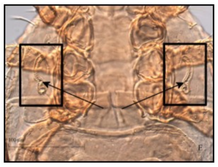
(B) Full body ventral view.

(C) Four sclerotized posterodorsal cavities (arrow).

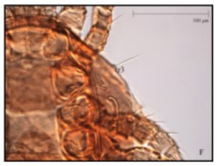


(D) All setae on opisthonotal shield are long and smooth.

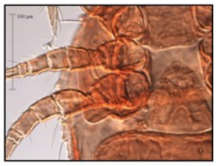
(E) Peritremes are elongate with a bend and an inner dilation (arrows).



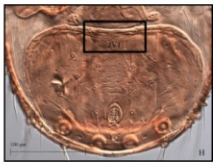
(F) Two setae (r1 and r3) on peritremal shield (r1 not visible).



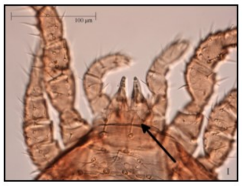
(G) Peritremal shield is not connected to ventrianal shield.



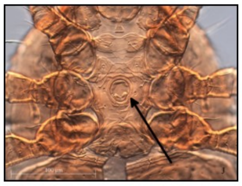
(H) Ventrianal shield with only one pair of setae present (JV1) along anterior border.



(I) *Zercon*-type tectum (arrow).



(J) Male genital opening rests ventrally, in between legs II and III (arrow).



Related Taxa

Five other species have thus far been found within this genus in Alberta. *Zercon alaskaensis* differs from them in having Z2 setae absent on opisthonotal shield.

Literature Used for Identification

Sikora 2014
Halašková 1977

Zercon cf. *columbianus* Berlese, 1910

Unless otherwise mentioned, all photos are of adult females

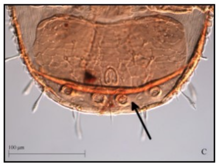
Morphological Characteristics

(click images to enlarge)

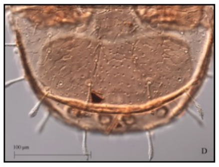
(A) Full body dorsal view.

(B) Full body ventral view.

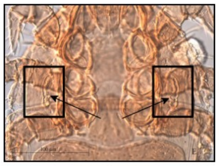
(C) Four sclerotized posterodorsal cavities (arrow).



(D) Setae on opisthonotal shield vary in length, and type.

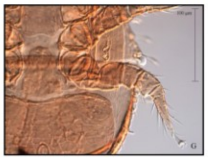


(E) Peritremes are elongate with a bend and an inner dilation (arrows).

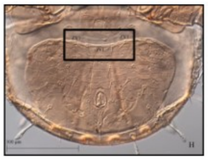


(F) Two setae (r1, r3) on peritremal shield (r1 not visible).

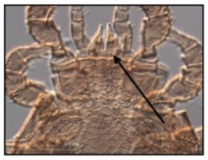
(G) Peritremal shield is not connected to ventrianal shield.



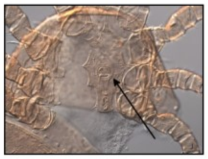
(H) Ventrianal shield with two pairs of setae present (JV1 and ZV1) along anterior border.



(I) *Zercon*-type tectum (arrow).



(J) Male genital opening rests ventrally, in between legs II and III (arrow).



Related Taxa

Five species have thus far been found within this genus in Alberta. *Zercon* c.f. *columbianus* differs from *Z. michaeli* Halašková and *Zercon* sp. 1 by having different length J series setae. *Zercon* cf. *columbianus* and *Zercon columbianus* Berlese are possibly the same species as both have long, plumose setae for J5, Z4, Z5, S4 and S5. Both species also have longer peritremes with a bend and an inner dilation. Pores gdS2 and gdZ4 are in similar locations for both species; however, *Zercon columbianus* has a three tined *Zercon*-type tectum, whereas *Zercon* cf. *columbianus* only has two.

Literature Used for Identification

Sikora 2014

Halašková 1977

Zercon michaeli Halašková, 1977

Unless otherwise mentioned, all photos are of adult females

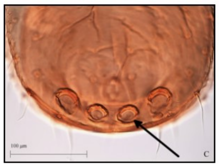
Morphological Characteristics

(click images to enlarge)

(A) Full body dorsal view.

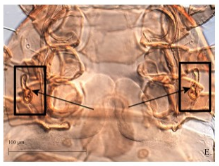
(B) Full body ventral view.

(C) Four sclerotized posterodorsal cavities (arrow).

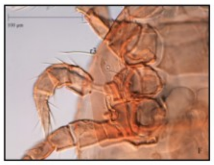


(D) Setae on opisthonotal shield vary in length, but all are smooth.

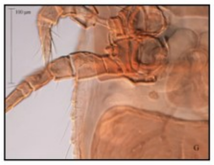
(E) Peritremes are short with an inner dilation (arrows).



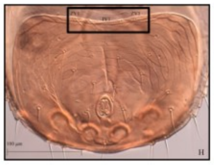
(F) Two setae (r1, r3) on peritremal shield (r1 not visible).



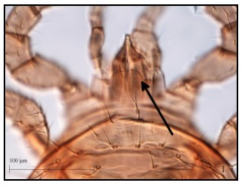
(G) Peritremal shield is not connected to ventrianal shield.



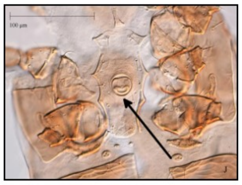
(H) Ventrianal shield with two pairs of setae present (JV1 and ZV1) along anterior border.



(I) *Zercon*-type tectum (arrow).



(J) Male genital opening rests ventrally, in between legs III and IV (arrow).



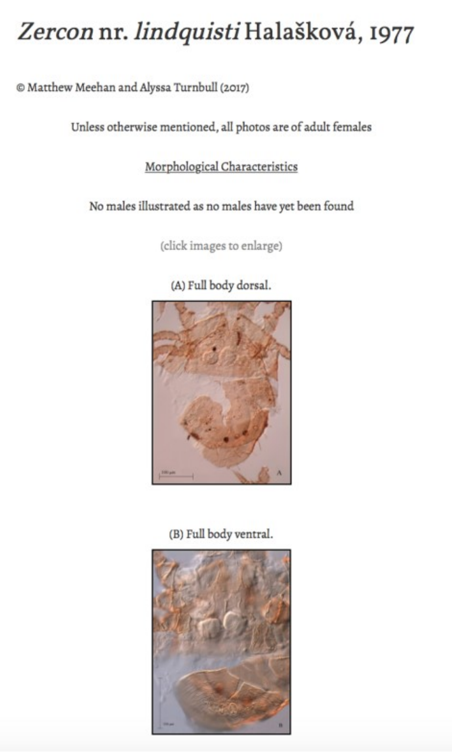
Related Taxa

Five other species have been found thus far within this genus in Alberta. *Zercon michaeli* J series setae are all similar in shape and length, unlike *Z.* cf. *columbianus* Berlese. *Zercon michaeli* Z3 setae reach the base of Z4, unlike *Zercon* sp. 1.

Literature Used for Identification

Sikora 2014

Halašková 1977



Zercon nr. *lindquisti* Halašková, 1977

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

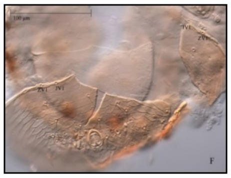
No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

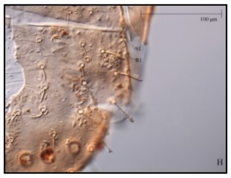
(B) Full body ventral.

(F) Ventrianal shield with two pairs of setae present (JV1 and ZV1) along anterior border.

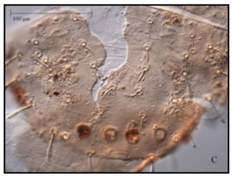


(G) *Zercon*-type tectum.

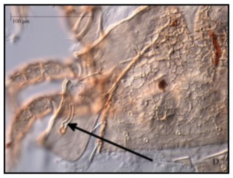
(H) R1 and S1 are dissimiliar in length and type.



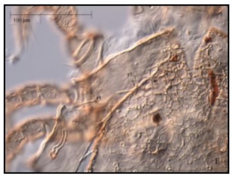
(C) Setae on opisthonotal shield are dissimilar in length and type.



(D) Peritremes are long, with a bend, and with one inner dilation.



(E) Two setae (r1 and r3) on peritremal shield.



Related Taxa
Five other species have been found within this genus in Alberta. *Zercon* nr. *lindquisti* differs from other species found in the genus by having S1 and R1 be dissimilar in length and type. *Zercon* nr. *lindquisti* was determined to not be Zercon lindquisti Halašková due to the different size and type of setae on opisthonotal shield, examples include Z3 and S2.

Literature Used for Identification
Halašková 1977
Sikora 2014

Zercon oregonus Sikora, 2014

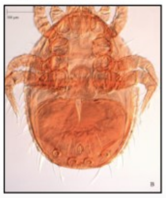
Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

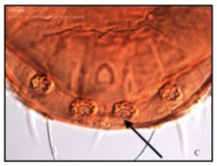
(click images to enlarge)

(A) Full body dorsal view.

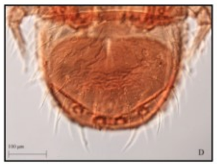
(B) Full body ventral view.



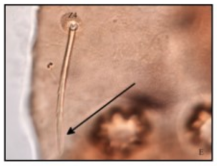
(C) Four sclerotized posterodorsal cavities (arrow).



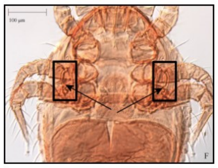
(D) Setae on opisthonotal shield vary in type and length, but are typically long. Setae Z4 and others will have hyaline sheath (see picture E).



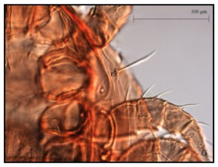
(E) Close up of the hyaline sheath on seta Z4 (arrow).



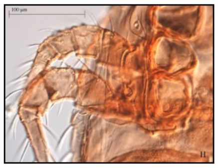
(F) Peritremes are elongate with a bend, and an inner dilation.



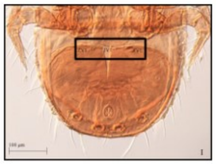
(G) Two setae (r1, r3) on peritremal shield (r1 not visible).



(H) Peritremal shield is not connected to ventrianal shield.

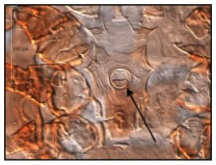


(I) Ventrianal shield with two pairs of setae present (JV1 and ZV1) along anterior border.



(J) *Zercon*-type tectum.

(K) Male Genital opening rests ventrally, in between legs II and III.



Related Taxa

Five other species have been thus far been found within this genus in Alberta. *Zercon oregonus* differs from *Zercon michaeli* Halašková, *Zercon* cf. *columbianus* Berlese and *Zercon* sp. 1 by having J5 reach the posterior margin of the opisthonotal shield. Sikora (2014) has *Zercon oregonus* with a three tined tectum; however, species were observed to have 3-4 tines. No other morphological character was different, meaning that this character may not be a reliable feature for species identification.

Literature Used for Identification

Sikora 2014

Zercon sp. 1

© Matthew Meehan and Alyssa Turnbull

Unless otherwise mentioned, all photos are of adult females

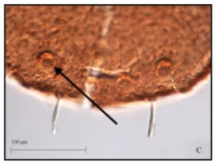
Morphological Characteristics

(click images to enlarge)

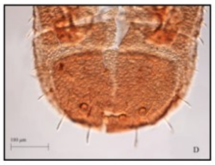
(A) Full body dorsal.

(B) Full body ventral.

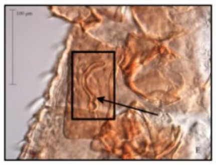
(C) Four sclerotized posterodorsal cavities (arrow).



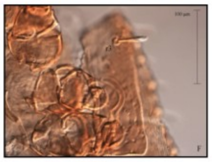
(D) Setae on opisthonotal shield vary in length and type.



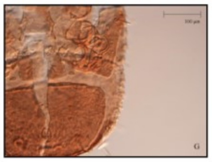
(E) Peritremes are long with a bend and an inner dilation (arrow).



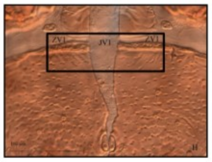
(F) Two setae on peritremal shield (r1 and r3. r1 not visible).



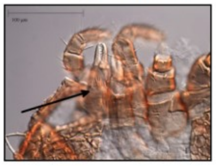
(G) Peritremal shield is not connected to ventrianal shield.



(H) Ventrianal shield with two pairs of setae (JV1 and ZV1).



(I) *Zercon*-type tectum (arrow).



(J) Male genital opening rests ventrally.

Related Taxa

Five other species have thus far been found within this genus in Alberta. Unlike other *Zercon* individuals, these ones were not identified to species level. Using the key provided in Sikora (2014), I identified them to be *Z. morazae* Sikora. Both *Zercon* sp. 1 and *Z. morazae* have barbed r3 and j1 setae. Both species also have long peritremes with a bend and the gdZ1 pores are located anteroparaxially to Z1. However, opisthonotal setae Z4, Z3, S4 and S3 are barbed on *Zercon* sp. 1, while on *Z. morazae* they are simple. Also, *Zercon* sp. 1 tectum has three tines, while *Z. morazae* tectum only has two

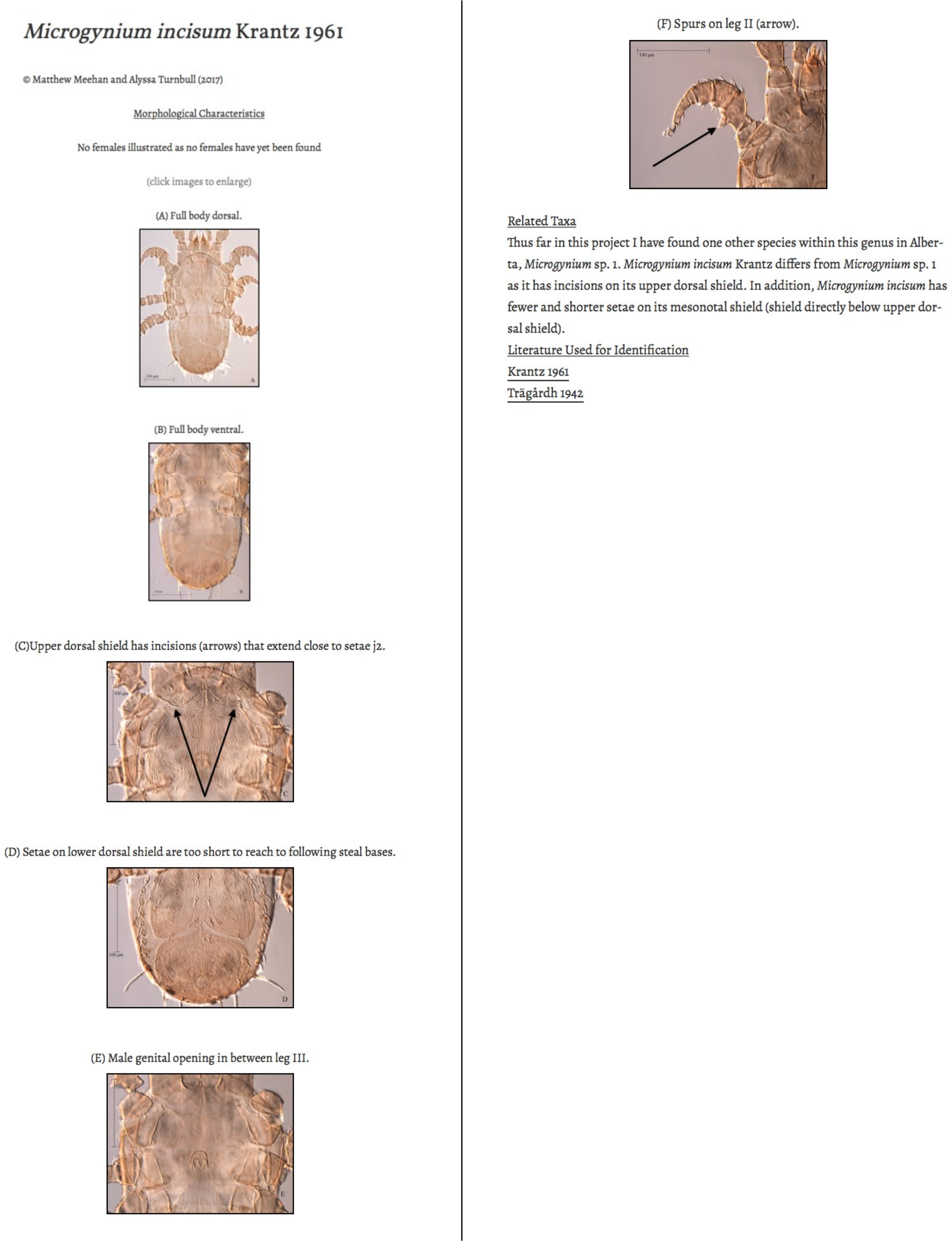
Literature used for identification

Sikora 2014

2.4.5.2 Cohort: Microgyniina

2.4.5.2.1 Microgynioidea

2.4.5.2.1.1 Microgyniidae



Microgynium incisum Krantz 1961

© Matthew Meehan and Alyssa Turnbull (2017)

Morphological Characteristics

No females illustrated as no females have yet been found

(click images to enlarge)

(A) Full body dorsal.

(B) Full body ventral.

(C)Upper dorsal shield has incisions (arrows) that extend close to setae j2.

(D) Setae on lower dorsal shield are too short to reach to following steal bases.

(E) Male genital opening in between leg III.

(F) Spurs on leg II (arrow).

Related Taxa

Thus far in this project I have found one other species within this genus in Alberta, *Microgynium* sp. 1. *Microgynium incisum* Krantz differs from *Microgynium* sp. 1 as it has incisions on its upper dorsal shield. In addition, *Microgynium incisum* has fewer and shorter setae on its mesonotal shield (shield directly below upper dorsal shield).

Literature Used for Identification

Krantz 1961

Trägårdh 1942

Microgynium sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

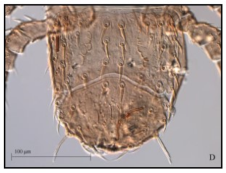
(click images to enlarge)

(A) Full body dorsal.

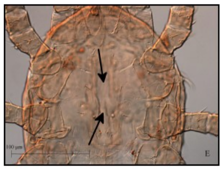
(B) Full body ventral.

(C) Upper dorsal shield, with no incisions.

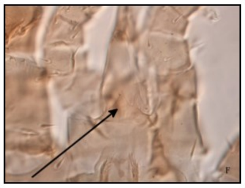
(D) Setae on lower dorsal shield are long enough to reach to following setal bases. S4 is on mesonotal shield..



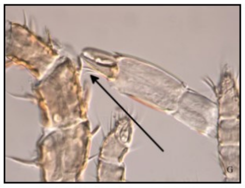
(E) Sternal shield is separated into two distinct shields.



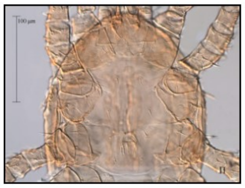
(F) Tectum (arrow).



(G) Chelicera with excrescenes (arrow).



(H) Male genital opening in between leg III.



Related Taxa

Thus far in this project I have found one other species within this genus in Alberta, *Microgynium incisum* Krantz. *Microgynium* sp. 1 differs from *Microgynium incisum* as it is missing incisions on its upper dorsal shield. In addition, *Microgynium* sp. 1 has more, longer setae on its mesonotal shield (shield directly below upper dorsal shield).

Literature Used for Identification

Krantz 1961

Trägårdh 1942

2.4.5.3 Cohort: Uropodina

2.4.5.3.1.1 Dinychidae

Dinychus sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

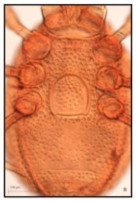
Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

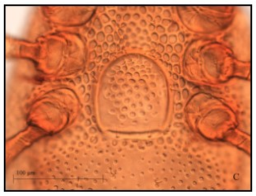
(click images to enlarge)

(A) Full body dorsal.

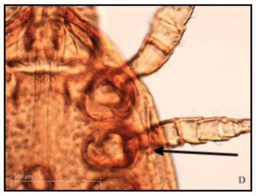
(B) Full body ventral.



(C) Female genital shield, with a foveolate pattern.

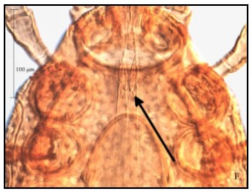


(D) Post-stigmatal part of peritreme extends very little past stigma (arrow, male).

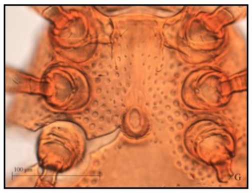


(E) Posteriorly, there is a row of 8 setae on the marginal shield (male).

(F) Chelicera with nodus (arrow).



(G) Male genital shield.



Related Taxa

Thus far in this project I have found seven other species within this genus in Alberta. This species is in the *septentrionalis* group, on the basis of having eight setae on its posterior platelet (Hirschmann et al. 1984). Using the key provided in Kontschán (2010), this species keys to *D. sellnicki* Hutu, because its peritreme has a short extension posterior to the stigma and there are large alveolar pits on the genital shield.

Dinychus sp. 2

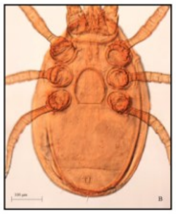
Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

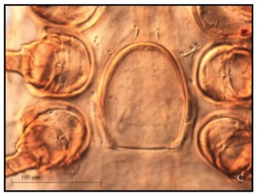
(click images to enlarge)

(A) Full body dorsal.

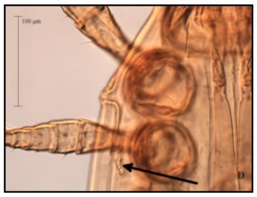
(B) Full body ventral.



(C) Female genital shield, with a punctuated pattern.

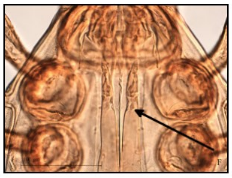


(D) Post-stigmatal part of peritreme extends very little past stigma (arrow, male).

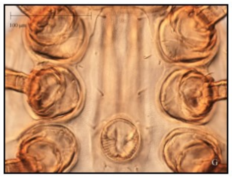


(E) Posteriorly, there is a row of 8 setae on the marginal shield.

(F) Chelicera with nodus (arrow, male).



(G) Male genital shield.



Related Taxa

Thus far in this project I have found seven other species within this genus in Alberta. This species is in the *septentrionalis* group, by having eight setae on its posterior platelet (Hirschmann et al. 1984). Using the key provided in Kontschán (2010), this species keys to *D. micropunctatus* Evans, because its peritreme has a short extension posterior to the stigma and because the idiosoma is dotted.

Literature Used for Identification

Hirschmann et al. 1984

Kontschán 2010

Kontschán 2015

Wagrowska-Adamcyzk and Hirschmann 1984

Dinychus sp. 3

Unless otherwise mentioned, all photos are of adult females

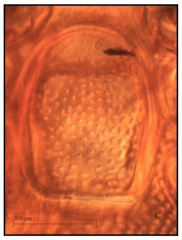
Morphological Characteristics

(click images to enlarge)

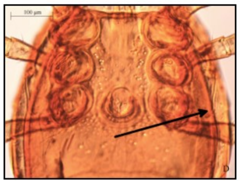
(A) Full body dorsal (male).

(B) Full body ventral (male).

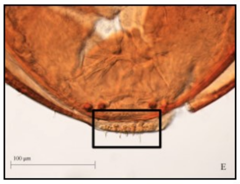
(C) Female genital shield, with a foveolate pattern.



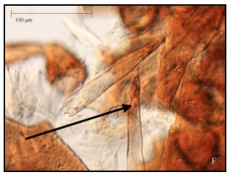
(D) Post-stigmatal part of peritreme extends to leg IV (arrow, male).



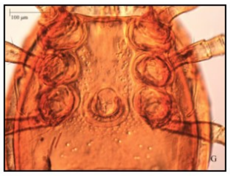
(E) Posteriorly, there is a row of 8 setae on the marginal shield (male).



(F) Chelicera with nodus (arrow, male).



(G) Male genital shield.



Related Taxa
Thus far in this project I have found seven other species within this genus in Alberta. This species is in the *septentrionalis* group, by having eight setae on its posterior platelet (Hirschmann et al. 1984). Using the key provided in Kontschán (2010), this species keys to D. crassus (Trägardh), due to having a long poststigmatid extension and having a reticulate pattern in the sternal region.

Literature Used for Identification
Hirschmann et al. 1984
Kontschán 2010
Kontschán 2015
Wagrowska-Adamcyzk and Hirschmann 1984

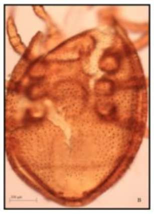
Dinychus sp. 4

Unless otherwise mentioned, all photos are of adult females

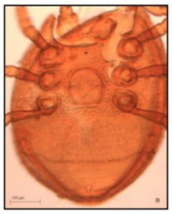
Morphological Characteristics

(click images to enlarge)

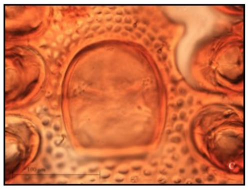
(A) Full body dorsal.



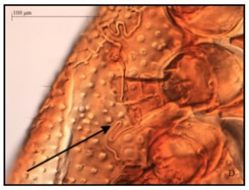
(B) Full body ventral.



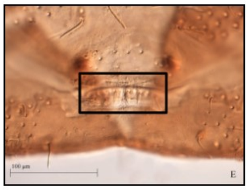
(C) Female genital shield, shield has no ornamentation.



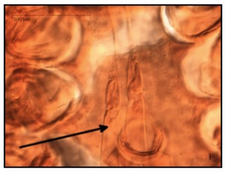
(D) Post-stigmatal part of peritreme extends to leg IV, peritreme is curved posteriorly (arrow).



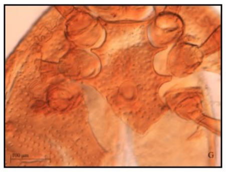
(E) 6 setae lining the posterior platelet.



(F) Chelicera with nodus (arrow).



(G) Male genital shield.



Related Taxa

Thus far in this project I have found seven other species within this genus in Alberta. This species is in the *perforatus* group, on the basis of having six setae on its posterior platelet, made up of both needle-like and feather shaped setae (Hirschmann et al. 1984). Using the key provided in Kontschán (2015), this species keys to *D. inermis* (C. L. Koch), because it has a long poststigmatid extension that bends several times, in addition to having a smooth genital shield.

Literature Used for Identification

Hirschmann et al. 1984
Kontschán 2010
Kontschán 2015
Wagrowska-Adamcyzk and Hirschmann 1984

Dinychus sp. 5

Unless otherwise mentioned, all photos are of adult females

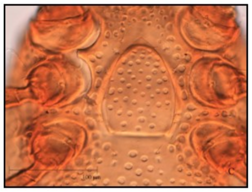
Morphological Characteristics

(click images to enlarge)

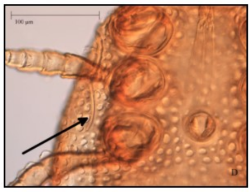
(A) Full body dorsal.

(B) Full body ventral.

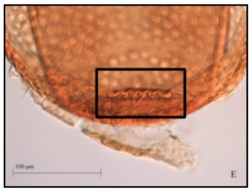
(C) Female genital shield, with a foveolate pattern.



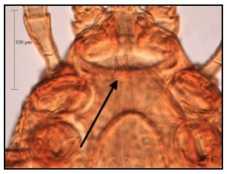
(D) Post-stigmatal part of peritreme extends to between leg III and IV (arrow, male).



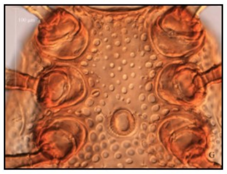
(E) 8 setae lining the posterior platelet (male).



(F) Chelicera with nodus (arrow).



(G) Male genital shield.



Related Taxa

Thus far in this project I have found seven other species within this genus in Alberta. This species is in the *septentrionalis* group, on the basis of having eight setae on its posterior platelet (Hirschmann et al. 1984). Using the key provided in Kontschán (2010), this species keys to *D. onishii* Hiramatsu, because it's peritreme has a long poststigmatid extension and by having two pairs of pilose setae anterior to the row of setae on the posterior platelet.

Literature Used for Identification

Hirschmann et al. 1984

Kontschán 2010

Kontschán 2015

Wagrowska-Adamcyzk and Hirschmann 1984

Dinychus sp. 6

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

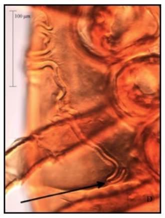
(click images to enlarge)

(A) Full body dorsal.

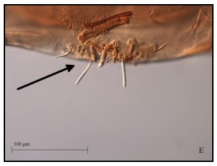
(B) Full body ventral.

(C) Female genital shield, shield is bare. Spiky extension on anterior portion of shield.

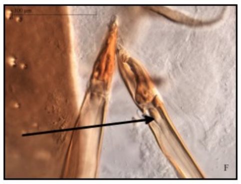
(D) Post-stigmata part of peritreme extends to IV, curves posteriorly.



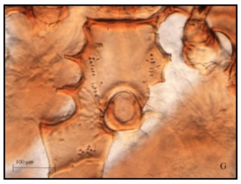
(E) 8 setae lining the posterior platelet (arrow, male).



(F) Chelicera with nodus (arrow, male).



(G) Male genital shield.



Related Taxa

Thus far in this project I have found seven other species within this genus in Alberta. This species is in the *septentrionalis* group, on the basis of having eight setae on its posterior platelet (Hirschmann et al. 1984). This species does not key to any listed in Kontschán (2010).

Literature Used for Identification

Hirschmann et al. 1984
Kontschán 2010
Kontschán 2015
Wagrowska-Adamcyzk and Hirschmann 1984

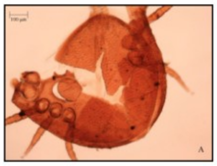
Dinychus sp. 7

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

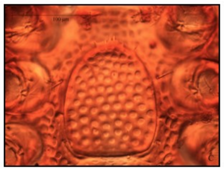
(click images to enlarge)

(A) Full body dorsal.

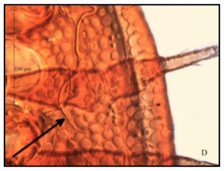


(B) Full body ventral.

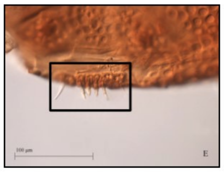
(C) Female genital shield with a foveolate pattern. Spiky extension on anterior portion of the shield.



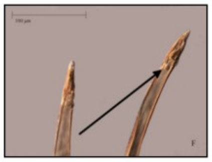
(D) Post-stigmatal part of peritreme extends to between leg III and IV (arrow, male).



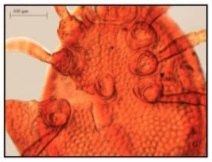
(E) 6 setae lining the posterior platelet (male).



(F) Chelicera with nodus (arrow, male).



(G) Male genital shield.



Related Taxa
Thus far in this project I have found seven other species within this genus in Alberta. This species is in the *perforatus* group, on the basis of having six setae on its posterior platelet, made up of both needle-like and feather shaped setae (Hirschmann et al. 1984). Using the key provided in Kontschán (2015), this species keys to *D. arcuatus* (Trägardh), because it has straight post-stigmatal extensions that reach the central area of leg IV, and because the posterior line of the genital is align with the central area of leg IV.

Literature Used for Identification
Hirschmann et al. 1984
Kontschán 2010
Kontschán 2015
Wagrowska-Adamcyzk and Hirschmann 1984

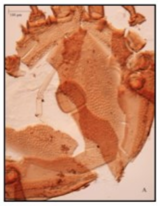
Dinychus sp. 8

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

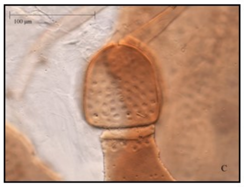
(click images to enlarge)

(A) Full body dorsal.

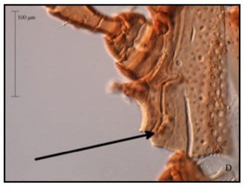


(B) Full body ventral.

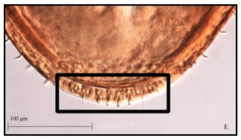
(C) Female genital shield, with a foveolate pattern.



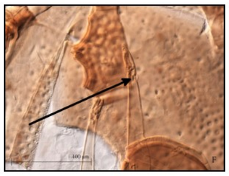
(D) Post-stigmatal part of peritreme extends very little past stigma.



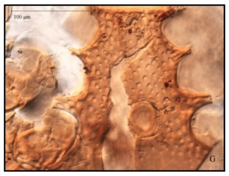
(E) 8 setae lining the posterior platelet (arrow)



(F) Chelicera with nodus.



(G) Male genital shield.



Related Taxa

Thus far in this project I have found seven other species within this genus in Alberta. This species is in the *septentrionalis* group, on the basis of having eight setae on its posterior platelet (Hirschmann et al. 1984). This species does not key to any listed in Kontschán (2010).

Literature Used for Identification

Hirschmann et al. 1984
Kontschán 2010
Kontschán 2015
Wagrowska-Adamcyzk and Hirschmann 1984

Urodiaspis sp. 1

Unless otherwise mentioned, all photos are of adult females

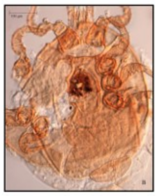
Morphological Characteristics

No males illustrated as no males have yet been found

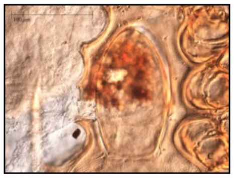
(click images to enlarge)

(A) Full body dorsal.

(B) Full body ventral.

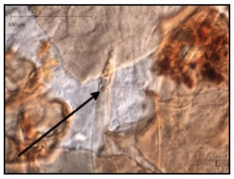


(C) Genital shield.

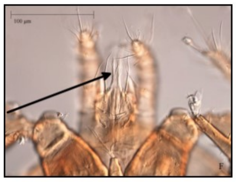


(D) Gnathosoma.

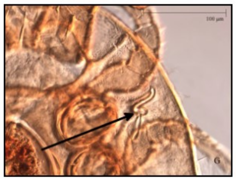
(E) Chelicera with nodus (arrow).



(F) Internal malae.

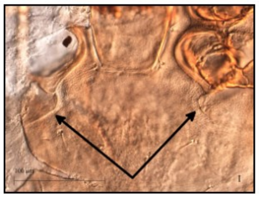


(G) Peritreme.



(H) Anal shield, with two pairs of setae.

(I) Metapodal line (arrows).



Related Taxa

Thus far in this project I have found no other species within this genus in Alberta.

Literature Used for Identification

No primary literature was consulted.

2.4.5.3.1.2 Dithinozerconidae

Iphidinychus sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

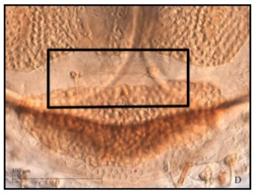
(click images to enlarge)

(A) Full body dorsal.

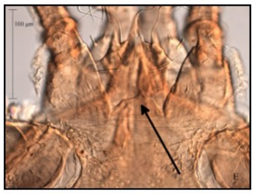
(B) Full body ventral.

(C) Sternal shield, note that st4 is located mesal to st3.

(D) Pair of setae present between pygidial shield and dorsal shield.



(E) Tritosternal base (arrow).

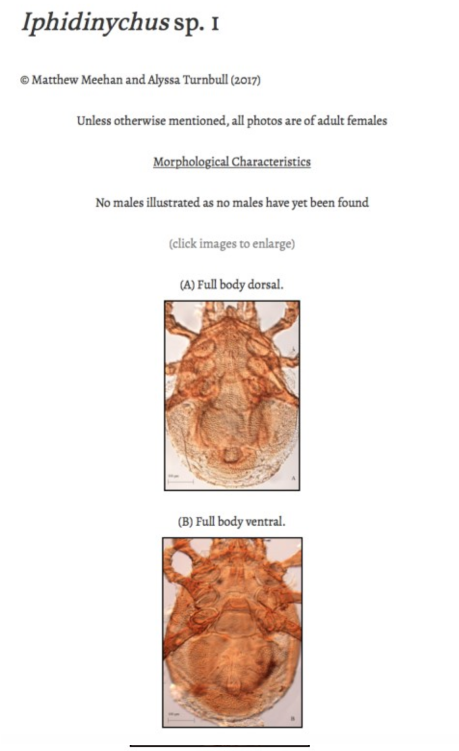


Related Taxa

Thus far in this project I have found one other species within this genus in Alberta, *Iphidinychus* sp. 2. *Iphidinychus* sp. 1 differs from *Iphidinychus* sp. 2 as st4 is mesal to st3 and because a pair of setae is present between the pygidial shield and dorsal shield.

Literature Used for Identification

No primary literature was consulted.



Iphidinychus sp. 1

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

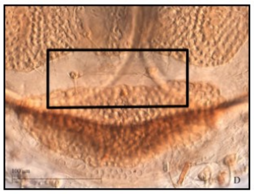
(click images to enlarge)

(A) Full body dorsal.

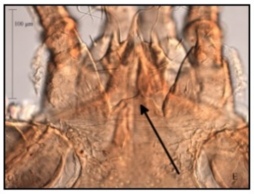
(B) Full body ventral.

(C) Sternal shield, note that st4 is located mesal to st3.

(D) Pair of setae present between pygidial shield and dorsal shield.



(E) Tritosternal base (arrow).



Related Taxa

Thus far in this project I have found one other species within this genus in Alberta, *Iphidinchyus* sp. 2. *Iphidinchyus* sp. 1 differs from *Iphidinchyus* sp. 2 as st4 is mesal to st3 and because a pair of setae is present between the pygidial shield and dorsal shield.

Literature Used for Identification

No primary literature was consulted.

2.4.5.3.1.3 Oplitidae

Unidentified Oplitidae Genus

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

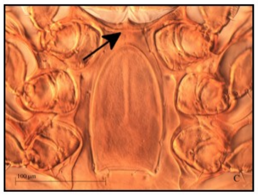
No males illustrated as no males have yet been found

(click images to enlarge)

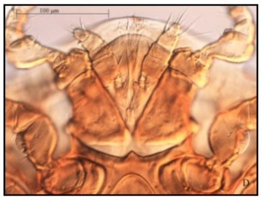
(A) Full body dorsal.

(B) Full body ventral.

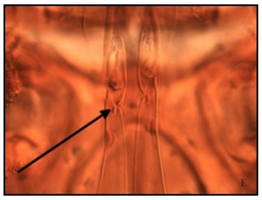
(C) Genital shield, with perigenital ring (arrow).



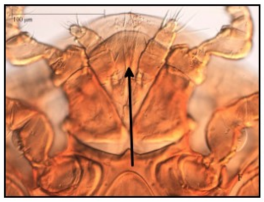
(D) Gnathosoma.



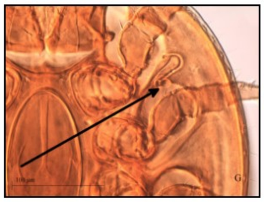
(E) Chelicera with nodus (arrow).



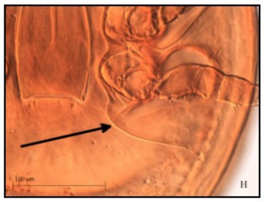
(F) Internal malae, note they are not bushy (arrow).



(G) Peritreme (arrow).



(H) Metapodal line (arrow).



Related Taxa

This species could not be identified to a genus in the Oplitidae. Genera within the family should have a bushy internal malae, unlike the internal malae on this species.

Literature Used for Identification

No primary literature was consulted.

2.4.5.3.1.4 Trachytidae

Trachytes sp. 1

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

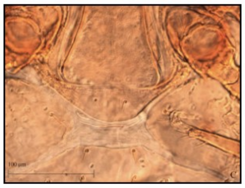
No males illustrated as no males have yet been found

(click images to enlarge)

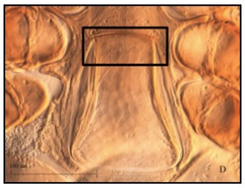
(A) Full body dorsal.

(B) Full body ventral.

(C) No holoventral shield, rather separate genital, ventrianal, and inguinal shields.

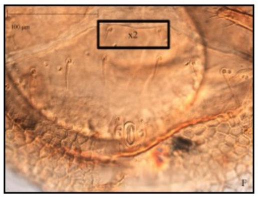


(D) Anterolateral corners of genital shield are pointed.



(E) v2 setae are located mesal to v3 setae.

(F) Setae x2 are on ventrianal shield.

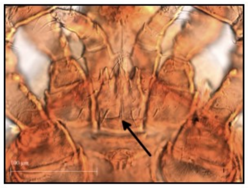


(G) Lateral parts of the vertex are distinctly ribbed and broad (arrow).

(H) Chelicera , with sword like extension (arrow).

(H) Chelicera , with sword like extension (arrow).

(I) Tritosternal base (arrow).



Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. Using the key provided by Mašán (2003), this species keys out to *T. aegrota* (C. L. Koch, 1841); however, *Trachytes* sp. 1 is smaller and has a different arrangement of setae on the ventrianal shield.

Literature Used for Identification

Hirschmann and Zirngibel-Nicol 1965* setae nomenclature
Hirschmann and Zirngibel-Nicol 1969* setae nomenclature
Mašán 2003

2.4.5.3.1.5 Trematuridae

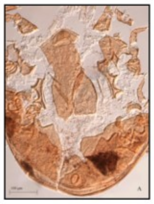
cf. *Trichouropoda* s.l. sp. 1

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

(A) Full body dorsal.

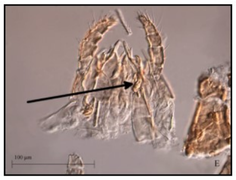


(B) Full body ventral.

(C) Genital shield.

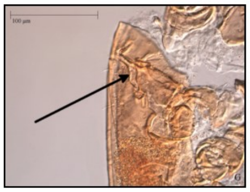
(D) Gnathosoma.

(E) Chelicera (arrow) with nodus.



(F) Internal malae (arrows).

(G) Peritreme (arrow).



Related Taxa

Thus far in this project I have found no other species within this genus in Alberta. As with most Uropodina, this mite was hard to identify to genus-level, as such, changes to this identification are likely.

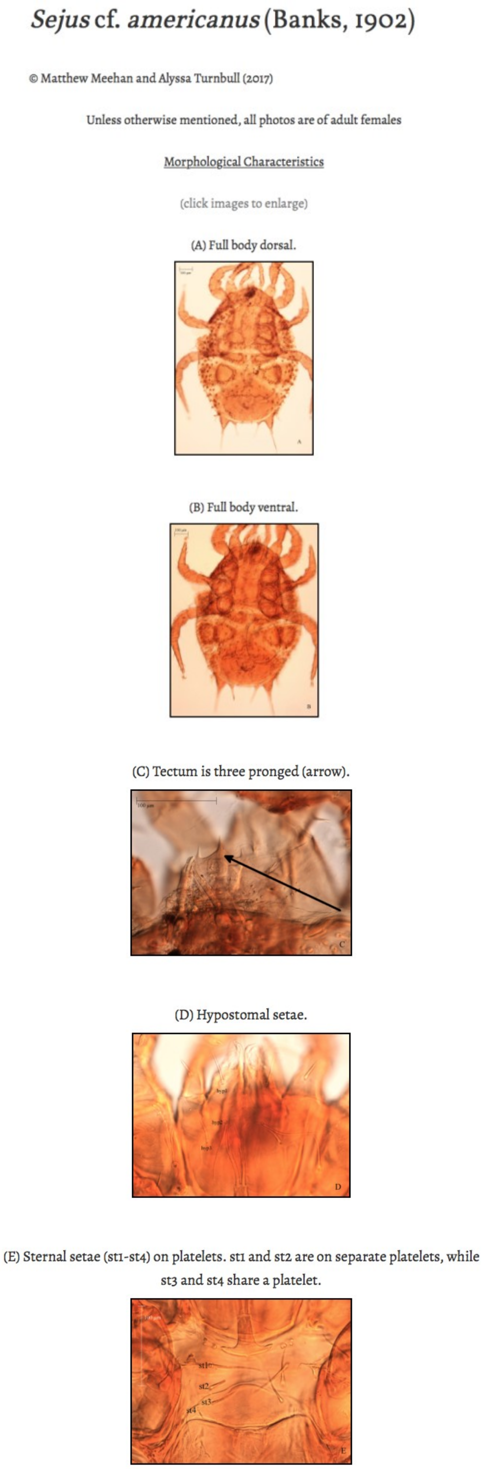
Literature Used for Identification

No primary literature was consulted.

2.4.6 Suborder: Sejida

2.4.6.1.1 Sejoidae

2.4.6.1.1.1 Sejidae



Sejus cf. _americanus_ (Banks, 1902)

© Matthew Meehan and Alyssa Turnbull (2017)

Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

(click images to enlarge)

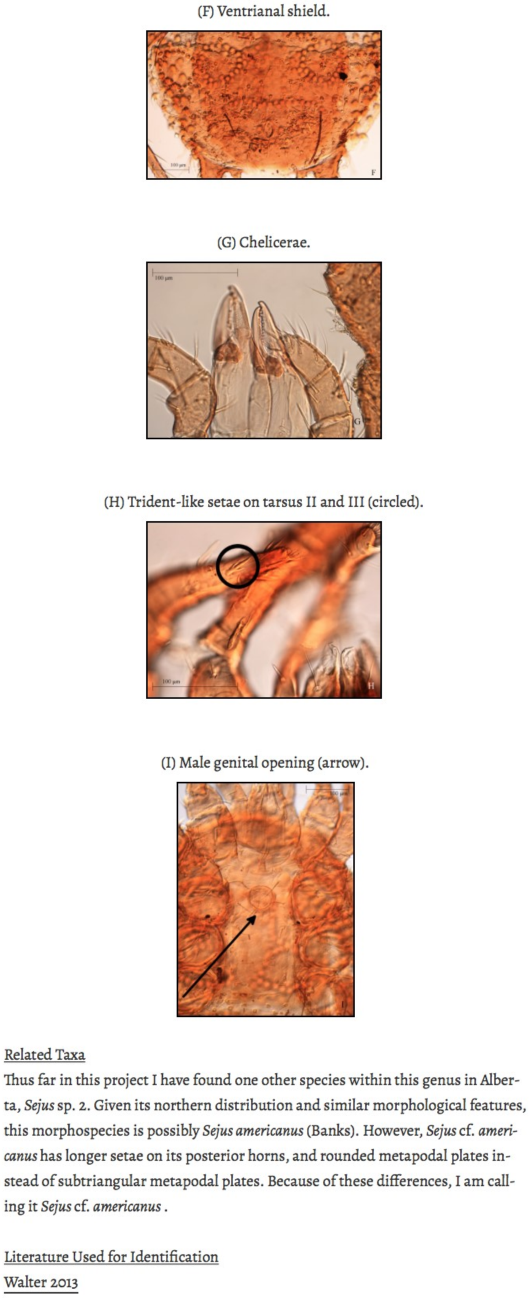
(A) Full body dorsal.

(B) Full body ventral.

(C) Tectum is three pronged (arrow).

(D) Hypostomal setae.

(E) Sternal setae (st1-st4) on platelets. st1 and st2 are on separate platelets, while st3 and st4 share a platelet.



(F) Ventrianal shield.

(G) Chelicerae.

(H) Trident-like setae on tarsus II and III (circled).

(I) Male genital opening (arrow).

Related Taxa

Thus far in this project I have found one other species within this genus in Alberta, *Sejus* sp. 2. Given its northern distribution and similar morphological features, this morphospecies is possibly *Sejus americanus* (Banks). However, *Sejus* cf. *americanus* has longer setae on its posterior horns, and rounded metapodal plates instead of subtriangular metapodal plates. Because of these differences, I am calling it *Sejus* cf. *americanus* .

Literature Used for Identification

Walter 2013

Sejus sp. 2

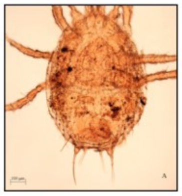
Unless otherwise mentioned, all photos are of adult females

Morphological Characteristics

No males illustrated as no males have yet been found

(click images to enlarge)

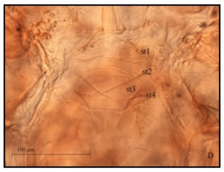
(A) Full body dorsal.



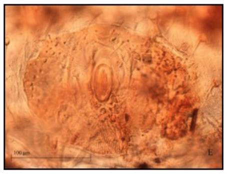
(B) Full body ventral.

(C) Tectum is three pronged.

(D) Sternal setae (st1-st4) on platelets. st1 and st2 are on separate platelets, while st3 and st4 share a platelet.



(E) Ventrianal shield.



(F) Chelicerae.

(G) Trident-like setae on tarsus II and III (circled).

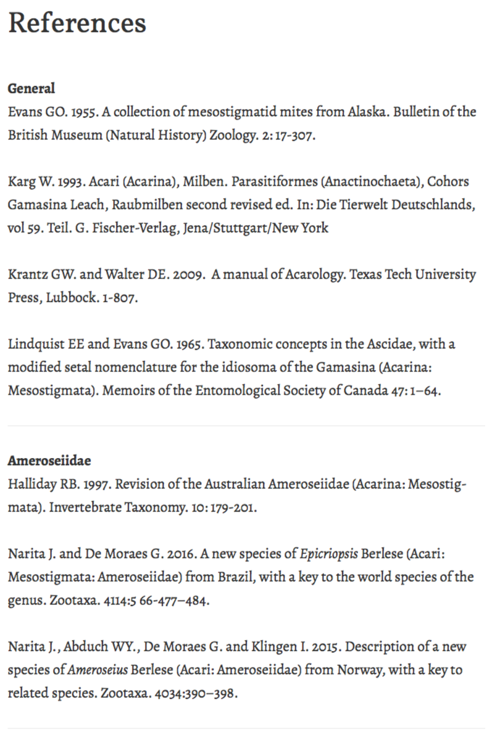
Related Taxa

Thus far in this project I have found one other species within this genus in Alberta, *Sejus* nr. *americanus*. *Sejus* sp. 2 differs from *Sejus* nr. *americanus* (Banks) by having a smaller ventrianal shield with less setae on it.

Literature Used for Identification

Walter 2013

2.4.7 References



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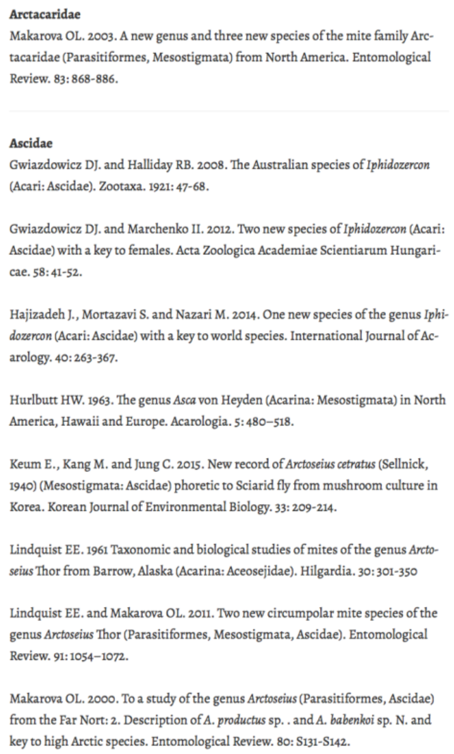

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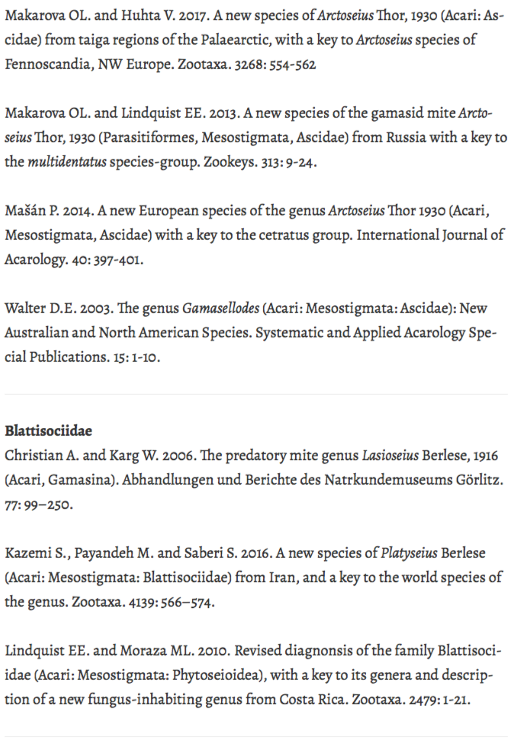

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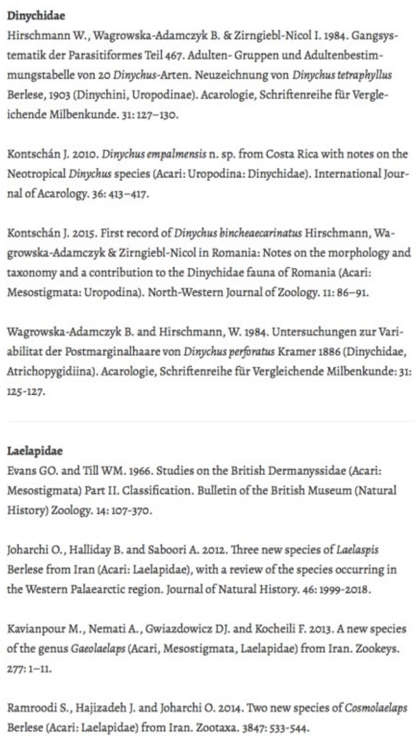

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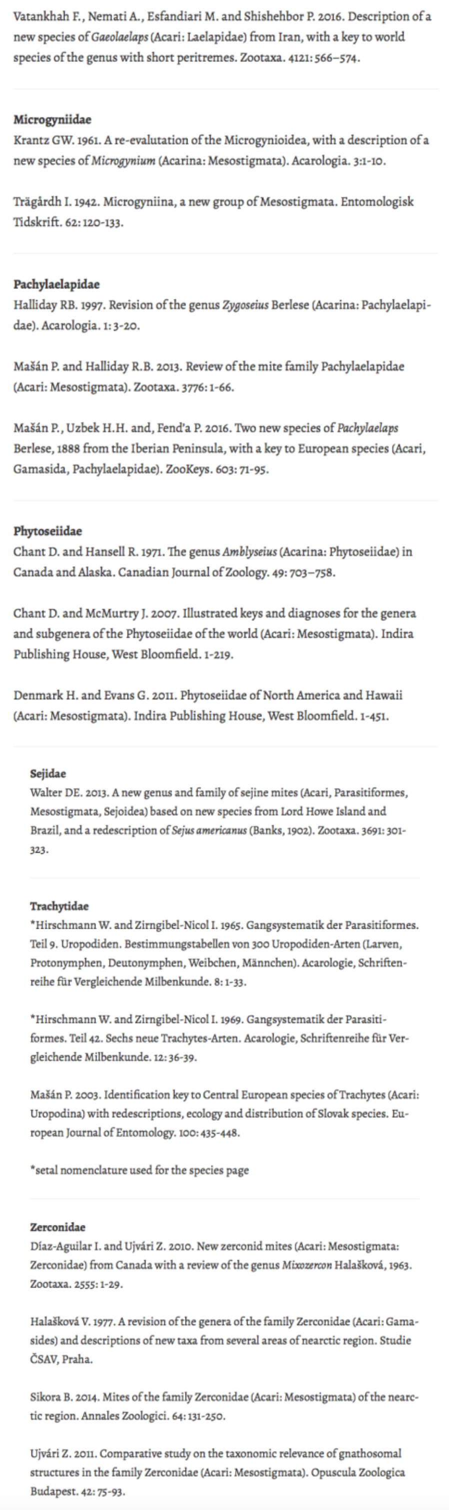

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2.6 Tables and Figures

Table 2-1. List of Mesostigmata species/morphospecies identified in my thesis. The last two columns indicate if the species/morphospecies was included in analyses in Chapter 3 and/or 4. Y=yes, N=no.

Family	Genus	Species	Taxonomic Authority	Year	Chapter 3	Chapter 4	Total Abundance
Ameroseiidae	*Ameroseius*	sp. 1			Y	Y	2
Ameroseiidae	*Ameroseius*	sp. 2			N	Y	2
Ameroseiidae	*Ameroseius*	sp. 3			Y	Y	9
Ameroseiidae	*Epicriopsis*	sp. 1			Y	Y	2
Arctacaridae	*Arctacarus*	*rostratus*	Evans	1955	Y	Y	3
Ascidae	*Arctoseius*	*brevichelis*	Karg	1969	Y	Y	1
Ascidae	*Arctoseius*	*cetratus*	(Sellnick)	1940	Y	Y	11
Ascidae	*Arctoseius*	*cetratus* gr. sp. 1 l			Y	Y	69
Ascidae	*Arctoseius*	*cetratus* gr. sp. 1 s			Y	Y	10
Ascidae	*Arctoseius*	cf. *confusus*	Lindquist	1961	Y	Y	8
Ascidae	*Arctoseius*	cf. *haarlovi*	Lindquist and Makarova	2011	N	Y	1
Ascidae	*Arctoseius*	cf. *idiodactylus*	Lindquist	1961	Y	Y	12
Ascidae	*Arctoseius*	*cf. semiscissus*	(Berlese)	1892	Y	Y	28
Ascidae	*Arctoseius*	*multidentatus*	Evans	1955	Y	Y	28
Ascidae	*Arctoseius*	nr. *minor* sp. 1	Lindquist	1961	Y	Y	41
Ascidae	*Arctoseius*	nr. *minor* sp. 2	Lindquist	1961	N	Y	1
Ascidae	*Arctoseius*	nr. *minutus* sp. 1	(Halbert)	1955	Y	Y	38
Ascidae	*Arctoseius*	nr. *minutus* sp. 2	(Halbert)	1955	Y	Y	13
Ascidae	*Arctoseius*	nr. *weberi*	Evans	1955	Y	Y	115

Family	Genus	Species	Taxonomic Authority	Year	Chapter 3	Chapter 4	Total Abundance
Ascidae	*Arctoseius*	*ornatus* gr. sp. 1			Y	Y	1
Ascidae	*Arctoseius*	*ornatus* gr. sp. 2			Y	Y	2
Ascidae	*Asca*	*aphidoides*	(Linneaus)	1758	Y	Y	57
Ascidae	*Asca*	*garmani*	Hurlbutt	1963	Y	Y	161
Ascidae	*Asca*	*nova*	Willman	1939	Y	Y	3
Ascidae	*Gamasellodes*	sp. 1			Y	Y	1
Ascidae	*Gamasellodes*	sp. 2			Y	N	1
Ascidae	*Iphidozercon*	cf. *altaicus*	Gwiazdowicz and Marchenko	2012	Y	Y	21
Ascidae	*Zerconopsis*	nr. *michaeli*	Evans and Hyatt	1960	Y	Y	43
Ascidae	*Zerconopsis*	sp. 2			Y	Y	1
Blattisociidae	*Cheiroseius*	(*Cheiroseius*) sp. 1			Y	Y	6
Blattisociidae	*Cheiroseius*	(*Cheiroseius*) sp. 2			Y	Y	4
Blattisociidae	*Cheiroseius*	(*Cheiroseius*) sp. 3			Y	Y	7
Blattisociidae	*Cheiroseius*	(*Cheiroseius*) sp. 4			Y	Y	1
Blattisociidae	*Cheiroseius*	(*Posttrematus*) sp. 1			Y	Y	5
Blattisociidae	*Cheiroseius*	(*Posttrematus*) sp. 2			N	Y	3
Blattisociidae	*Cheiroseius*	(*Posttrematus*) sp. 3			Y	N	2

Family	Genus	Species	Taxonomic Authority	Year	Chapter 3	Chapter 4	Total Abundance
Blattisociidae	*Lasioseius*	nr. *oblongus*	(Ewing)	1909	Y	Y	7
Blattisociidae	*Platyseius*	cf. *tendens*	(Schrank)	1803	Y	Y	4
Digamasellidae	*Dendrolaelaps*	sp. 1			Y	Y	23
Digamasellidae	*Dendrolaelaps*	sp. 2			Y	Y	3
Digamasellidae	*Dendrolaelaps*	sp. 3			Y	Y	3
Digamasellidae	*Dendrolaelaps*	sp. 4			Y	Y	13
Digamasellidae	*Dendrolaelaps*	sp. 6			Y	Y	72
Digamasellidae	*Dendrolaelaps*	sp. 7			Y	Y	5
Digamasellidae	*Dendrolaelaps*	sp. 8			Y	Y	99
Digamasellidae	*Dendrolaelaps*	sp. 9			Y	Y	5
Digamasellidae	*Dendrolaelaps*	sp. 11			Y	Y	2
Digamasellidae	*Dendrolaelaps*	sp. 13			Y	Y	4
Digamasellidae	*Dendrolaelaps*	sp. 14			Y	Y	1
Digamasellidae	*Dendrolaelaps*	sp. 15			N	Y	1
Dinychidae	*Dinychus*	sp. 1			Y	Y	45
Dinychidae	*Dinychus*	sp. 2			Y	Y	9
Dinychidae	*Dinychus*	sp. 3			Y	Y	21
Dinychidae	*Dinychus*	sp. 4			Y	Y	8
Dinychidae	*Dinychus*	sp. 5			Y	Y	29
Dinychidae	*Dinychus*	sp. 6			Y	Y	12
Dinychidae	*Dinychus*	sp. 7			Y	Y	23
Dinychidae	*Dinychus*	sp. 8			Y	Y	3
Dinychidae	*Urodiaspis*	sp. 1			Y	Y	1
Dithinozerconidae	*Iphidinychus*	sp. 1			Y	Y	9
Dithinozerconidae	*Iphidinychus*	sp. 2			Y	Y	11
Halolaelapidae	*Halodarcia*	sp. 1			Y	Y	2
Halolaelapidae	*nr. Saprosecans*	sp. 1			Y	Y	6
Laelapidae	*Cosmolaelaps*	sp. 1			Y	Y	1
Laelapidae	*Gaeolaelaps*	sp. 1			Y	Y	89

Family	Genus	Species	Taxonomic Authority	Year	Chapter 3	Chapter 4	Total Abundance
Laelapidae	*Gaeolaelaps*	sp. 2			Y	Y	12
Laelapidae	*Gaeolaelaps*	sp. 3			Y	Y	19
Laelapidae	*Gaeolaelaps*	sp. 4			Y	Y	4
Laelapidae	*Hypoaspis*	sp. 1			Y	Y	1
Laelapidae	*Laelaspis*	sp. 1			Y	N	1
Laelapidae	*Ololaelaps*	*veneta*	(Berlese)	1904	Y	Y	7
Melicharidae	*Proctolaelaps*	sp. 1			Y	Y	1
Melicharidae	*Proctolaelaps*	sp. 2			Y	Y	1
Microgyniidae	*Microgynium*	*incisum*	Krantz	1961	Y	Y	1
Microgyniidae	*Microgynium*	sp. 1			Y	Y	60
Ologamasidae	*Gamasellus*	sp. 1			Y	Y	27
Ologamasidae	*Gamasellus*	sp. 2			Y	Y	204
Ologamasidae	*Gamasellus*	sp. 3			Y	Y	1
Oplitidae	*G.*	sp. 1			Y	Y	6
Pachylaelapidae	*Pachylaelaps*	sp. 1			Y	Y	28
Pachylaelapidae	*Zygoseius*	*furciger*	Berlese	1916	Y	Y	30
Parasitidae	*Paragamasus*	sp. 1			Y	N	4
Parasitidae	*Volgarogamasus*	sp. 1			N	Y	1
Phytoseiidae	*Amblydromalus*	sp. 1			Y	Y	1
Phytoseiidae	*Amblyseuis*	sp. 1			Y	N	1
Phytoseiidae	*Arrenoseius*	sp. 1			Y	Y	1
Phytoseiidae	*Chelaseius*	*floridanus*	(Muma)	1955	Y	Y	5
Phytoseiidae	*Neoseiulus*	sp. 1			Y	Y	9
Phytoseiidae	*Proprioseiopsis*	sp. 1			Y	Y	2
Phytoseiidae	*Proprioseiopsis*	sp. 2			Y	N	1
Rhodacaridae	*Rhoadacarellus*	sp. 1			Y	Y	4
Sejidae	*Sejus*	cf. *americanus*	(Banks)	1902	Y	Y	20
Sejidae	*Sejus*	sp. 2			N	Y	1
Trachytidae	*Trachytes*	sp. 1			Y	Y	193

Trematuridae	*cf. Trichourpoda*	sp. 1			N	Y	1
Zerconidae	*Boreozercon*	*emendi*	Díaz-Aguilar and Ujvári	2010	Y	Y	77
Zerconidae	*Mixozercon*	*borealis*	Díaz-Aguilar and Ujvári	2010	Y	Y	59
Zerconidae	*Mixozercon*	*jasoniana*	Díaz-Aguilar and Ujvári	2010	Y	Y	18
Zerconidae	*Parazercon*	*radiatus*	Berlese	1910	Y	Y	621
Zerconidae	*Rafaskas*	sp. 1			Y	Y	2
Zerconidae	*Skeironozercon*	embersoni	Halašková	1977	Y	Y	90
Zerconidae	*Skeironozercon*	*tricavus*	Blaszak	1982	Y	Y	509
Zerconidae	*Zercon*	*alaskaensis*	Sellnick	1958	Y	Y	193
Zerconidae	*Zercon*	cf. *columbianus*	Halašková	1977	Y	Y	30
Zerconidae	*Zercon*	*michaeli*	Halašková	1977	Y	Y	5
Zerconidae	*Zercon*	nr. *linquisti*	Halašková	1977	Y	Y	1
Zerconidae	*Zercon*	*oregonus*	Sikora	2014	Y	Y	5
Zerconidae	*Zercon*	sp. 1			Y	Y	3
Zerconidae	*Zercon*	sp. 2			N	Y	1

3 Chapter 3: The Roles of Environmental and Spatial Factors in Structuring Assemblages of Forest-floor Mesostigmata in Northern Alberta, Canada

3.1 Introduction

Many environmental and spatial factors influence the composition of communities. These factors can affect communities at more than one spatial scale, and a given taxon can be affected by different environmental factors at different spatial scales (Wheatley 2010; da Silva et al. 2015). Typically though, factors such as niche preferences and dispersal capacity greatly structure community composition (Leibold et al. 2004; Leibold and McPeek 2006), in addition to environmental filtering, biotic interactions, and disturbance (Bengtsson 2002; Gotelli et al. 2010; Ingimarsdóttir et al. 2012; Maaß et al. 2015). At a very broad scale, species richness (both taxon-specific and at the community level) decreases with increasing latitude (Willig et al. 2003), while beta diversity can be influenced by spatial distance (Legendre et al. 2005). Beta diversity (sensu Whittaker 1960) combines both local diversity (alpha diversity) and landscape diversity (gamma diversity) to determine the change in species composition between regions. Beta diversity is made up of two phenomena, species turnover and nestedness. Species turnover is the replacement or addition of species present in one site, by different species in a different site. In contrast, nestedness is when species-poor sites are compositional subsets of species-rich sites (Wright and Reeves 1992; Qian et al. 2005; Baselga 2010)

Aboveground and belowground systems are intimately linked with one another (Wardle et al. 2004). Yet belowground systems remain a “black box” because they are physically opaque and difficult to study (Cortois and de Deyn 2012). Because of their diversity, they have been called the “poor man’s tropical forest” (Giller 1996). The dominant animals in soil systems are nematodes and microarthropods (Coleman et al. 2004). The most diverse of the soil microarthropods are the primarily fungivorous and detritivorous oribatid mites (Acariformes: Sarcoptiformes: Oribatida), with about 9000 described species (not including the cohort Astigmata) (Norton and Behan-Pelletier 2009). There has been a fair number of studies determining the factors that influence assemblage structure of soil oribatids (Maraun and Scheu 2000; Lindo et al. 2008; Lindo and Winchester 2008; Lindo and Winchester 2009; Vu 2011; Erdmann et al. 2012). In contrast, relatively little is known of what factors influence diversity and assemblage structure of the dominant microarthropod predators in soil, members of the mite order Mesostigmata (Parasitiformes). With 11,000 described species, mesostigmatid mites are the most species rich order within Parasitiformes (Arachnida: Parasitiformes: Mesostigmata) (Walter and Proctor 2013). Most mesostigmatid mites are soil predators, but some are symbionts of vertebrates or invertebrates. Most free-living soil mesostigmatid mites prey on nematodes and collembolans, with very few consuming fungi (Walter and Proctor 1998; Klarner et al. 2013; Walter and Proctor 2013). Soil Mesostigmata are extremely abundant, and can have roughly the same biomass as larger soil predators, like centipedes and beetles (Scheu et al. 2003). They are also important for ecosystem function, as they are connected to the three main energy channels in soil: primary production from plants and fungal and bacterial pathways (Ruf and Beck 2005).

In Mesostigmata, habitat types (Nielsen et al. 2008; Beaulieu 2012; Nielsen et al. 2012; Díaz-Aguilar et al. 2013) and plant form groups (e.g. moss, lichens, shrubs (Mitchell et al. 2017)) influence assemblage composition. In contrast, there is less evidence that microhabitats affect assemblages, as Čoja and Bruckner (2003) found similar assemblages within different microhabitats. Microhabitats tested by Čoja and Bruckner (2003) include different layers of mineral soils, and spruce needles and rotten spruce branches (decay class three) found on the forest floor. In addition to being found in soil, mesostigmatid mites associated with forest floors are also found in downed woody debris (DWD hereafter). DWD encompasses both coarse woody debris (CWD) and fine woody debris (FWD) (ABMI 2012), and is made up of bark, chunks of wood, and snags (Harmon et al. 1986). Some studies indicate that DWD is important in maintaining Mesostigmata diversity, as different decay classes of DWD can host distinct assemblages of mites (Gwiazdowicz et al. 2011; Beaulieu 2012).

As a group, soil Mesostigmata can survive in temperatures as high as 45°C (Avdonin and Striganova 2004) to as low as -11°C (Convey et al. 2015); however, it is unlikely that any single species can endure such a temperature range. The effects of precipitation and soil moisture on mesostigmatid mite assemblages range from strong (Berg et al. 1998; Bedano and Ruf 2007; Wissuwa et al. 2012), to negligible (Nielsen et al. 2008). Nielsen et al. (2010) found that precipitation can influence Mesostigmata assemblages more strongly than vegetation or soil properties. These results may be scale-dependent though, as Nielsen et al. (2008) found that soil moisture had little effect on assemblage composition in a small sampling area, while Nielsen et al. (2010) found the opposite, with a large sampling area.

Disturbance can be either natural or anthropogenic, and has been observed to affect Mesostigmata assemblages in Europe (Koehler 1999; Bogorodskaya et al. 2010; Madej and Kozub 2014). Disturbance events can vary in frequency, type, and intensity and is expected to disrupt ecosystem and community structure (White and Pickett 1985), by shifting community composition to an alternative state (Bender et al. 1984; Bengtsson 2002). These events can be "pulses" (brief) or "presses" (long lasting) with its effect on the community depending on the event itself, and whether species are pre-adapted or can adapt to it.

Support for an independent effect of space on assemblage structure of Mesostigmata ranges from tenuous (Chen et al. 2014) to strong (Nielsen et al. 2012). Similar to the effects of precipitation, this may be scale dependent. Chen et al. (2014) tested the influence of space on mite assemblages on moss carpets in Canada at a large scale (3-130 km), while Nielsen et al. (2012) tested it at < 1 km scale, in a forest habitat in Europe. Surprisingly, despite the distance spanned in their study, Chen et al. (2014) did not find that beta diversity increased with increasing spatial distance. Dispersal ability of the members of the assemblage will greatly influence the effect of spatial distance on beta-diversity (Hubbell 2001; Soininen et al. 2007); however, abiotic and biotic factors can correlate with spatial distance and may be the true drivers of community composition (Nielsen et al. 2012).

In this study, I sought to understand the environmental and spatial factors that influence assemblage structure of mesostigmatid mites from the boreal forest in northern Alberta, with the goal of improving our understanding of their ecology. Given the scale studied, I predict that landscape factors like mean annual temperature and precipitation will greatly influence Mesostigmata assemblages (Nielsen et al. 2010; Erdmann et al. 2012). In addition, I predict that distance between sampled assemblages will also greatly influence their composition, given their relatively low autonomous dispersal rate compared to that of larger-bodied or winged arthropods (Cameron et al. 2013).

3.2 Methods

3.2.1 Sampling Technique

Samples for this study were collected by the Alberta Biodiversity Monitoring Institute (ABMI) and provided by the Royal Alberta Museum (RAM) in Edmonton, Alberta. Sampling and extraction methods are described in Chapter 2, Methods 2.2.1. Results presented in this chapter are based only on adult mesostigmatid mites from the 50-300 μm and > 300 μm residuals for analysis. A list of published taxonomic literature used for identification can be found in Chapter 2.

3.2.2 Environmental and Spatial Data

ABMI provides approximate site location coordinates that are within 5 km of the true sampling points through their online data portal (ABMI 2014, Figure 1); however, they do not provide quadrant-level locations (where soil samples are collected), these locations were created on ArcGIS. For this study, all spatial data manipulation was performed on ArcMap 10.1, while layers and geographic coordinates were projected into NAD83 (CSRS) / Alberta 10-TM (Forest) coordinate system (ESRI 2011). Quadrant-level locations were generated by applying an 80 m distance in the NE (45°), NW (315°), SE (135°) and SW (225°) direction from site-center. ABMI also does not provide the locations of off-grid sites; because of this, a 2 km buffer was placed around each corresponding on-grid site (e.g. 2 km buffer around 1171 for OG-ABMI-1171-1) and a random point was placed within the buffer that was used as the off-grid site. Quadrant-level locations for off-grid sites were generated as described above for on-grid sites.

ABMI samples more than 20 environmental variables within each quadrant. The variables they sampled that were used for this study are: natural and anthropogenic disturbance types and intensities (as measured by % of the quadrant disturbed), land cover (animal matter, bare ground, fungi, grass, lichen, litter, moss, other vascular plants, rock, sedge/rush, shrub, water, and wood), number of small DWD pieces, and diameter width and decay class of large DWD. For this study, I took the median decay class of DWD sampled, and the sum of diameters of all large DWD pieces. Land cover data and DWD (both small and large) data were collected within the quadrant itself, and not where soil samples are collected. For this study, they acted as a proxy for the soil sample locations. In addition, land cover type that was calculated to be "<1%", was changed to 0.5 to make it amenable to data analysis. Additional environmental data on average annual precipitation and temperature were downloaded from WorldClim bioclimatic variables (30 arc seconds) from the WorldClim database at http://www.worldclim.org/version1 (Hijmans et al. 2005). On ArcMap, the extract values from points tool was used to obtain precipitation and temperature data for each quadrant location.

3.2.3 Statistical Analysis

All analyses were performed using the R statistical program (R Core Team 2017). I used a rarefaction curve (via the "specaccum" function from the package vegan) to determine if further sampling would have revealed more taxa of Mesostigmata. I ran unconstrained (NMDS) and constrained (redundancy analysis, hereafter RDA) ordinations to determine the influence on the environment on assemblage composition. For this, disturbance intensity and 2-dimensional land cover variables were arcsine/square root transformed, while precipitation, temperature, number of small DWD pieces and sum of large DWD were log transformed. Decay class of DWD was made numeric, and not kept as a categorical variable.

NMDS (non-metric multidimensional scaling) plots were created with transformed (log (x+ 1)) abundance data showing assemblage composition within each quadrant. NMDS is an unconstrained ordination, meaning no additional factors (e.g. environmental variables) influence the formation of the plot. Singletons were taken out of the NMDS; for this study, singletons were defined as any species/morphospecies that only appeared in one quadrant. Additionally, outliers were also taken out of the NMDS. The first NMDS plot was overlaid with common species/morphospecies. 'Common' species/morphospecies were defined as species that were present in 25 or more quadrants, and had 50 or more individuals. The second NMDS plot contained 'relevant' species/morphospecies; I defined relevant species/morphospecies as those with the largest axis loading while forming the multivariate plot. In addition, significant environmental variables (as determined by "envfit" in vegan), and disturbance types were also overlain on the ordinations. As NMDS is an unconstrained ordination, environmental variables do not affect the structure of the NMDS plot; rather, environmental variables and disturbance types are plotted post hoc, to determine if there is any correlation between quadrants and environmental variables. NMDS plots were produced using the "metaMDS" function in the vegan package, while coordinates for the environmental variables, and disturbance types were determined using the "envfit" function in vegan.

RDA's were performed with the "rda" function in the vegan package. For this, community data were Hellinger transformed. RDA is a constrained ordination, meaning that environmental variables influence the positioning of species/morphospecies in the ordination plot. Forward selection was performed to determine the significant environmental variables that correlate mesostigmatid mite assemblages (Blanchet et al. 2008). Disturbance types were not analyzed using the RDA as forward selection can not be done with nominal groups (unless dummy variables are used for analysis), such as disturbance types. Top variables were determined by forward selection based on adjusted R^2. Similar to the NMDS, both relevant and common species were plotted with significant environmental variables. Spatial data (quadrant locations) were produced through distance-based Moran's eigenvector maps (positive autocorrelation), using the "dbmem" function in the adespatial package. RDA's were performed with Monte Carlo permutation tests (999 permutations). Partitioning analysis was also used to tease apart the effects of environmental and spatial variables on mesostigmatid mite assemblages. Collinearity was tested for using Variance Inflation Factor (VIF) (determined through the "vif" function in car package. I applied a stepwise reduction of highly collinear variables (VIF >10) starting with the largest, until all environmental factors had a VIF score < 10.

In addition, I ran generalized linear models to observe the effect of increasing latitude on mite species richness and number of individuals per quadrant. For these models I used a negative binomial distribution, because species richness and number of individuals had overdispersed count data. I also tested whether patterns in beta diversity (Sørenson's dissimilarity) were best explained by nestedness or by species turnover using the "beta.multi" feature from the package betapart. In addition, I tested whether beta diversity increased with greater spatial distance between quadrants through a Mantel test. For this, Sørenson's dissimilarity matrix (created with "beta.part" function in betapart) was compared to a matrix of geographic coordinates of sites with Euclidean distances applied to it. In addition, a partial Mantel was run to evaluate the "pure" effect of spatial distance on beta diversity, with environmental data acting as a condition. For this, the transformed environmental data went into a PCA, with the first two PCA axes being extracted. Afterwards, a Euclidean distance was applied to the PCA axes. Prior to the PCA, the environmental data were standardized using the "decostand" function in vegan.

3.3 Results

In total, I identified 21 families, 43 genera and 101 species/morphospecies from 3021 individual Mesostigmata, with rarefaction analysis suggesting that quadrants had been sufficiently sampled (Figure 3-2). I found an average of 5.25 ± 2.92 (mean ± SD) species/morphospecies and 13.98 ± 12.38 individuals within quadrants. Images of species/morphospecies identified for this study can be found at Meehan and Turnbull (2017) (Table 2-1). NMDS plots showed little aggregation between common species and environmental variables, or disturbance types (Figure 3-3); however, there was some overlap between relevant species and both environmental variables and disturbance type (Figure 3-4). Notably, there was little overlap between environmental variables (Figure 3-5) and disturbance types, suggesting that quadrants are influenced differently by these variables (Figure 3-6).

The RDA model was significant ($P = 0.001$). Eleven environmental variables were found to potentially influence mesostigmatid mite assemblages, the top three being % moss cover, precipitation and disturbance intensity (Table 3-1). Through variance partitioning, I found that environmental alone explained 5.1%, spatial variables alone explained 5.5% and that environmental ∩ spatial explained 4.8% of assemblage composition, leaving ~ 85% of the variance unexplained (Figure 3-7 and Figure 3-8).

My GLMs showed latitude was not correlated with species richness ($P = 0.49$) or number of individuals ($P = 0.68$) (Figure 3-9). Species turnover explained considerably more variation in the assemblages (98.2%) than did nestedness (0.6%), meaning that beta diversity was driven by species turnover. Finally, Mantel and partial Mantel tests showed that beta diversity increased with spatial distance between samples, regardless of the influence of environmental dissimilarity (with environment, $r_m = 0.147$, $P < 0.01$, without environment, $r_m = 0.184$, $P < 0.01$) (Figure 3-10).

3.4 Discussion

The aim of my study was to assess the potential influence of environmental variables and spatial distance on assemblage structure of forest-associated mesostigmatan mites from northern Alberta. I predicted that landscape-level variables like mean temperature and precipitation would influence assemblages greatly, and that distance between assemblages would also explain composition well. I found that precipitation but not temperature was strongly correlated with assemblages of Mesostigmata, and that pure spatial distance explained as much variation in assemblages as did environmental variables. I also determined that land cover variables such as moss, lichen and litter were also correlated with assemblage composition, in addition to disturbance intensity.

Precipitation strongly correlated with assemblage composition as it likely filters species in local communities (Dornelas et al. 2006; Gao et al. 2014). Precipitation has previously been found to influence Mesostigmata assemblages (Nielsen et al. 2010), and suggests that climate is important factor in regulating Mesostigmata assemblages. At large spatial scales, climate will regulate species distribution (Hortal et al. 2010), and can correlate more with belowground composition than habitat type (Erdmann et al. 2012). Interestingly, temperature did not significantly correlate with Mesostigmata assemblage composition. This is possibly due to temperature being similar across all quadrants (temperature range was 6.8°C), while precipitation varied relatively more (precipitation range was 214 mm).

Studies such as those by Mitchell et al. (2017) have found that different land cover types (e.g. moss and lichen) explained Mesostigmata assemblage composition more than aboveground flora communities. If mesostigmatid mites are indeed as unaffected by microhabitats as suggested by Čoja and Bruckner (2003) changes in prey groups may be driving this response to land cover. Mesostigmatid mites feed mainly on nematodes and lightly sclerotized microarthropods including collembolans and certain oribatids (Schneider and Maraun 2009, Klarner et al. 2013). All three prey groups have some degree of specialization of food source (Bongers and Bongers 1998; Chahartaghi et al. 2005; Bluhm et al. 2015), meaning that their assemblages could be directly affected by different land cover types.

Disturbance intensity greatly influenced Mesostigmata assemblage structure. Disturbance can shift mortality rate and carrying capacity in communities (Dornelas 2010), and will affect r-select and K-selected species differently (Bohn et al. 2014). Mesostigmata encompasses both r/K traits (Ruf 1998), meaning the effect of disturbance is species dependent. Generally though, intermediate levels of disturbance leads to greater diversity of organisms, than high or low levels of disturbance (Connell 1978). This is because few species can survive in highly disturbed areas, while low levels of disturbance leads to species outcompeting one another. Disturbance may also influence the nature of morphological and ecological traits present in an assemblage. In flora communities, increased disturbance decreased the total number of distinctively different traits present in their communities (Biswas and Mallik 2010). Although untested in my study, shifts in assemblage composition may correlate with changes in traits and should be investigated further.

Species richness and number of individuals were not significantly greater at lower latitudes. It's possible that because I sampled one major habitat type (the boreal forest) and a relatively small sampling area (distance between most northern and southern quadrants were < 800 km apart) these patterns were not present; increased sampling south to warmer regions may have invoked this pattern (Mittelbach et al. 2007). Similar to Nielsen et al. (2012), I found that pure spatial distance had as much effect on assemblage structure as did non-spatial variables. In addition, I found that community dissimilarity grew with increasing spatial distance, which was not observed for Mesostigmata by Chen et al. (2014), but was seen in oribatid mites (Lindo and Winchester 2009). Spatial influence on communities can be due to dispersal capacity of species. Mesostigmatid mites' dispersal ability is species-specific, as some use phoresy along with active locomotion to disperse, while others only use locomotion. Due to the prevalence of phoretic behaviour, it is likely found within the species/morphospecies sampled in this study (Athias-Binche 1994; Klompen et al. 2007). Phoretic behaviour occurs frequently and non-discriminately, Bajerlein and Blosyk (2004) found that the uropodine species *Uropoda oribularis* (Müller) were on 80% of beetle species tested (25 out of 31). In addition, beetles can carry more than one species of mite (Pfammatter et al. 2016), meaning diverse beetle assemblages can increase mite diversity. Active dispersal (locomotion) is affected by many factors. Temperature, light intensity and drought can increase locomotion of *Neoseiulus californicus* (McGregor), while prey availability and high levels of moisture decreases it (Auger et al. 1999). Active dispersal is also related to other traits, such as feeding preference. Jung and Croft (2001) found that feeding specialists dispersed longer distances than generalists. Total dispersal distance between phoretic and non-phoretic species can vary dramatically. Active dispersal amongst soil Mesostigmata has been shown to be up to 60 cm/day (Cameron et al. 2013); phoretic mites attach onto larger, more mobile animals, suggesting that their dispersal ability is at minimum one-magnitude larger (e.g. dispersal capacity of mountain pine beetles, Evenden et al. 2014). However, given that samples in this study were often several hundred kilometers apart, individual mites (both phoretic and non-phoretic) are unlikely to be able to disperse across the entire range of sites in this study. Therefore, I predicted that greater geographic distances should produce greater dissimilarity amongst assemblages, with new species being present. This was shown, as species turnover explained almost all of the beta diversity in the assemblages. Species turnover is typically greater in taxa with low dispersal capacity (e.g. soil invertebrates), and taxa in higher trophic positions (Soininen et al. 2007) both of which are attributable to mesostigmatid mites.

Spatial distance can also correlate with environmental factors (both tested and untested) that are influencing Mesostigmata assemblages. One example is soil pore volume. Soil pore volume can greatly affect Mesostigmata, as it may affect prey abundance (Nielsen et al. 2008). Mesostigmata live within air pockets but their prey can be significantly smaller and inhabit smaller spaces (Coleman et al. 2004), making them inaccessible to predate on. Competition between Mesostigmata species may have also affected assemblage composition (Gotelli et al. 2010), in addition to competition between prey groups. Ingimarsdóttir et al. (2012) found that collembolan (secondary food source) and oribatid mites (tertiary food source) occur less frequently with each other than by random chance. Change in prey proportions will affect mesostigmatid mites, as they weakly prefer specific prey groups (Buryn and Brandl 1992).

As shown but this and other studies, environmental and spatial processes appear important in structuring mesostigmatid mite assemblages; however, little is known about their ecology and why these environmental variables are correlated with presence/ absence and abundance of particular taxa. Manipulative, laboratory-based experiments can further our understanding on what structures Mesostigmata assemblages. A mixture of abiotic conditions (e.g., soil moisture and temperature), and biotic conditions (e.g., presence/absence of collembolans and oribatid mites) can achieve this. Until a causal link between environmental variables and assemblage composition is established, our understanding of these diverse, abundant taxa will remain limited.

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3.6 Tables and Figures

Table 3-1 Environmental variables that were significant ($P < 0.05$) in explaining mesostigmatid mite assemblages in the RDA, ranked from most to least significant..

Environmental Variables	Cumulative Adjusted R^2	Pseudo *F* value	*P* value
Precipitation	0.022	5.796	0.001
Moss	0.045	6.139	0.001
Disturbance Intensity	0.056	3.434	0.001
Decay Class	0.063	2.66	0.001
Lichen	0.07	2.717	0.001
Shrub	0.077	2.555	0.001
Bare Ground	0.082	2.085	0.003
Number of Small DWD Pieces	0.086	1.995	0.003
Grass	0.09	1.878	0.012
Wood	0.093	1.703	0.023
Sedge/Rush	0.096	1.56	0.046

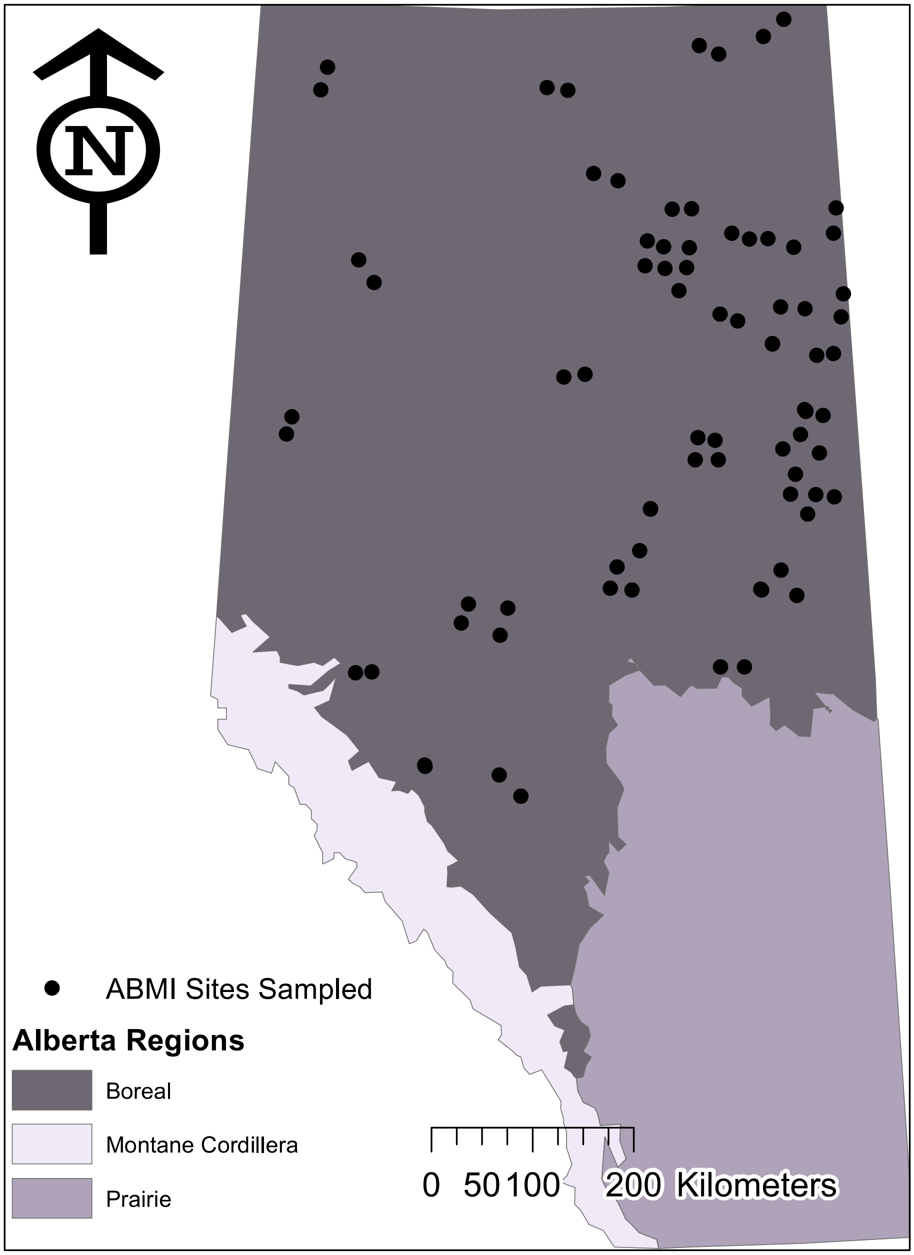

Figure 3-1. Map of Alberta Biodiversity Monitoring Institute sites sampled for this study.

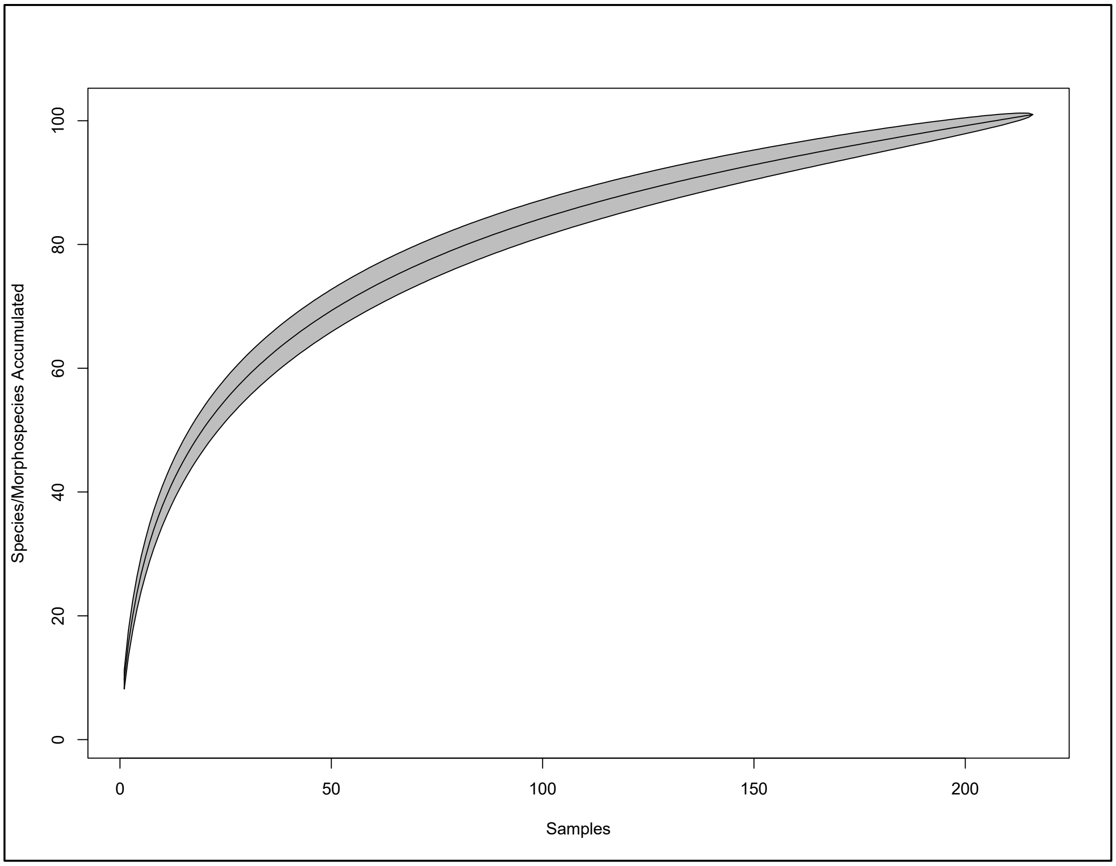

Figure 3-2. Rarefaction curve of Mesostigmata species/morphospecies sampled. Gray area represents 95% confidence interval

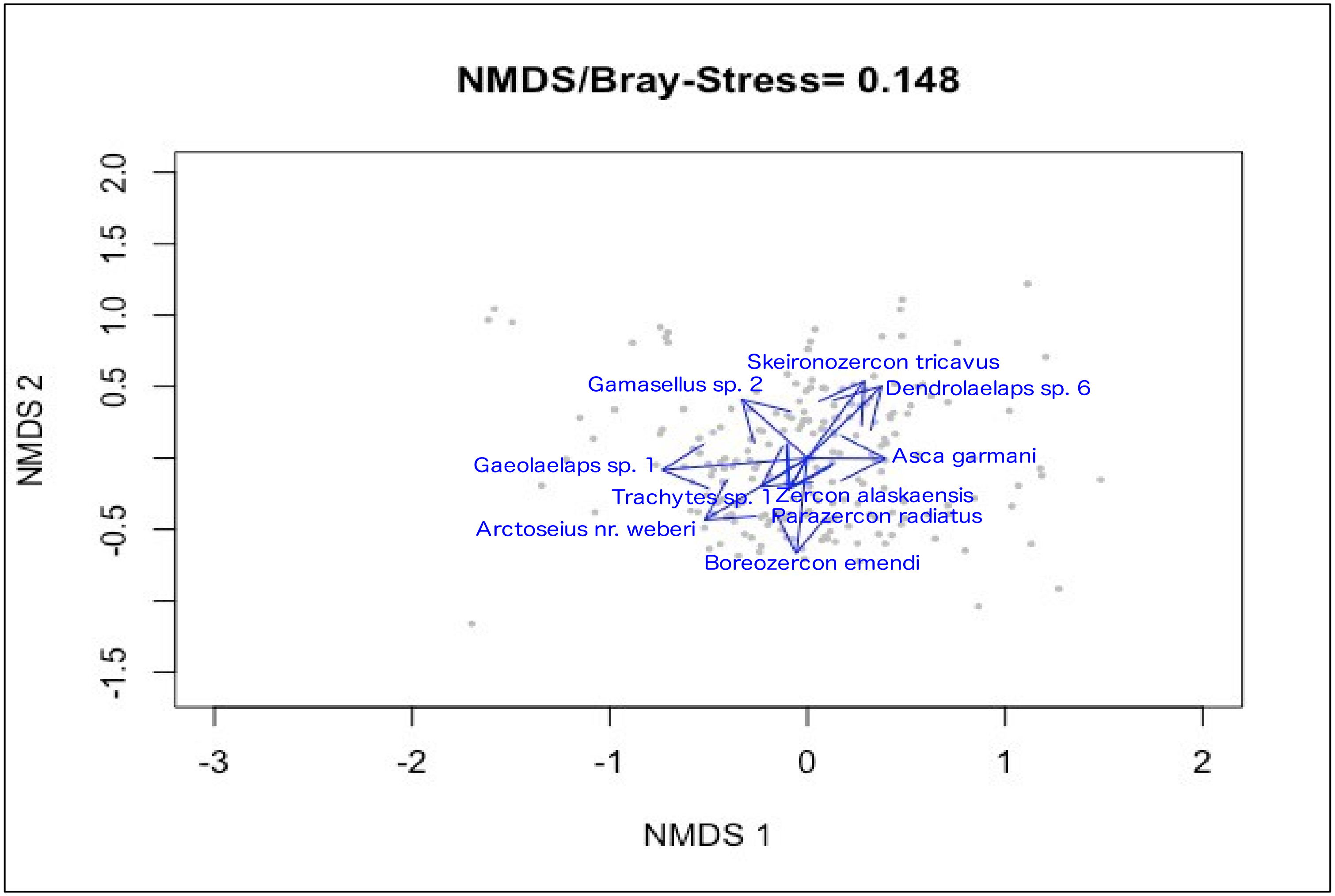

Figure 3-3. NMDS (non-metric multidimensional scaling) plot of quadrants overlain with common species/morphospecies. 'Common species' was defined as a species that was present in 25 or more quadrants, and had 50 or more individuals.

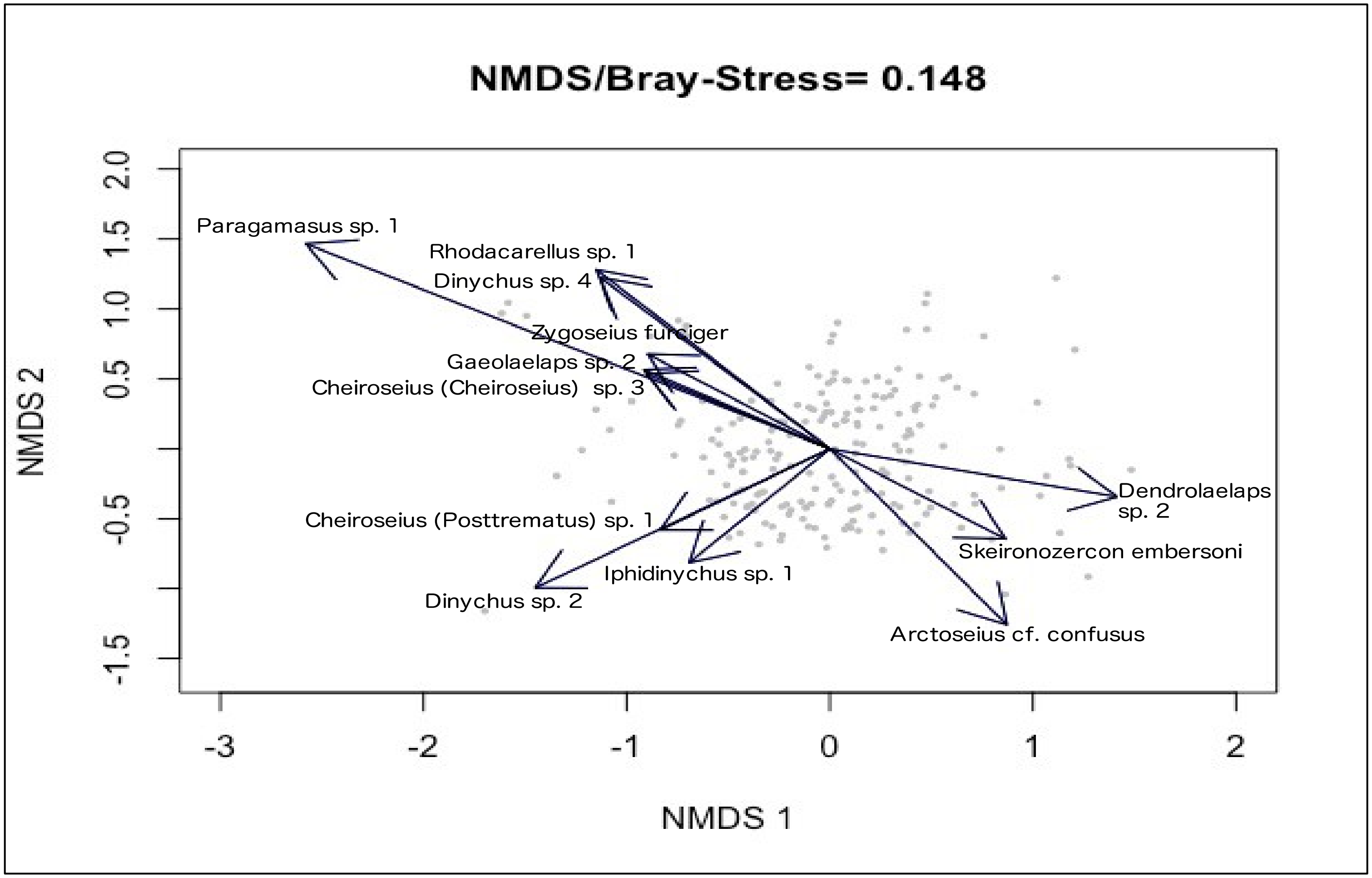

Figure 3-4. NMDS (non-metric multidimensional scaling) plot of quadrants overlain with relevant species/morphospecies. Relevant species had the largest axis loading when formulating the NMDS plot

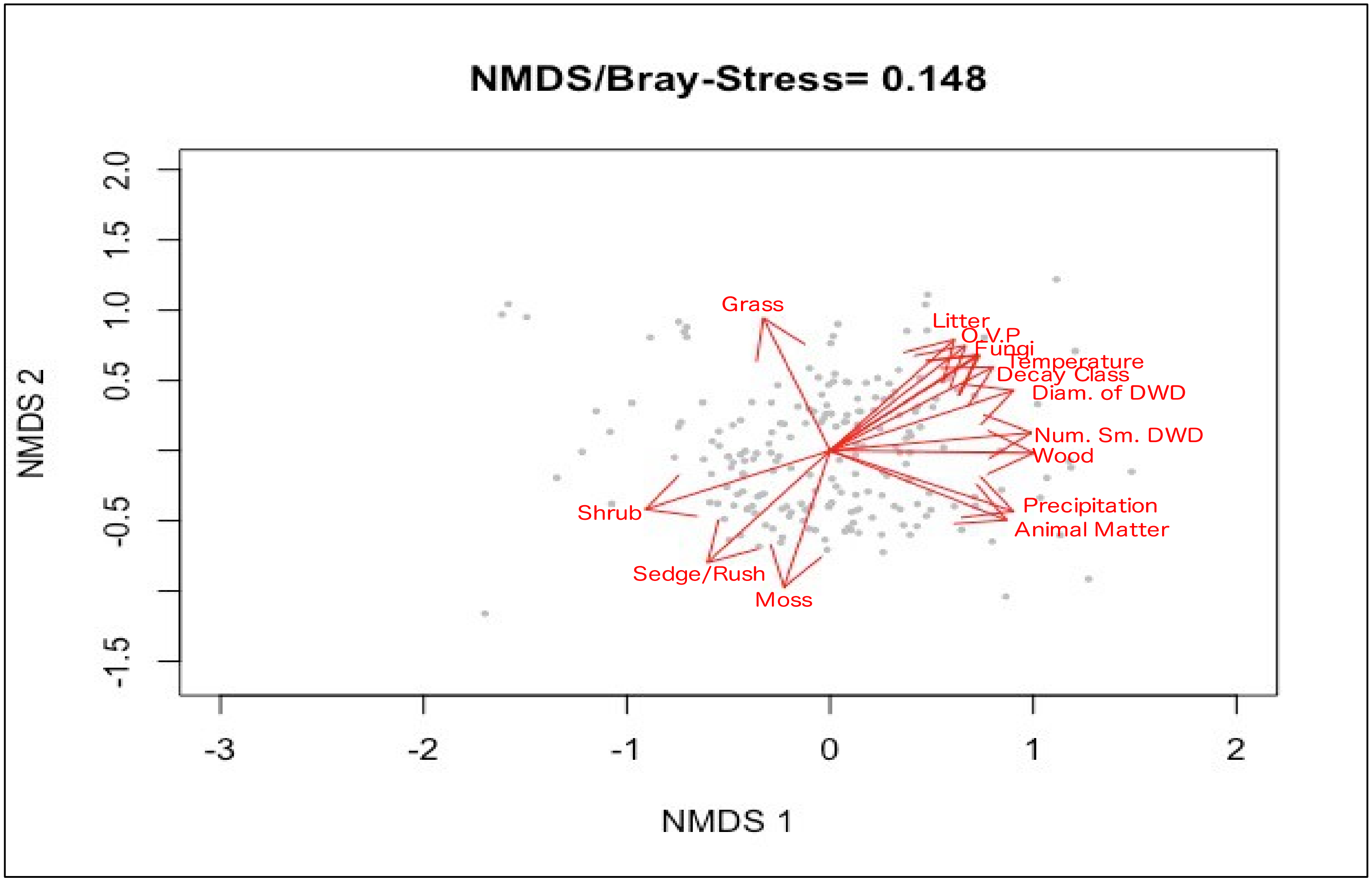

Figure 3-5. NMDS (non-metric multidimensional scaling) plot of quadrants overlain with vectors of significantly correlated environmental variables. Nm. Sm. DWD = Number of Small DWD Pieces, Diam. Of DWD = Diameter of DWD, O.V.P = Other Vascular Plants.

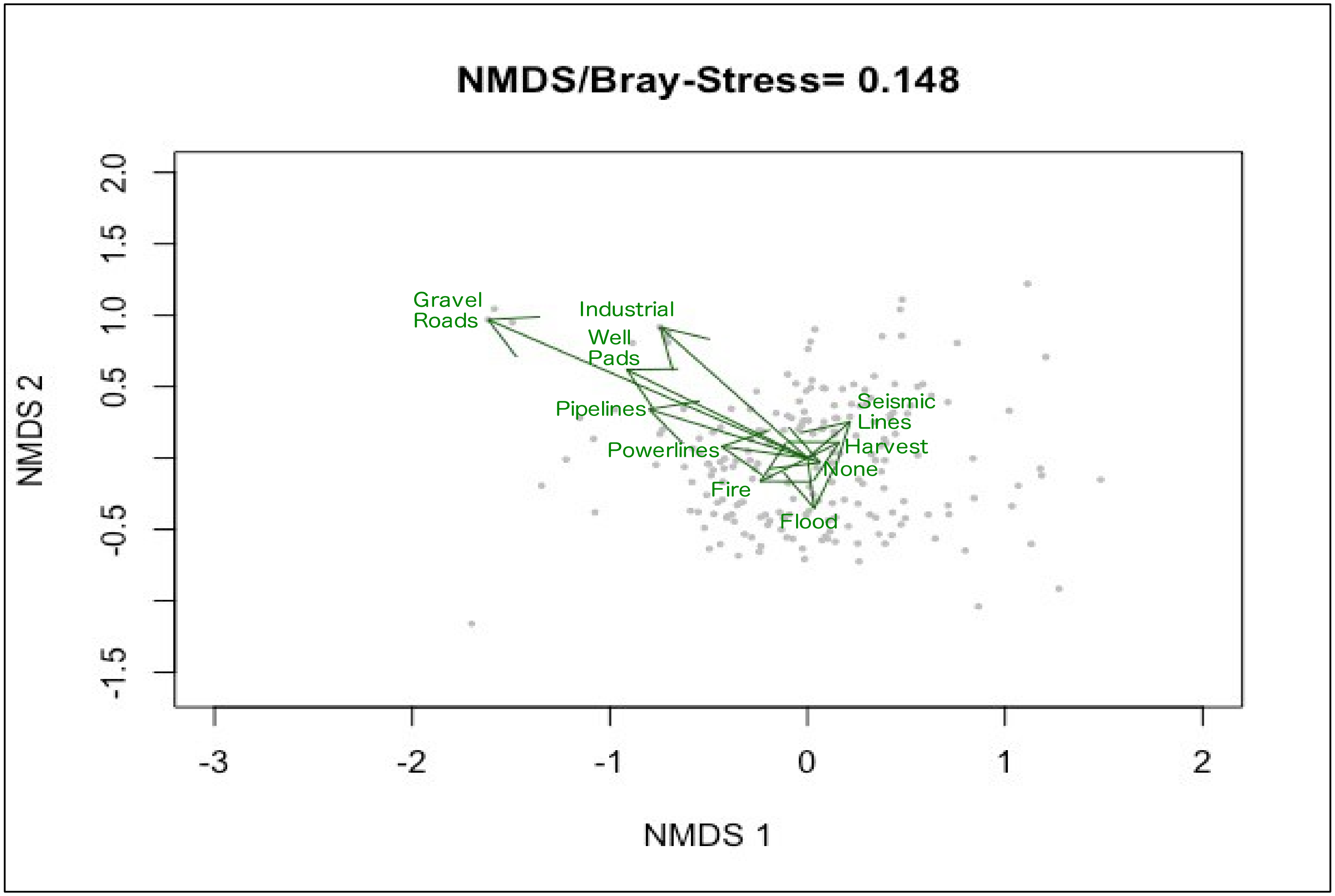

Figure 3-6. NMDS (non-metric multidimensional scaling) plot of quadrants overlain with vectors of disturbance types.

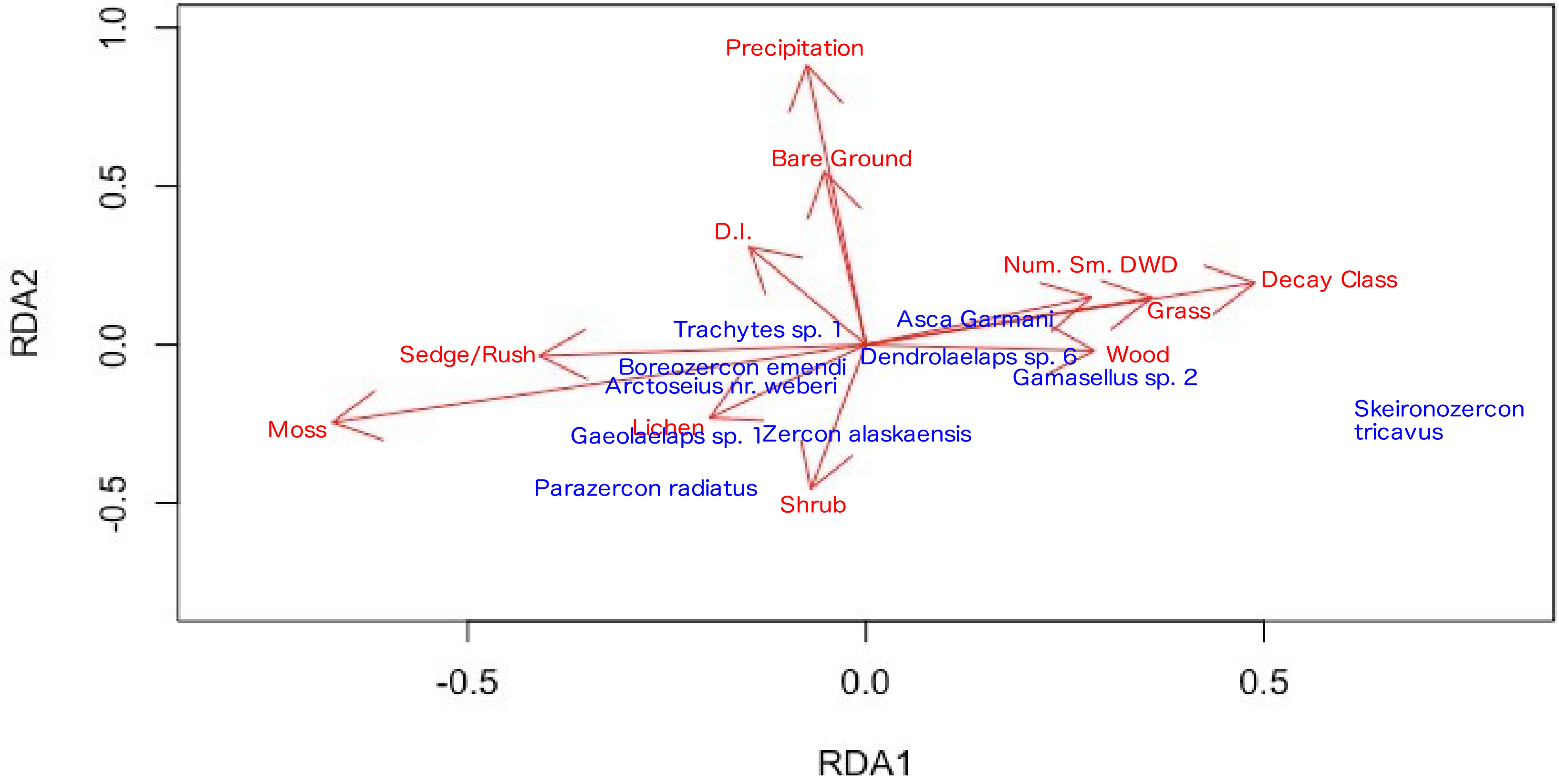

Figure 3-7. RDA (redundancy analysis) plot of significant environmental variables (red) and common species (blue). 'Common species' was defined as a species that was present in 25 or more quadrants, and had 50 or more individuals. Nm. Sm. DWD = Number of Small DWD Pieces, D.I. = Disturbance Intensity.

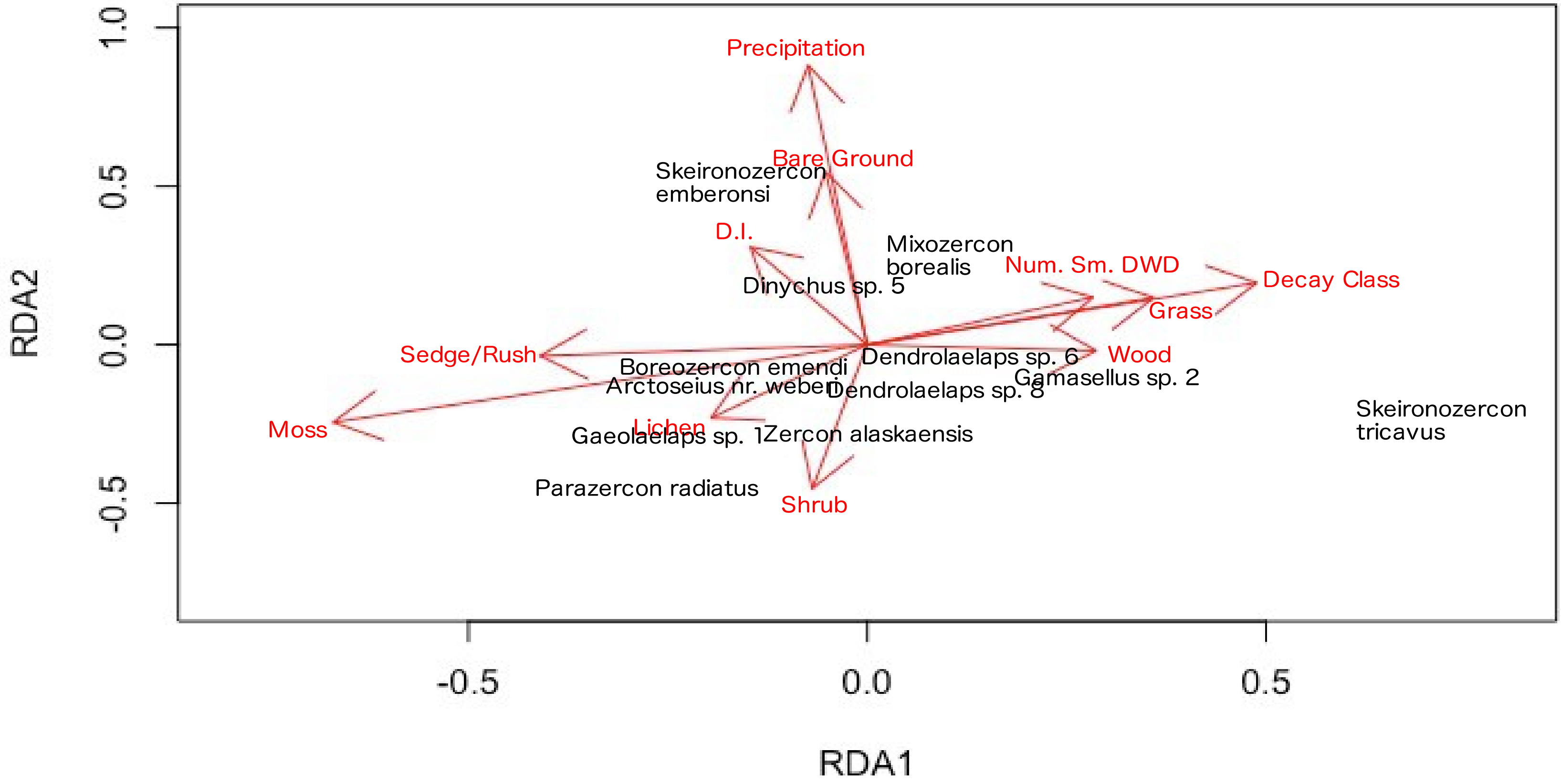

Figure 3-8. RDA (redundancy analysis) plot of significant environmental variables (red) and relevant species (black). Relevant species were determined by having the largest axis loading when formulating the RDA. Nm. Sm. DWD = Number of Small DWD Pieces, D.I. = Disturbance Intensity.

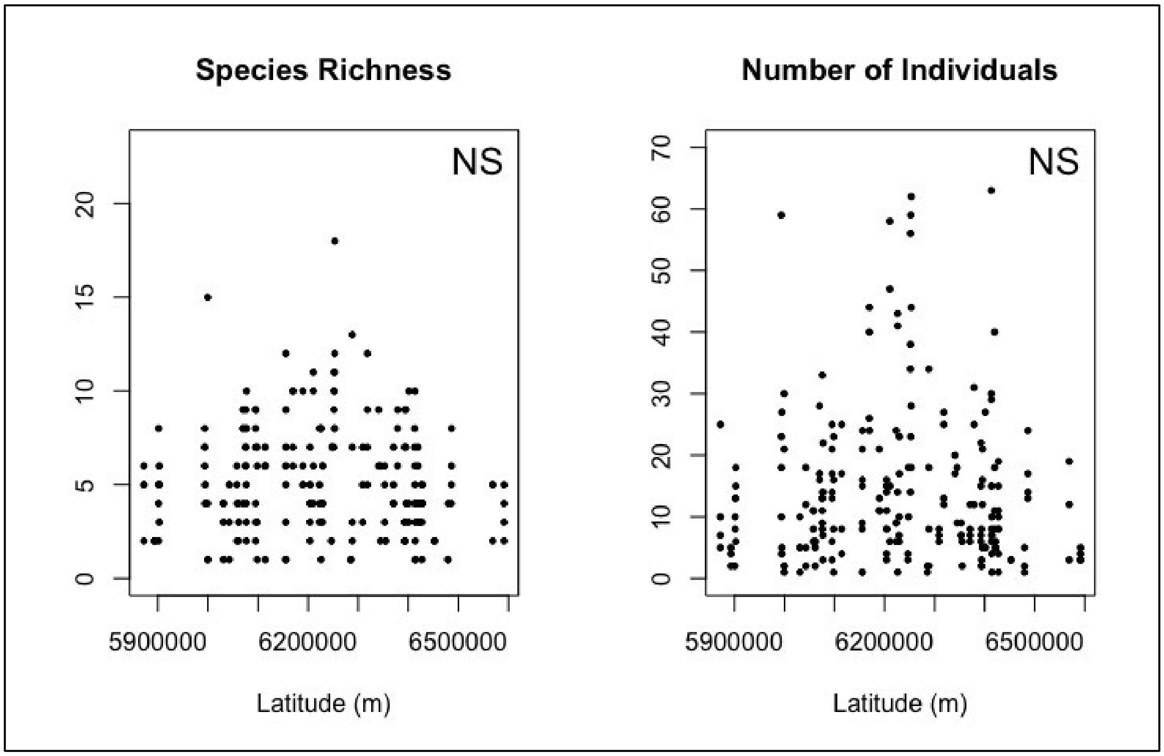

Figure 3-9. The effect of latitude on species richness (left) and number of individuals (right). Dotted red line is line of best fit. NS = not significant.

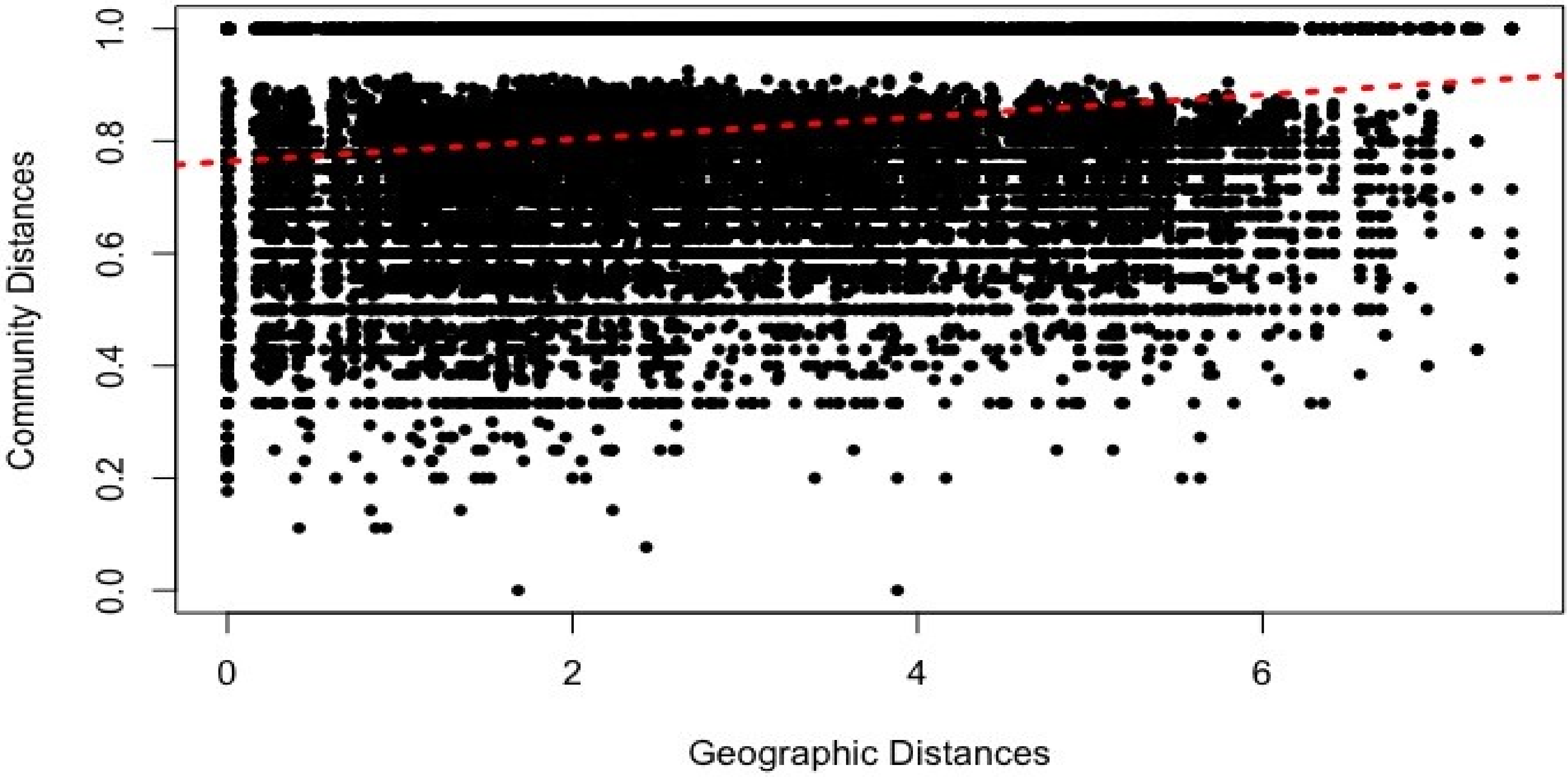

Figure 3-10. Scatter plot of community distances vs. geographic distances. Mantel and partial Mantel tests showed that increasing geographic distance led to greater beta diversity amongst assemblages, with ($r_m = 0.147$, $P < 0.01$) and without ($r_m = 0.184$, $P < 0.01$) environmental distances controlled for.

4 Chapter 4: The relative utility of soil mesostigmatid and oribatid mites as bioindicators of disturbance in the boreal forest in Northern Alberta, Canada

4.1 Introduction

Ecosystem services are the societal benefits that humans obtain from the environment. These services fall under four categories: provisioning, regulating, cultural and supporting (MEA 2005). Services produced or maintained by soil systems have received greater attention recently (Dominati et al. 2010), which has led to a global effort to assess and monitor them (Pulleman et al. 2012 and references within). Nevertheless, disturbance events continue to globally threaten soil systems and the ecosystem services they provide. Disturbance can be defined as a discrete event that alters ecosystem, community or population structure, and changes resource and substrate availability (White and Pickett 1985) and may lead to loss of ecosystem services (Walker 2011; Thom and Seidl 2016; Seidl et al. 2017).

Ecological indicators can measure ecosystem health to ensure services are protected, in soil systems they can be physical, chemical or biological in nature (Karlen et al. 1997). Biological indicators (bioindicators) use species and assemblages, such as plants, mammals, reptiles, fish, amphibians and invertebrates to measure ecosystem health (Burger 2006). Taxa differ in specificity and resolution as bioindicators (van Straalen 1998). Specificity refers to the number of environmental factors an indicator responds to, with very specific bioindicators responding only to one or a few disturbances, while resolution refers to the degree of environmental change that an indicator is sensitive to. The nature of the metrics used to assess the utility of bioindicators depends in part on the biology of the taxon. Groups that have low local diversity and whose population size is difficult to determine may offer only presence/absence information, while more locally diverse and easily surveyed groups, like many invertebrates, offer multivariate approaches (Wilson 1988; Bedano et al. 2011). Multivariate analyses is often used for monitoring of marine and freshwater invertebrates, e.g., protocols for RIVPACS (River Invertebrates Prediction And Classification System) (Wright 2000). Invertebrates are also often used as soil bioindicators, and can be classified according to size, with one common classification being microfauna (< 100 μm), mesofauna (100-2000 μm) and macrofauna (> 2000 μm) (Bardgett 2005). Among soil mesofauna, mites (Arachnida: Acariformes and Parasitiformes) are the most taxonomically and ecologically diverse, and are frequently used as bioindicators (Breure et al. 2005).

Mites are diverse arthropods with 55,000 described species; however, true richness is believed to be 1,000,000 (Walter and Proctor 2013). The two mite taxa that are used most frequently as soil bioindicators are Mesostigmata and Oribatida. With 11,000 described species, Mesostigmata are the most diverse order within the Parasitiformes (Walter and Proctor 2013). Mesostigmata are typically 200-4,500 μm in size, and occupy a variety of niches including predators in soil, predators in vertebrate and invertebrate nests, and parasites of vertebrates and invertebrates (Dowling and OConnor 2010). Soil-dwelling Mesostigmata (and Mesostigmata in general) have various dispersal tactics; some are phoretic on winged insects, while others are restricted by their own locomatory capacity (Ruf and Beck 2005). Phoretic species can be either facultative or obligatory, and will disperse frequently between habitats (Hunter and Rosario 1988). Mesostigmata are often abundant in soil, where they can have roughly the same biomass as larger predators such as spiders and centipedes (Scheu et al. 2003). Soil mesostigmatids feed mainly on decomposers such as springtails and nematodes (Scheu 2002; Klarner et al. 2013), but generally will eat other small and unsclerotized taxa (Schneider and Maraun 2009).

Oribatida (Acariformes: Sarcoptiformes) are a diverse suborder with over 9,000 species described (excluding Astigmata, Norton and Behan-Pelletier, 2009) and typically make up 60-90% of mite species found in a given soil patch (Gulvik 2007). Oribatid mites play an important role in decomposition and, in conjunction with other soil microarthropods, can increase decomposition rates of litter and alter elemental concentrations (Seastedt 1984). Soil oribatid mite dispersal is more limited than that of Mesostigmata as they have no specialized dispersal stage and seldom disperse by wind (Lehmitz et al. 2011), this limited dispersal can influence their assemblage composition (Minor 2011). Lehmitz et al. (2012) found that dispersal rates were species dependent, and ranged from 0.3-2.1 cm/day. Oribatid mites are similar in size to Mesostigmata (150-2,000 μm), they feed mainly on detritus and fungi, although some will also opportunistically feed on nematodes or dead arthropods (Norton and Behan-Pelletier 2009).

Both Mesostigmata and Oribatida have been demonstrated as effective bioindicators of disturbance (Breure et al. 2005). For Mesostigmata, this includes agriculture systems (Koehler 1999; Bedano et al. 2006), post-fire systems (Bogorodskaya et al. 2010; Kamczyc et al. 2017) and reclaimed industrial areas (Madej and Stodółka 2008; Madej and Kozub 2014). Ruf (1997, 1998) created a soil-maturity index using Mesostigmata similar to Bongers (1990) nematode-based index, that proved sensitive to detecting disturbance. However, oribatid mites are used more frequently than mesostigmatid mites as bioindicators, as their taxonomy is better known (at least in Europe) and there are more existing protocols for them (Balogh and Balogh 1992; Balogh and Balogh 2002; Ruf and Beck 2005). Oribatida are strong indicators of agricultural disturbance (Behan-Pelletier 1999; Gergócs and Hufnagel 2017), and are sensitive to other disturbance types like fire (Camann et al. 2008), harvest (Battigelli et al. 2004), and linear disturbance (Magro et al. 2013), heavy metal pollution (Ivan and Vasiliu 2009), in addition to habitat fragmentation (Starzomski and Srivastava 2007). At times, Mesostigmata and Oribatida have been combined as bioindicators, the OM/PA (Oribatida + Mesostigmata / Prostigmata + Astigmata) index assesses all mite taxa in soil and is based on the expectation that each major taxon has a unique response to a disturbance type (Bedano et al. 2011) stemming from differences in life history traits (Siepel 1994; Siepel 1995; Behan-Pelletier 1999). Bedano et al. (2011) found that natural areas had a higher OM/PA index value than disturbed ones. Although both Mesostigmata and Oribatida have proven their effectiveness as bioindicators, due the difficulty of species-level identification, paucity of literature on juvenile identification, and rarity of taxonomic experts (Gulvik 2007), their use remains limited (taxonomic impediment).

Lenat and Resh, (2001) and Verdonschot, (2006) have argued for species-level identification of bioindicators, as it offers the highest degree of ecological resolution. However, studies such as Jiang et al. (2013, 2017), Milošević et al. (2014) and Terlizzi et al. (2009) have found that genus-level identifications are often sufficient (have “allowable information loss”). These studies follow the premise of taxonomic sufficiency (TS) (Ellis 1985), which is when taxa are identified to the coarsest taxonomic level possible, (whether species, genus, family etc.) to suffice the objective of the study. Bevilacqua et al. (2013) applied this philosophy in their BestAgg method, which identifies the number of surrogates at different taxonomic ranks (potentially including an array of finely and coarsely identified taxa) needed to attain the same results as identification of all taxa to species-level. Since this methodology was first introduced, numerous studies have found it to be effective in marine and freshwater ecosystems (Jiang et al. 2013; Milošević et al. 2014; Jiang et al. 2017). Milošević et al. (2014) applied this methodology to chironomids, a notoriously hard group to identify and found that of 114 originally identified species, and only 17 surrogate taxa were needed to attain species-level results, representing an 85% reduction in taxonomic effort. To my knowledge, BestAgg analysis has yet to be performed with a terrestrial dataset.

In this study I investigated the utility of soil mesostigmatid and oribatid mites as bioindicators of three disturbance types in boreal forest in Alberta, Canada: fire, harvest, and linear features (pipeline, powerlines and seismic lines). My specific objectives were to: 1) test their utility as bioindicators with species, genus and family-level identifications; 2) include mesostigmatid nymphs at family level (paired with adults), to test whether they augment adult-only approaches; 3) apply the BestAgg approach designed by Bevilacqua et al. (2013) and determine its effectiveness at reducing taxonomic effort with a soil mite dataset; and 4) determine what specific species, genera and families of Mesostigmata and Oribatida can be used as indicator taxa of different disturbance types.

4.2 Methods

4.2.1 Sampling Technique

Samples for this study were collected by Alberta Biodiversity Monitoring Institute (ABMI) between the years 2010-2015 and initially processed by the Royal Alberta Museum (RAM), both based in Edmonton, Alberta. Sampling and extraction methods are described in Chapter 2, Methods 2.2.1. For this study, I used oribatid identification data from the RAM and mesostigmatid mite data, based on my own sorting and identifications. In contrast to the ABMI protocols, I included both adult and nymphal mesostigmatid mites from both 50-300 μm and > 300 μm residuals. Slides have been deposited in the RAM's reference collection.

Adult oribatid mites were identified by RAM taxonomists to the species or genus and morphospecies level (ABMI 2014). Similarly, I identified adult Mesostigmata to the species/morphospecies level; however, male *Dendrolaelaps* (Digamasellidae) were identified only to genus due to the lack of reliable morphological characters to match males with the easier to identify females. Ten other individuals were also identified only to genus-level because they were too crushed to identify to species/morphospecies-level (e.g. they were too crushed on the slide). When possible, nymphs were identified to the family, otherwise they were placed in their respective cohorts (e.g. Gamasina or Uropodina). Literature used for identifications came in part from unpublished keys acquired by MM at the 2016 Acarology Summer Program at The Ohio State University. A list of published taxonomic literature used for identification can be found in Chapter 2.

I investigated three disturbance types common in the boreal forest of Alberta: fire, harvest and linear features (powerlines, pipelines and seismic features). Adjacent pairs of disturbed and undisturbed sites were selected based on these criteria: 1) paired sites must be sampled within the same year; 2) sites cannot be farther than 30 km apart;

3) sites must be (approximately) north of Edmonton (the most southern site is ~30 km south of Edmonton); 4) sites must be within the same ecoregion as defined by Agriculture and Agri-Food Canada (1995); 5) for 'undisturbed' sites, all 4 quadrants (NE, NW, SE, SW) have to be undisturbed to be selected; 6) all 'disturbed' sites must only be affected by one type of disturbance (e.g., a site with NE, NW disturbed by fire, and SE, SW disturbed by wind would not be selected); 7) for fire and harvest, the sites minimum degree disturbed was 50%, for linear features, the minimum degree disturbed was 10% and 8) a 'disturbed' site must have a minimum of two quadrants disturbed to be selected. Using these criteria, I selected 13 pairs of disturbed-undisturbed sites (96 quadrants total) for fire, 11 pairs (74 quadrants) for harvest and 7 pairs (38 quadrants) for linear disturbance (Figure 4-1).

4.2.2 Datasets

I constructed numerous datasets based on different taxonomic resolution. For adult Mesostigmata > 300 μm, separate matrices were made at species/morphospecies-, genus- and family-level resolutions, and an additional matrix of family-level identifications including both adults and nymphs was also created. Matrices for Mesostigmata in the 50-300 μm range were constructed in a similar manner, and combined with the > 300 μm matrices (50-300 + > 300 μm). As mentioned, ABMI only identifies adult Oribatida > 300 μm and therefore I made only species/morphospecies-, genus- and family-level data matrices for oribatids. For analysis I did not combine quadrants, as I did not want to lose fine scale information. Information on site pairs (i.e. which sites were paired with one another) was added to the dataset, as site pairs were a co-variable when analyzed. Meaning, disturbed and undisturbed quadrants of a site pair were directly compared against one another.

BestAgg datasets were created using R code that I modified from the code provided in Bevilacqua et al. (2013). The BestAgg method was applied only when assemblages were significantly different at species-level identification, for any and all disturbance types. BestAgg determines the lowest number of surrogate groups (G_{min}) that can be used to produce a result similar to species-level identifications ($G_{min} = \phi_{low}$ x S, where ϕ_{low} is the minimum percent of surrogate groups needed, and S is the number of species identified). To determine ϕ_{low}, species-level matrix was first constructed as species (column) × quadrants (row). Then, 5% step-wise reductions of the species-level matrix were done by progressively lumping the corresponding amounts of species-level data (from 95% of total number of species to 5%) by columns, with 19 reductions in total (ϕ=100%/5%-1). I ran 1000 random aggregations for each reduction, where results from each random aggregation and the species-level identifications were compared using Spearman's correlation (transformed by Bray-Curtis dissimilarity). Next, a PERMANOVA was performed for each reduction's random aggregation (1000 total), with disturbed vs. undisturbed as the fixed factor and site pair as the random factor. The PERMANOVA was based on Bray-Curtis dissimilarity with log (x+1) transformed data. The PERMANOVA and correlation results were then made into matrices, each were constructed as ϕ (19 columns) × aggregation (1000 rows). The PERMANOVA results were used to determine if 95% of random aggregation matrices produced results consistent with that of the species-level matrix, while the matrix of correlation results was visualized as a semi-log plot of correlation coefficients (1000 for each ϕ) against corresponding ϕ values to determine ϕ_{low}.

Once the G_{min} was calculated, surrogates for the dataset was established. Surrogates in this study, were a combination of species, species groups, genera and families. The surrogates were created using criteria from Bevilacqua et al. (2013), which are relevance, ease of identification and resemblance. Relevance relates to common species found, and it was determined through SIMPER analysis (Clarke 1993), any species with an average contribution value ≥ 1% were considered relevant. Different criteria for ease of identification were applied to Mesostigmata and Oribatida, as more is known about the oribatid fauna in Alberta. For Mesostigmata, there were two sets of criteria to determine if a species was easy to identify: 1) the availability of relevant taxonomic literature, and 2) the number of species within a genus. Species within a diverse genus were usually considered hard to identify, due to the limited knowledge of Mesostigmata fauna for Alberta. Oribatida only had one criterion and it was applied to genus-level identification, which was that a mite was considered easy to identify if it did not need to be slide-mounted. Under this criterion most oribatid mites are easy to identify; however, difficult groups still exist, such as genera in the Suctobelbidae. Resemblance refers to the taxonomic or functional similarity amongst taxa. In this study, resemblance was the same for both Mesostigmata and Oribatida, species that were considered hard, non-relevant or both were grouped together. The BestAgg dataset was validated by producing a Spearman's correlation coefficient between the BestAgg dataset and the species-level one, to determine where the coefficient fell relative to the coefficients created by randomly aggregated groups of the same number of surrogates.

4.2.3 Statistical Analysis of Datasets

I performed all statistics with the R statistical package (R Core Team, 2017). To improve normality, community matrices were log (x+1) transformed. A mixed-effect ANOVA, with site pair as the random factor and disturbed vs. undisturbed as the fixed factor, was used on species/morphospecies-, genus- and family-level (adults and adults+nymphs) identifications to determine if there was a difference between richness and diversity (Shannon-Weiner index) between disturbed and undisturbed sites for all disturbance types. Pearson correlations, with log (x+1) transformed data, was tested to determine the similarity of species/morphospecies-, genus-, family-level (for adults and adults+nymphs), and BestAgg's taxa richness and diversity to one another, for both Mesostigmata and the Oribatida datasets.

A mixed-effect PERMANOVA (with site pair as random effect, and using Bray-Curtis dissimilarity) determined whether differences between disturbed and undisturbed assemblages are significant. This was performed using the adonis function in the vegan package, with the F stat adjusted, given that site pair is a random effect, not a fixed effect. I performed a distance-based RDA (db-RDA, using Bray-Curtis dissimilarity) through the capscale function in the vegan package to visually show assemblage composition. Site pairs were added as a condition for the db-RDA. Site pairs were removed from PERMANOVA and the db-RDA if all quadrants of either disturbed or undisturbed member of the pair had zero individuals (empty quadrants were left in for ANOVA). Spearman correlations were used to assess the similarity of community datasets (log (x+1) transformed and Bray-Curtis dissimilarity data) were to another for species, genus, family-level (adults only and adults+nymphs), and BestAgg. Family-level comparisons using the adults+nymphs dataset were at times not possible, as additional quadrants had nymphs present, meaning the matrices for the different taxonomic levels had different dimensions (Bray-Curtis dissimilarity does not compute when quadrants (or samples) have zero individuals, because of that, quadrants with zero individuals are taken out).

I performed indicator analysis for all datasets using the multiplatt function from the indicspecies package. Indicator analysis was performed to determine whether taxa were positive indicators of fire, harvest or linear disturbance. Each disturbance type was analyzed separately and was done for all taxonomic levels. To avoid having very rare taxa, spuriously identified as indicators, I excluded species, genera and families with fewer than 5 individuals. P-values are represented both as raw and corrected by Holm-Bonferroni.

4.3 Results

For adult Mesostigmata > 300 µm in length, I found 1165 individuals representing 20 families, 41 genera and 89 species/morphospecies (Table 2-1). There was an average of 5.70 ± 5.85 (mean ± SD) adults > 300 µm per quadrant, with a total of 1186 individuals. Family-level identifications of nymphs > 300 µm added one additional family (Veigaiidae) and an additional 742 individuals, with an average of 9.27 ± 9.05 adults+nymph per quadrant (1928 > 300 µm individuals total). Including adult individuals 50-300 µm in size, added an additional 13 species and two new genera, and one new family (Rhodacaridae), for a total of 2779 individuals, with an average of 13.36 ± 12.51 individuals per quadrant. Adding 50-300 µm nymphs yielded no new taxa, but did add 1434 individuals, with an average of 20.25 ± 17.99 individuals per quadrant (4213 individuals total from 50-300 + > 300 µm). For the 2598 adult Oribatida > 300 µm from the same samples, taxonomists at the RAM identified 39 families, 69 genera and 107 species, at a density of 12.49 ± 14.71 individuals per quadrant (Table 4-1).

For mesostigmatid mites > 300 µm ANOVA had one significant result, taxon richness was significantly lower in disturbed sites of fire disturbed quadrants, with family adult+nymphs identifications (Table 4-2). For PERMANOVA, two site pairs from fire disturbance were removed. Assemblage differences were observed for fire disturbance at the species and family (adults+nymphs) level identification. In addition, significant differences were seen with harvest disturbance at the species-, genus-, family (adults)-, and family (adults+nymphs)-level. And finally, significant differences between assemblages were observed for linear disturbance at species-level (Table 4-3A, Figure 4-2-Figure 4-5).

For Mesostigmata 50-300 + > 300 µm ANOVA found significantly lowered taxon richness and diversity with fire disturbance at species, genus, family (adults), and for family-level (adults+nymphs) (Table 4-4). For PERMANOVA, one fire disturbed/undisturbed group pair was dropped from analysis. Assemblage differences were seen for fire disturbance at species-, genus-, family- (adults), and family (adults+nymphs)-level, and from linear disturbance, at species-, genus-, family- (adults), and family (adults+nymphs)-level (Table 4-3B, Figure 4-6-Figure 4-9).

For oribatid adults > 300 µm, taxon richness and diversity was significantly less for fire disturbance at species-, genus-, and family- level identifications, and harvest disturbance at species/morphospecies-, genus-, and family-level, identifications. In addition, there was a significantly less taxa diversity at the family-level in linear disturbed site (Table 4-5). For PERMAOVA, one group pair from fire disturbance was removed. Significant results of PERMANOVA analysis were observed with fire disturbance at species-, genus- and family-level, and for linear disturbance at genus- and family-level (Table 4-3C, Figure 4-10-Figure 4-12).

For BestAgg analysis with a significant regression model ($P < 0.05$), a lone BestAgg dataset was produced for Mesostigmata 50-300 + > 300 µm linear disturbance ($\phi_{low} = 0.4$, $G_{min} = 23$). The BestAgg dataset produced was predominantly made up of species and genera (Table 4-6). The BestAgg dataset was successfully validated. The PERMANOVA and ANOVA attained similar results to species-level identification (Table 4-3D, Table 4-7, Figure 4-13). Taxa richness, taxa diversity and community structure from all taxonomic levels (including BestAgg), were significantly correlated to one another (Table 4-8). Analyses of the BestAgg datasets produced results more similar to species-level identification than did analyses at the genus- or family-levels for adult Mesostigmata or for the family-level for adults+nymphs. Although significant results were seen with Mesostigmata > 300 µm for fire, harvest and linear disturbance, a step-wise reduction of surrogates was at most 5% from species identified. Because there was little reduction in surrogate groups, a BestAgg dataset was not produced. In addition, Mesostigmata 50-300 + > 300 µm fire disturbance and Oribatida > 300 µm fire disturbance datasets saw a reduction to 34 surrogates from an original 68 taxa ($\phi_{low} = 0.5$) and 52 surrogates from 72 taxa ($\phi_{low} = 0.7$); however, there were still fewer genera present then surrogate groups after reduction. Because of that, a BestAgg dataset was not produced. Table 4-9 shows the taxa selected as significant indicators of fire, harvest and linear disturbance. After Holm-Bonferroni correction, few indicators retained their significance; however, all those that did, were indicators of linear disturbance.

4.4 Discussion

4.4.1 Mesostigmata and Oribatida as bioindicators of disturbance

I found that the Mesostigmata assemblages were useful as bioindicators for all disturbance types, and Oribatida assemblages for fire and linear disturbance. Large Mesostigmata alone (> 300 µm) was an effective indicator of harvest; however 50-300 + > 300 µm Mesostigmata was not. Typically, larger-bodied soil organisms are affected more by disturbance than smaller bodied ones (Postma-Blaauw et al., 2010). For > 300 µm Mesostigmata harvest disturbed assemblages, I saw the opposite, as the abundance of the relatively small-bodied zerconids *Skeironozercon tricavus* Blaszak and *S. embersoni* Halašková greatly declined in harvest-disturbed sites, while larger-bodied *Gamasellus* sp. 1, *Sejus* cf. *americanus* (Banks) and *Trachytes* sp. 1 increased. This is similar to Peck and Niwa (2005) findings, they found that smaller bodied mites (Zerconidae) had a greater reduction in thinned stands than larger bodied mites (Ologamasidae) in soil. In addition, Battigelli et al. (2004) did find that that larger-bodied Collembola increased, while smaller-bodied individuals decreased under certain harvest regimes. Larger Mesostigmata typically live closer to the surface of the soil, while smaller Mesostigmata are farther belowground (Walter and Ikonen 1989; Koehler 1999). As harvest disturbance leads to decreased litter diversity (Negrete-Yankelevich et al. 2007), one would have expected larger Mesostigmata to decrease in response to harvest disturbance; however, this was not the case here.

Mesostigmata (> 300 µm and 50-300 + 300 µm) and Oribatida (> 300 µm) assemblages were both significantly altered by linear disturbance. The effects of linear disturbance on megafauna and bird species is well documented (Benítez-López et al.

2010) while less is known for soil arthropods. As soil fauna are affected by aboveground vegetation (Wardle 2006 and references within), changes to vegetation caused by linear disturbance (Jones et al. 2014), will undoubtedly alter belowground fauna. Studies have found differences in species richness, number of individuals and density of Mesostigmata and Oribatida within different floral assemblages (Coulson et al. 2003; Gwiazdowicz and Coulson 2011), this is partly caused by differences in microhabitats (Nielsen et al. 2012). Linear disturbance is also associated with an increase in edge habitat. Edges usually have different abiotic conditions than interior habitat, including decreases in soil moisture, increase of light levels and changes in air and soil temperatures (Foggo et al. 2001). All of these abiotic differences could have an effect on presence and abundance of particular mite taxa (e.g. Berg et al. 1998; Vandegehuchte et al. 2015). In general, edge habitat decreases invertebrate abundance (Haskell 2000), including predatory mites (Ferguson 2004). Habitat fragmentation has also been shown to disproportionately affect smaller animals, as it limits their dispersal (Niebuhr et al. 2015). This means that non-phoretic mesostigmatid and oribatid mite species movement may be hampered as on-going stochastic events, will result in increasingly dissimilar assemblages in disturbed and undisturbed habitats.

Mesostigmata (> 300 µm and 50-300 + 300 µm) and Oribatida (> 300 µm) were also effective indicators of fire disturbance. This is, in part, due to the drastic increase in soil surface temperature by fire, and changes in organic matter and abiotic properties (Certini, 2005 and references within) that likely affected their assemblages. Changes to biotic factors may also influence mite assemblages after fire. Mesostigmatans main prey are nematodes and collembolan (Scheu 2002; Klarner et al. 2013), their assemblages can shift under fire disturbance (Huebner et al. 2012, Malmström 2012, Butenko et al. 2017). As Mesostigmata weakly specialize on certain prey groups (Buryn and Brandl 1992), their assemblages may change in response to changes in prey assemblages. Similarly, oribatid mites occupy different niches, and specialize on food sources (Schneider et al. 2004). Reductions in litter, and changes in fungal communities with fire disturbance (Camann et al. 2008; Bogorodskaya et al. 2010) may affect oribatid mites food intake as they will not change food source under environmental change (Gan et al. 2014). Because of this, they are more susceptible to fire disturbance.

4.4.2 Coarse taxonomy and its effectiveness in indicating disturbance

Biomonitoring studies that identify organisms through coarse taxonomy are common, particularly those focusing on aquatic invertebrates (Terlizzi et al. 2009; Jiang et al. 2013; Milošević et al. 2014; Jiang et al. 2017). Similar studies with terrestrial invertebrates like ants, beetles and nematodes have also indicated that coarse taxonomy can delineate various aspects of the environment (Groc et al. 2010; Rosser and Eggleton, 2012; Bhusal et al. 2014; Souza et al. 2016). Nevertheless, Bedano and Ruf (2010) found that coarser levels of identifications had significant information loss and argued that species-level identification should be used. In this study, mesostigmatid and oribatid mite assemblage composition at the genus and family level showed clear differences between disturbed and undisturbed sites. Genus-level identifications were more similar to species level identifications than family (adults) and family (adults+nymphs); however, taxa richness and diversity and community structure from all taxonomic levels were correlated with species-level identification. Here, I argue that genus-level identifications have allowable information loss, meaning, they can be used in place of species-level identification. Family-level identification should only be used when taxonomic expertise is not available. Previous studies have argued that mites, as a whole, are too difficult to identify to be used as bioindicators (Gerlach et al. 2013). Given that I found good discriminatory ability with only 43 genera and 21 families of Mesostigmata and 69 genera and 39 families of Oribatida, I feel that soil mites identified to these levels are suitable as bioindicators. The addition of nymphs to family-level identifications led to significant results that were not always observed at family (adults)-level alone. Although taxonomic literature for juveniles is scarce (Gulvik 2007), once adults from a site are identified, this greatly aids identification of nymphs.

To my knowledge, this study is the first to use BestAgg analysis on a terrestrial dataset. I found this method to be effective in delineating disturbed and undisturbed sites only for Mesostigmata 50-300 + > 300 μm linear disturbance. Richness, diversity and assemblage structure of the BestAgg dataset were highly correlated with species-level identification, and more so than genus-level was. Conversely, this method failed to greatly reduce surrogate total for most disturbance types. Mesostigmata > 300 μm fire and harvest disturbance had no reduction, and linear disturbance only had a 5% reduction. 50-300 + > 300 μm Mesostigmata and > 300 μm Oribatida fire disturbance had a 50% and 30% reduction; however, the number of surrogates remained was similar or greater than the number of genera present in the original dataset. I feel that when genus-level identifications are successful in describing different environments (whether categorized by habitat type, land use type, disturbance etc.) and the BestAgg method provides a surrogate total that is similar or greater than number of genera identified, BestAgg surrogates should not be applied, and genus-level identifications used instead.

Although previous uses of this method have included several taxonomic orders of invertebrates in their dataset (Bevilacqua et al. 2013, Jiang et al. 2017), while this study only analyzed one order/suborder of mites at a time, it is unclear why so little reduction occurred, especially given that Milošević et al. (2014) saw a reduction to 17 groups (only 15% of species identified) for the fly family Chironomidae. Future studies should test whether a combined Mesostigmata/Oribatida dataset may prove better than each mite taxon analyzed separately. With this being the first attempt with a terrestrial group, I am somewhat pessimistic of its utility for these taxa; however, this method needs to be applied more with soil mites (and terrestrial fauna in general) and more disturbance types before any conclusive statement can be made.

Initial analysis showed many taxa (species, genera and families) indicators of fire, harvest or linear disturbance; however, few remained once corrected using Holm-Bonferroni. Interestingly, all significant taxa (once corrected) were indicators of linear disturbance. The mesostigmatan family Blattisociidae was found to be indicators of linear disturbance. In this study, Blattisociidae was represented by the genera *Cheiroseius*, *Lasioseius* and *Platyseius*. In general, Blattisociidae is diverse, as members of this family have adapted to a wide range of habitats, including, terrestrial, arboreal and subaquatic (Lindquist et al.2009). Oribatid genera that were indicators of linear disturbance include: *Punctoribates and Zetomimus,* these genera have wide distribution across North America (Behan-Pelletier and Schatz 2010). Given that linear disturbance on belowground assemblages has been infrequently tested, I am cautious in saying that these taxa are reliable indicators of linear disturbance across multiple locales. However, in Alberta (and its surrounding area) they should be considered indicators of linear disturbance.

In this study, I found that assemblages of Mesostigmata and Oribatida could detect several types of forest disturbance at the species-level, with both groups detecting fire disturbance. As ABMI only sorts soil invertebrates that are > 300 µm, in the context of this study, the best comparison can be made is between adult Oribatida > 300 um and adult Mesostigmata > 300 µm. Mesostigmata had fewer species, genera and families, than Oribatida, including fewer individuals, meaning they take less time to identify than the more diverse oribatids. However, as Mesostigmata and Oribatida occupy two different niches in the environment (Scheu 2002), they offer different perspectives on how disturbance is affecting functional groups. Because of this, sampling them concurrently may be best to determine soil health. Both groups are effective as bioindicators with coarse taxonomy, and resources like Krantz and Walter (2009), make this level of identification achievable. For Alberta (and surrounding areas), resources on oribatid (Walter and Latonas 2011; Walter et al. 2014) and mesostigmatid (Meehan and Turnbull 2017) are also available. In addition, sampling protocols can be amended to cut down on lab processing, e.g. only slide individuals if they cannot be identified to genus/family-level through coarse sorting, this will shorten identification time and be more cost effective. Because of that, I recommend the continued use of both groups as bioindicators of soil health, given that sampling protocols can be revised to allow for easier identification.

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4.6 Tables and Figures

Table 4-1. Oribatida species identified by the Alberta Biodiversity Monitoring Institute that were in samples I assessed for Mesostigmata. Years sampled span 2010-2015.

Family	Genus	Species	Taxonomic Authority	Year described
Achipteridae	*Achipteria*	*coleoptrata*	(Linnaeus)	1758
Achipteridae	*Achipteria*	sp. 1 DEW	DEW	
Achipteridae	*Anachipteria*	sp. 1 DEW	DEW	
Achipteridae	*Parachipteria*	*bella*	(Sellnick)	1928
Autognetidae	*Autogneta*	sp. 2 DEW	DEW	
Camisiidae	*Camisia*	*biurus*	(C.L. Koch)	1939
Camisiidae	*Camisia*	*biverrucata*	(C.L. Koch)	1839
Camisiidae	*Heminothrus*	*longisetosus*	Willman	1925
Camisiidae	*Neonothrus*	*humicola*	Forsslund	1955
Camisiidae	*Platynothrus*	*peltifer*	(C.L. Koch)	1839
Camisiidae	*Platynothrus*	*yamasakii*	(Aoki)	1958
Carabodidae	*Carabodes*	*granulatus*	Banks	1895
Carabodidae	*Carabodes*	*labyrinthicus*	(Michael)	1879
Carabodidae	*Carabodes*	*wonalancetanus*	Reeves	1989
Cepheidae	*Cepheus*	sp. 1 DEW	DEW	
Cepheidae	*Cepheus*	sp. 2 DEW	DEW	
Cepheidae	*Oribatodes*	*mirabilis*	Banks	1895
Ceratozetidae	*Ceratozetes*	*cuspidatus*	Jacot	1939
Ceratozetidae	*Ceratozetes*	*gracilis*	(Michael)	1884
Ceratozetidae	*Ceratozetes*	*thienemanni*	Willman	1943
Ceratozetidae	*Dentizetes*	*ledensis*	Behan-Pelletier	2000
Ceratozetidae	*Dentizetes*	*rudentiger*	Hammer	1952
Ceratozetidae	*Diapterobates*	*humeralis*	(Hermann)	1984
Ceratozetidae	*Fuscozetes*	*fuscipes*	(C.L. Koch)	1844
Ceratozetidae	*Neogymnobates*	*luteus*	Oudemans	1917
Ceratozetidae	*Neogymnobates*	sp. 1 DEW	DEW	
Ceratozetidae	*Sphaerozetes*	*arcticus*	Hammer	1952
Ceratozetidae	*Trichoribates*	*copperminensis*	Hammer	1952
Ceratozetidae	*Trichoribates*	sp. 3 DEW	DEW	
Chamobatidae	*Chamobates*	*cuspidatus*	(Michael)	1884
Damaeidae	*Epidamaeus*	*arcticola*	(Hammer)	1952
Damaeidae	*Epidamaeus*	*coxalis*	(Hammer)	1952
Damaeidae	*Epidamaeus*	*floccosus*	Behan-Pelletier & Norton	1985
Damaeidae	*Epidamaeus*	*koyukon*	Behan-Pelletier & Norton	1985
Damaeidae	*Epidamaeus*	sp. 1 DEW	DEW	
Damaeidae	*Epidamaeus*	sp. 2 DEW	DEW	

Family	Genus	Species	Taxonomic Authority	Year
Damaeidae	*Epidamaeus*	sp. 3 DEW	DEW	
Damaeidae	*Epidamaeus*	sp. 4 DEW	DEW	
Damaeidae	*Epidamaeus*	sp. 5 DEW	DEW	
Damaeidae	*Quatrobelba*	*montana*	Norton	1980
Eniochthoniidae	*Eniochthonius*	*crosbyi*	(Ewing)	1909
Eniochthoniidae	*Eniochthonius*	*minutissimus*	(Berlese)	1903
Eniochthoniidae	*Eniochthonius*	sp. 1 LML	DEW	
Eremaeidae	*Eremaeus*	*translamellatus*	Hammer	1952
Eremaeidae	*Eueremaeus*	*marshalli*	Behan-Pelletier	1993
Eremaeidae	*Eueremaeus*	*quadrilamellatus*	(Hammer)	1952
Eremaeidae	*Eueremaeus*	*tetrosus*	(Higgins)	1979
Euphthiracaridae	*Euphthiracarus*	*flavus*	(Ewing)	1908
Euphthiracaridae	*Rhysotritia*	*ardua*	(C.L. Koch)	1841
Galumnidae	*Pergalumna*	sp. 1 DEW	DEW	
Galumnidae	*Pilogalumna*	sp. 1 DEW	DEW	
Galumnidae	*Pilogalumna*	sp. 2 DEW	DEW	
Gustaviidae	*Gustavia*	sp. 1 DEW	DEW	
Gymnodamaeidae	*Gymnodamaeus*	*ornatus*	Hammer	1952
Gymnodamaeidae	*Roynortonella*	sp. 1 DEW	DEW	
Haplozetidae	*Peloribates*	*canadensis*	(Hammer)	1952
Haplozetidae	*Peloribates*	*pilosus*	Hammer	1952
Haplozetidae	*Peloribates*	sp. 3 DEW	DEW	
Haplozetidae	*Protoribates*	*haughlandae*	Walter & Latonas	2013
Haplozetidae	*Protoribates*	*robustior*	(Jacot)	1937
Hermanniellidae	*Hermanniella*	*robusta*	Ewing	1918
Hydrozetidae	*Hydrozetes*	sp. E RAN	DEW	
Hypochthoniidae	*Hypochthonius*	*rufulus*	CL Koch	1835
Malaconothridae	*Malaconothrus*	*mollisetosus*	Hammer	1952
Malaconothridae	*Trimalaconothrus*	*maior*	(Berlese)	1910
Malaconothridae	*Trimalaconothrus*	sp. 3 DEW	DEW	
Mycobatidae	*Mycobates*	*incurvatus*	Hammer	1952
Mycobatidae	*Mycobates*	*perates*	Behan-Pelletier	1994
Mycobatidae	*Punctoribates*	*palustris*	(Banks)	1895
Nanhermanniidae	*Nanhermannia*	sp. 1 DEW	DEW	
Nothridae	*Nothrus*	*borussicus*	Sellnick	1928
Nothridae	*Nothrus*	*pratensis*	Sellnick	1929
Nothridae	*Nothrus*	sp. B DEW	DEW	
Oppiidae	*Oppiella*	*washburni*	(Hammer)	1952
Oribatellidae	*Oribatella*	*jacoti*	Behan-Pelletier	2011
Oribatellidae	*Oribatella*	*reticulatoides*	(Hammer)	1955

Family	Genus	Species	Taxonomic Authority	Year
Oribatellidae	*Oribatula*	sp. 1 DEW	DEW	
Oribatulidae	*Eporibatula*	sp. 1 DEW	DEW	
Oribatulidae	*Lucoppia*	*burrowsii*	(Michael)	1890
Oribatulidae	*Zygoribatula*	*bulanovae*	Kulijew	1961
Oribotritiidae	*Protoribotritia*	sp. 1 DEW	DEW	
Parakalummidae	*Neoribates*	sp. 1 DEW	DEW	
Parakalummidae	*Neoribates*	sp. 2 DEW	DEW	
Peloppiidae	*Ceratoppia*	*bipilis*	(Hermann)	1804
Peloppiidae	*Ceratoppia*	*quadridentata*	(Haller)	1882
Phenopelopoidae	*Eupelops*	*septentrionalis*	(Trägårdh)	1910
Phenopelopoidae	*Propelops*	*alaskensis*	(Hammer)	1955
Phenopelopoidae	*Propelops*	*canadensis*	(Hammer)	1952
Phthiracaridea	*Atropacarus*	*striculus*	(C.L. Koch)	1835
Phthiracaridea	*Hoplophthiracarus*	*illinoisensis*	(Ewing)	1909
Phthiracaridea	*Phthiracarus*	*borealis*	(Trägårdh)	1910
Phthiracaridea	*Phthiracarus*	*boresetosus*	Jacot	1930
Scheloribatidae	*Scheloribates*	*pallidulus*	(C.L. Koch)	1841
Suctobelbidae	*Allosuctobelba*	sp. 2 DEW	DEW	
Tectocepheidae	*Tectocepheus*	*sarekensis*	Trägårdh	1910
Tectocepheidae	*Tectocepheus*	*velatus*	(Michael)	1880
Tegoribatidae	*Lepidozetes*	*singularis*	Berlese	1910
Tegoribatidae	*Scutozetes*	*lanceolatus*	Hammer	1952
Tegoribatidae	*Tegoribates*	*americanus*	Hammer	1958
Tenulialidae	*Hafenferrefia*	sp. 1 DEW	DEW	
Thyrisomidae	*Banksinoma*	*lanceolata*	(Michael)	1885
Trhypochthoniidae	*Mainothrus*	*badius*	(Berlese)	1985
Trhypochthoniidae	*Mucronothrus*	*nasalis*	(Willman)	1929
Trhypochthoniidae	*Trhypochthonius*	*cladonicola*	(Willman)	1929
Trhypochthoniidae	*Trhypochthonius*	*tectorum*	(Berlese)	1896
Unduloribatidae	*Unduloribates*	*dianae*	Behan-Pelletier & Walter	2009
Zetomimidae	*Zetomimus*	*francisi*	(Habeeb)	1974

Table 4-2. Means, standard deviations and ANOVA results for undisturbed and disturbed quadrants in > 300 µm Mesostigmata samples for fire, harvest, and linear disturbance, at species-, genus-, family- (adults) and family- (adults+nymphs)-level identifications. Bold represents significance at $P < 0.05$.

	Taxon Richness			Taxon Diversity		
Species	Disturbed	Undisturbed		Disturbed	Undisturbed	
Fire	2.13 ± 1.58	2.75 ± 2.04	$F_{1,82} = 2.45, P = 0.12$	0.63 ± 0.56	0.79 ± 0.61	$F_{1,82} = 1.64, P = 0.20$
Harvest	3.22 ± 2.47	4.08 ± 2.68	$F_{1,62} = 2.92, P = 0.09$	0.88 ± 0.66	1.10 ± 0.66	$F_{1,62} = 2.87, P = 0.10$
Linear	3.89 ± 2.28	2.68 ± 1.57	$F_{1,30} = 2.85, P = 0.10$	1.08 ± 0.66	0.78 ± 0.56	$F_{1,30} = 1.79, P = 0.19$
Genus						
Fire	1.92 ± 1.44	2.58 ± 1.84	$F_{1,82} = 3.53, P = 0.06$	0.55 ± 0.54	0.74 ± 0.59	$F_{1,82} = 2.65, P = 0.11$
Harvest	3.16 ± 2.24	3.84 ± 2.61	$F_{1,62} = 1.7, P = 0.20$	0.90 ± 0.62	1.04 ± 0.63	$F_{1,62} = 1.36, P = 0.25$
Linear	3.74 ± 2.18	2.74 ± 1.56	$F_{1,30} = 1.99, P = 0.17$	1.04 ± 0.65	0.80 ± 0.55	$F_{1,30} = 1.16, P = 0.29$
Family (adults)						
Fire	1.81 ± 1.39	2.42 ± 1.65	$F_{1,82} = 3.61, P = 0.06$	0.51 ± 0.51	0.69 ± 0.55	$F_{1,82} = 2.83, P = 0.01$

Harvest	2.92 ± 1.91	3.16 ± 1.88	$F_{1,62} = 0.53$, $P = 0.47$	0.84 ± 0.57	0.88 ± 0.52	$F_{1,62} = 0.17$, $P = 0.68$
Linear	3.58 ± 1.98	2.53 ± 1.54	$F_{1,30} = 3.01$, $P = 0.09$	1.02 ± 0.63	0.7 ± 0.57	$F_{1,30} = 2.48$, $P = 0.13$
Family (adults+nymphs)						
Fire	2.42 ± 1.81	3.23 ± 1.74	**$F_{1,82} = 7.97$, $P = 0.01$**	0.69 ± 0.57	0.90 ± 0.51	**$F_{1,82} = 4.03$, $P = 0.05$**
Harvest	3.76 ± 2.24	4.03 ± 2.25	$F_{1,62} = 0.58$, $P = 0.45$	0.99 ± 0.59	1.06 ± 0.55	$F_{1,62} = 0.52$, $P = 0.47$
Linear	4 ± 2.03	3.37 ± 1.86	$F_{1,30} = 1.07$, $P = 0.31$	1.08 ± 0.55	0.90 ± 0.57	$F_{1,30} = 0.93$, $P = 0.34$

Table 4-3. PERMANOVA results for fire, harvest and linear disturbance. SR = same response as species-level (only applies to BestAgg). Bold represents significance at $P < 0.05$.

> 300 µm
Mesostigmata (A)

Taxonomic Level	Disturbance Type	
Species	Fire	**$F_{1,62}$= 1.75, P = 0.04**
	Harvest	**$F_{1,55}$ = 1.73, P = 0.03**
	Linear	**$F_{1,29}$ = 1.95, P = 0.03**
Genus	Fire	$F_{1,62}$= 1.78, P = 0.09
	Harvest	**$F_{1,55}$ = 1.98, P = 0.03**
	Linear	$F_{1,29}$ = 1.47, P = 0.14
Family (adults)	Fire	$F_{1,62}$ = 2.20, P = 0.05
	Harvest	**$F_{1,55}$ = 1.05, P = 0.02**
	Linear	$F_{1,29}$ = 1.98, P = 0.06
Family (adults+nymphs)	Fire	**$F_{1,66}$ = 2.80, P = 0.01**
	Harvest	**$F_{1,59}$ = 2.33, P = 0.02**
	Linear	$F_{1,29}$ = 1.75, P = 0.11

50-300 + >300 µm
Mesostigmata (B)

Taxonomic Level	Disturbance Type	
Species	Fire	**$F_{1,70}$ = 2.80, P < 0.01**
	Harvest	$F_{1,62}$ = 1.22, P = 0.24
	Linear	**$F_{1,30}$ = 3.34, P < 0.01**
Genus	Fire	**$F_{1,70}$ = 3.20, P < 0.01**
	Harvest	$F_{1,62}$ = 1.22, P = 0.29
	Linear	**$F_{1,30}$ = 3.03, P < 0.01**
Family (adults)	Fire	**$F_{1,70}$ = 2.34, P = 0.03**

	Harvest	$F_{1,62} = 1.24$, $P = 0.30$
	Linear	**$F_{1,30} = 4.08$, $P < 0.01$**
Family (adults+nymphs)	Fire	**$F_{1,71} = 3.01$, $P < 0.01$**
	Harvest	$F_{1,62} = 1.68$, $P = 0.10$
	Linear	**$F_{1,30} = 3.43$, $P < 0.01$**

>300 µm Oribatida (C)

Taxonomic Level	Disturbance Type	
Species	Fire	**$F_{1,72} = 2.20$, $P < 0.01$**
	Harvest	$F_{1,59} = 1.26$, $P = 0.21$
	Linear	$F_{1,30} = 1.61$, $P = 0.06$
Genus	Fire	**$F_{1,72} = 1.82$, $P = 0.32$**
	Harvest	$F_{1,59} = 1.23$, $P = 0.25$
	Linear	**$F_{1,30} = 1.89$, $P = 0.02$**
Family (adults)	Fire	**$F_{1,72} = 1.86$, $P = 0.03$**
	Harvest	$F_{1,59} = 1.58$, $P = 0.09$
	Linear	**$F_{1,30} = 2.61$, $P < 0.01$**

BestAgg (D)

Taxonomic Level	Disturbance Type		SR
50-300 + > 300 µm Mesostigmata	Linear	**$F_{1,30} = 3.04$, $P < 0.01$**	Y

Table 4-4. Means, standard deviations and ANOVA results for undisturbed and disturbed quadrants in 50-300 + > 300 µm Mesostigmata samples for fire, harvest, and linear disturbance, at species/morphospecies-, genus-, and family-levels for adults, and at family-level for adults+nymphs. Bold represents significance at $P < 0.05$.

	Taxon Richness			Taxon Diversity		
Species	Disturbed	Undisturbed		Disturbed	Undisturbed	
Fire	3.46 ± 2.55	4.52 ± 2.13	**$F_{1,82} = 7.97$, $P = 0.01$**	0.99 ± 0.63	1.2 ± 0.51	**$F_{1,82} = 4.67$, $P = 0.03$**
Harvest	5.59 ± 2.92	6.68 ± 3.29	$F_{1,62} = 3.23$, $P = 0.08$	1.36 ± 0.58	1.5 ± 0.53	$F_{1,62} = 1.36$, $P = 0.25$
Linear	5.47 ± 3.04	6.11 ± 3.25	$F_{1,30} = 0.61$, $P = 0.44$	1.36 ± 0.74	1.42 ± 0.57	$F_{1,30} = 0.3$, $P = 0.59$
Genus						
Fire	2.96 ± 2.03	4.23 ± 1.92	**$F_{1,82} = 12.18$, $P < 0.01$**	0.87 ± 0.59	1.14 ± 0.49	**$F_{1,82} = 7.92$, $P = 0.01$**
Harvest	5.08 ± 2.37	5.84 ± 2.7	$F_{1,62} = 2.04$, $P = 0.16$	1.30 ± 0.54	1.39 ± 0.5	$F_{1,62} = 0.80$, $P = 0.38$
Linear	5.05 ± 2.74	5.37 ± 2.34	$F_{1,30} = 0.50$, $P = 0.48$	1.28 ± 0.7	1.31 ± 0.51	$F_{1,30} = 0.22$, $P = 0.64$
Family (adults))						
Fire	2.54 ± 1.66	3.44 ± 1.60	**$F_{1,82} = 8.87$, $P < 0.01$**	0.74 ± 0.53	0.92 ± 0.45	**$F_{1,82} = 4.56$, $P = 0.04$**

Harvest	3.92 ± 1.69	4.00 ± 1.87	$F_{1,62} = 0.03$, $P = 0.86$	1.03 ± 0.46	1.00 ± 0.43	$F_{1,62} = 0.07$, $P = 0.8$
Linear	4.11 ± 2	3.84 ± 1.5	$F_{1,30} = 0.05$, $P = 0.94$	1.1 ± 0.58	1.04 ± 0.4	$F_{1,30} < 0.01$, $P = 0.97$
Family (adults+nymphs)						
Fire	3.23 ± 2.02	4.23 ± 1.67	**$F_{1,82} = 9.05$, $P < 0.01$**	0.88 ± 0.57	1.09 ± 0.41	**$F_{1,82} = 5.90$, $P = 0.01$**
Harvest	4.89 ± 1.98	4.92 ± 2.22	$F_{1,62} < 0.01$, $P = 0.95$	1.23 ± 0.41	1.16 ± 0.4	$F_{1,62} = 0.78$, $P = 0.39$
Linear	4.63 ± 2.03	4.63 ± 1.74	$F_{1,30} = 0.00$, $P = 1$	1.17 ± 0.52	1.13 ± 0.41	$F_{1,30} = 0.06$, $P = 0.80$

Table 4-5. Means, standard deviations and ANOVA results for undisturbed and disturbed quadrants in 300 O samples for fire, harvest, and linear disturbance, at species/morphospecies-, genus-, family- (adults) and family- (adults+nymphs)-level identifications. Bold represents significance at $P < 0.05$.

	Taxa Richness			Taxa Diversity		
Species	Disturbed	Undisturbed		Disturbed	Undisturbed	
Fire	3.48 ± 2.86	5.1 ± 3.36	**$F_{1,82} = 11.49$, $P < 0.01$**	0.90 ± 0.7	1.21 ± 0.66	**$F_{1,82} = 7.21$, $P = 0.01$**
Harvest	4.62 ± 3.36	5.62 ± 2.49	**$F_{1,62} = 7.68$, $P = 0.01$**	1.05 ± 0.76	1.44 ± 0.48	**$F_{1,62} = 11.28$, $P < 0.01$**
Linear	5.11 ± 2.85	5.79 ± 2.57	$F_{1,30} = 1.19$, $P = 0.28$	1.16 ± 0.56	1.41 ± 0.4	$F_{1,30} = 3.22$, $P = 0.08$
Genus						
Fire	3.40 ± 2.72	5.06 ± 3.3	**$F_{1,82} = 11.9$, $P < 0.01$**	0.89 ± 0.68	1.20 ± 0.66	**$F_{1,82} = 7.22$, $P = 0.01$**
Harvest	4.49 ± 3.17	5.46 ± 2.47	**$F_{1,62} = 7.16$, $P = 0.01$**	1.03 ± 0.74	1.41 ± 0.49	**$F_{1,62} = 10.57$, $P < 0.01$**
Linear	5.00 ± 2.77	5.53 ± 2.65	$F_{1,30} = 0.68$, $P = 0.42$	1.15 ± 0.55	1.36 ± 0.42	$F_{1,30} = 2.23$, $P = 0.15$

Family (A)						
Fire	3.38 ± 2.69	4.9 ± 3.19	**$F_{1,82}$ = 10.69, P < 0.01**	0.89 ± 0.68	1.17 ± 0.64	**$F_{1,82}$ = 6.35, P = 0.01**
Harvest	4.19 ± 2.99	5.32 ± 2.46	**$F_{1,62}$ = 8.89, P < 0.01**	0.97 ± 0.72	1.37 ± 0.49	**$F_{1,62}$ = 12.39, P < 0.01**
Linear	4.37 ± 2.5	5.26 ± 2.38	$F_{1,30}$ = 2.06, P = 0.16	1.02 ± 0.54	1.32 ± 0.41	**$F_{1,30}$ = 5.03, P = 0.03**

Table 4-6. Surrogate taxa for 50-300 + > 300 µm Mesostigmata BestAgg analysis of linear disturbance. Group types: S= species, SG=species group, G= genus, F=family, R=remainder of taxa*=monotypic in dataset, only one species present, Y=yes, N=no, E =easy, H=hard.

Surrogate	Family	Genus	Species	Relevant	Easiness	Group type
1	Zerconidae	*Parazercon*	*radiatus*	Y	E	S
2	Blattisociidae	*Platyseius*	c.f. *tendens*	Y	E	S
3	Zerconidae	*Zercon*	*alaskaensis*	Y	E	S
4	Zerconidae	*Zercon*	cf. *columbianus*	Y	E	S
5	Zerconidae	*Skeironozercon*	*tricavus*	Y	E	S
6	Trachytidae	*Trachytes*	sp. 1	Y	E	S
7	Ascidae	*Arctoseius*	cetratus gr. sp. 1 l	Y	H	SG1
7	Ascidae	*Arctoseius*	cetratus gr. sp. 1 s	N	E	SG1
7	Ascidae	*Arctoseius*	cf. *semiscissus*	N	H	SG1
8	Pachylaelapidae	*Zygoseius*	*furciger*	Y	E	S
9	Ameroseiidae	*Ameroseius*	sp. 1	N	H	G1
9	Ameroseiidae	*Ameroseius*	sp. 3	N	H	G1
10	Blattisociidae	*Cheiroseius*	(*Cheiroseius*) sp. 2	N	H	G2
10	Blattisociidae	*Cheiroseius*	(*Cheiroseius*) sp. 3	N	H	G2
10	Blattisociidae	*Cheiroseius*	(*Posttreamtus*) sp. 1	N	H	G2
11	Blattisociidae	*Lasioseius*	nr. *oblongus*	Y	E	S
12	Laelapidae	*Gaeolaelaps*	sp. 1	Y	H	G3
12	Laelapidae	*Gaeolaelaps*	sp. 3	Y	H	G3
13	Ascidae	*Asca*	*aphidoides*	Y	E	S
14	Ascidae	*Asca*	*garmani*	Y	E	S

Surrogate	Family	Genus	Species	Relevant	Easiness	Group
15	Dinychidae	*Dinychus*	sp. 4	Y	E	S
16	Ologamasidae	*Gamasellus*	sp. 1	N	H	G4
16	Ologamasidae	*Gamasellus*	sp. 2	Y	H	G4
17	Ascidae	*Arctoseius*	nr. weberi	Y	E	S
18	Zerconidae	*Mixozercon*	*borealis*	Y	E	S
19	Digamasellidae	*Dendrolaelaps*	sp. 1	N	H	G5
19	Digamasellidae	*Dendrolaelaps*	sp. 3	N	H	G5
19	Digamasellidae	*Dendrolaelaps*	sp. 4	N	H	G5
19	Digamasellidae	*Dendrolaelaps*	sp. 6	N	H	G5
19	Digamasellidae	*Dendrolaelaps*	sp. 8	Y	H	G5
19	Digamasellidae	*Dendrolaelaps*	sp. 9	Y	H	G5
19	Digamasellidae	*Dendrolaelaps*	sp. 11	N	H	G5
20	Ascidae	*Arctoseius*	*cetratus*	N	E	F1
20	Ascidae	*Arctoseius*	cf. *idiodactylus*	N	H	F1
20	Ascidae	*Arctoseius*	*multidentatus*	N	E	F1
20	Ascidae	*Arctoseius*	nr. minor sp. 1	Y	H	F1
20	Ascidae	*Arctoseius*	nr. *minutus* sp. 1	Y	H	F1
20	Ascidae	*Arctoseius*	nr. *minutus* sp. 2	N	H	F1
20	Ascidae	*Arctoseius*	ornatus gr. sp. 1	N	H	F1
20	Ascidae	*Asca*	nova	N	E	F1
20	Ascidae	*Iphidozercon*	cf. *altaicus*	N	E	F1
20	Ascidae	*Gamasellodes*	sp. 1	N	H	F1
20	Ascidae	*Zerconopsis*	nr. *michaeli*	Y	E	F1
21	Phytoseiidae	*Chelaseius*	*floridanus*	N	E	F*1
22	Zerconidae	*Boreozercon*	*emendi*	N	E	F2

Surrogate	Family	Genus	Species	Relevant	Easiness	Group
22	Zerconidae	*Mixozercon*	*jasoniana*	N	E	F2
22	Zerconidae	*Zercon*	sp. 2	N	H	F2
23	Dinychidae	*Dinychus*	sp. 3	N	E	F3
23	Dinychidae	*Dinychus*	sp. 6	N	E	F3
23	Dinychidae	*Dinychus*	sp. 7	N	E	F3
23	Dinychidae	*Dinychus*	sp. 8	N	H	F3
23	Dinychidae	*Urodiaspis*	sp. 1	N	H	F3
24	Laelapidae	*Cosmolaelaps*	sp. 1	N	H	F4
24	Laelapidae	*Hypoaspis*	sp. 1	N	H	F4
25	Pachylaelapidae	*Pachylaelaps*	sp.1	Y	H	F*2
26	Microgyniidae	*Microgynium*	sp. 1	N	H	R
26	Sejidae	*Sejus*	cf. *americanus*	N	H	R

Table 4-7. Mean and SD's (standard deviation) and ANOVA results for undisturbed and disturbed quadrants for the BestAgg datasets. Bold represents significance. SR = same results, refers to species-level identification. Bold represents significance. $P < 0.05$.

BestAgg	Taxa Richness				Taxa Diversity			
	Disturbed	Undisturbed		SR	Disturbed	Undisturbed		SR
50-300 / 300 Linear	5.26 ± 2.86	5.47 ± 2.46	$F_{1,30}$ = 0.33, P = 0.57	Y	1.32 ± 0.73	1.34 ± 0.51	$F_{1,30}$ = 0.2, P = 0.66	Y

Table 4-8. Correlations of species-level identification with genus, family (adults), family (adults+nymphs), when applicable) and BestAgg (when applicable) datasets for taxa richness, diversity and Bray-Curtis community structure. M=Mesostigmata, O=Oribatida, NA = non applicable, meaning that analysis was not done. Bold represents significance, $P < 0.05$.

Correlated with Species-level identification

	> 300 µm M(A)	Genus-level	Family (adults)-level	Family (adults+nymphs)-level
Fire	Taxa Richness	**0.983**	**0.971**	**0.864**
	Taxa Diversity	**0.954**	**0.929**	**0.759**
	Community Structure	**0.767**	**0.626**	NA
Harvest	Taxa Richness	**0.954**	**0.840**	**0.701**
	Taxa Diversity	**0.929**	**0.833**	**0.543**
	Community Structure	**0.759**	**0.577**	NA
Linear	Taxa Richness	**0.989**	**0.965**	**0.862**
	Taxa Diversity	**0.988**	**0.943**	**0.801**
	Community Structure	**0.858**	**0.710**	**0.645**

	50-300 + > 300 µm M (B)	Genus-level	Family (adults)-level	Family (adults+nymphs)-level	BestAgg
Fire	Taxa Richness	**0.978**	**0.940**	**0.900**	NA
	Taxa Diversity	**0.949**	**0.871**	**0.826**	NA
	Community Structure	**0.740**	**0.486**	NA	NA
Harvest	Taxa Richness	**0.965**	**0.840**	**0.701**	NA
	Taxa Diversity	**0.970**	**0.833**	**0.543**	NA
	Community Structure	**0.751**	**0.577**	NA	NA
Linear	Taxa Richness	**0.974**	**0.923**	**0.846**	**0.985**
	Taxa Diversity	**0.985**	**0.944**	**0.823**	**0.993**
	Community Structure	**0.843**	**0.691**	NA	**0.857**

	> 300 µm O (C)	Genus-level	Family (adults)-level
Fire	Taxa Richness	**0.998**	**0.997**
	Taxa Diversity	**0.998**	**0.996**
	Community Structure	**0.882**	**0.788**
Harvest	Taxa Richness	**0.996**	**0.985**
	Taxa Diversity	**0.996**	**0.983**
	Community Structure	**0.905**	**0.786**
Linear	Taxa Richness	**0.988**	**0.954**
	Taxa Diversity	**0.989**	**0.937**
	Community Structure	**0.896**	**0.761**

Table 4-9. Taxa at the species, genus, family (adults) and family (adults+nymphs)-level that were found to be the top indicators of disturbance (fire, harvest, linear). M=Mesostigmata, O=Oribatida. P values were corrected using Holm Bonferroni; bold represents significance at $P < 0.05$ for corrected P values.

Taxon and Size	Type	Disturbance Type	Taxon Group	R value	P value	Corrected P Value
> 300 µm M	Species	Harvest	*Sejus* cf. *americanus*	0.334	0.047	1
> 300 µm M	Species	Linear	*Cheiroseius* (*Cheiroseius*). sp .3	0.272	0.045	1
> 300 µm M	Species	Fire	*Gaeolaelaps* sp. 2	0.278	0.019	0.589
> 300 µm M	Genus	Harvest	*Sejus*	0.334	0.024	0.36
> 300 µm M	Family (adults)	Harvest	Sejidae	0.334	0.016	0.112
> 300 µm M	Family (adults)	Linear	Blattisociidae	0.483	0.001	**0.01**
> 300 µm M	Family (adults+nymphs)	Linear	Blattisociidae	0.445	0.002	**0.02**
50-300 + > 300 µm M	Species	Harvest	*Mixozercon jasoniana*	0.372	0.006	0.258
50-300 + > 300 µm M	Species	Harvest	*Sejus nr.americanus*	0.334	0.023	0.943
50-300 + > 300 µm M	Species	Linear	*Zercon* cf. *columbianus*	0.395	0.004	0.176
50-300 + > 300 µm M	Species	Fire	*Dinychus* sp. 3	0.311	0.047	1
50-300 + > 300 µm M	Species	Fire	*Gaeolaelaps* sp. 2	0.278	0.049	1
50-300 + > 300 µm M	Genus	Harvest	*Sejus*	0.334	0.017	0.272
50-300 + > 300 µm M	Family (adults)	Harvest	Sejidae	0.334	0.03	0.216
50-300 + > 300 µm M	Family (adults)	Linear	Blattisociidae	0.478	0.001	**0.011**
50-300 + > 300 µm M	Family (adults+nymphs)	Linear	Blattisociidae	0.44	0.004	**0.044**
> 300 µm O	Species	Linear	*Achipteria coleoptrata*	0.34	0.003	0.18
> 300 µm O	Species	Linear	*Punctoribates palustris*	0.459	0.001	0.062
> 300 µm O	Species	Linear	*Sphaerozetes arcticus*	0.319	0.016	0.88
> 300 µm O	Species	Linear	*Zetomimus francisi*	0.397	0.001	0.062
> 300 µm O	Species	Fire	*Epidamaeus arcticola*	0.345	0.008	0.464
> 300 µm O	Genus	Linear	*Punctoribates*	0.459	0.001	**0.046**

Taxon and Size	Type	Disturbance Type	Taxon Group	R value	P value	Corrected P Value
> 300 µm O	Genus	Linear	*Sphaerozetes*	0.319	0.008	0.344
> 300 µm O	Genus	Linear	*Zetomimus*	0.397	0.001	**0.046**
> 300 µm O	Family (adults)	Linear	Mycobatidae	0.394	0.042	1
> 300 µm O	Family (adults)	Linear	Zetomimidae	0.397	0.001	0.031

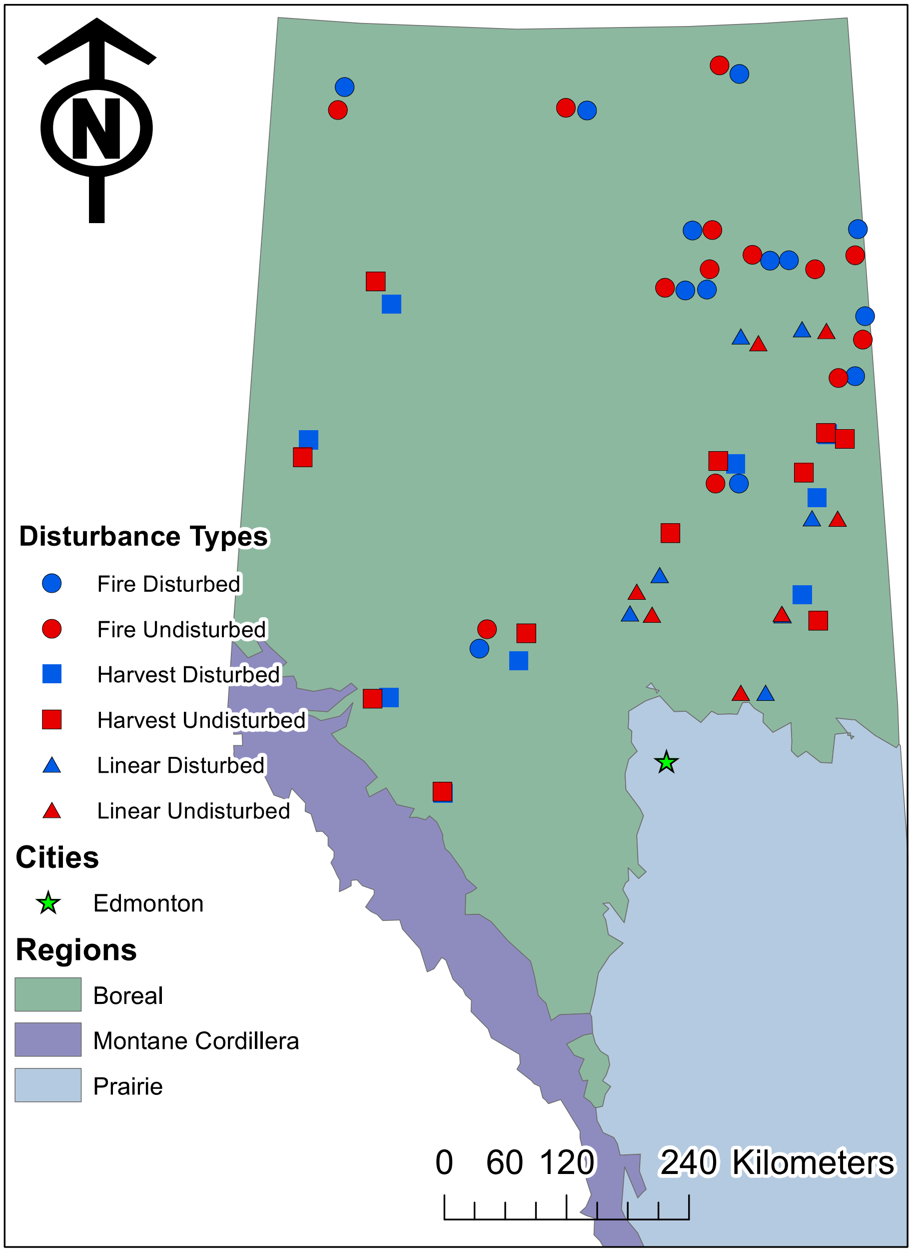

Figure 4-1.Map showing the geographic distribution of Alberta Biodiversity Monitoring Institute sites sampled. Sites are split up into their disturbance system (fire, harvest and linear) and whether they are disturbed or undisturbed.

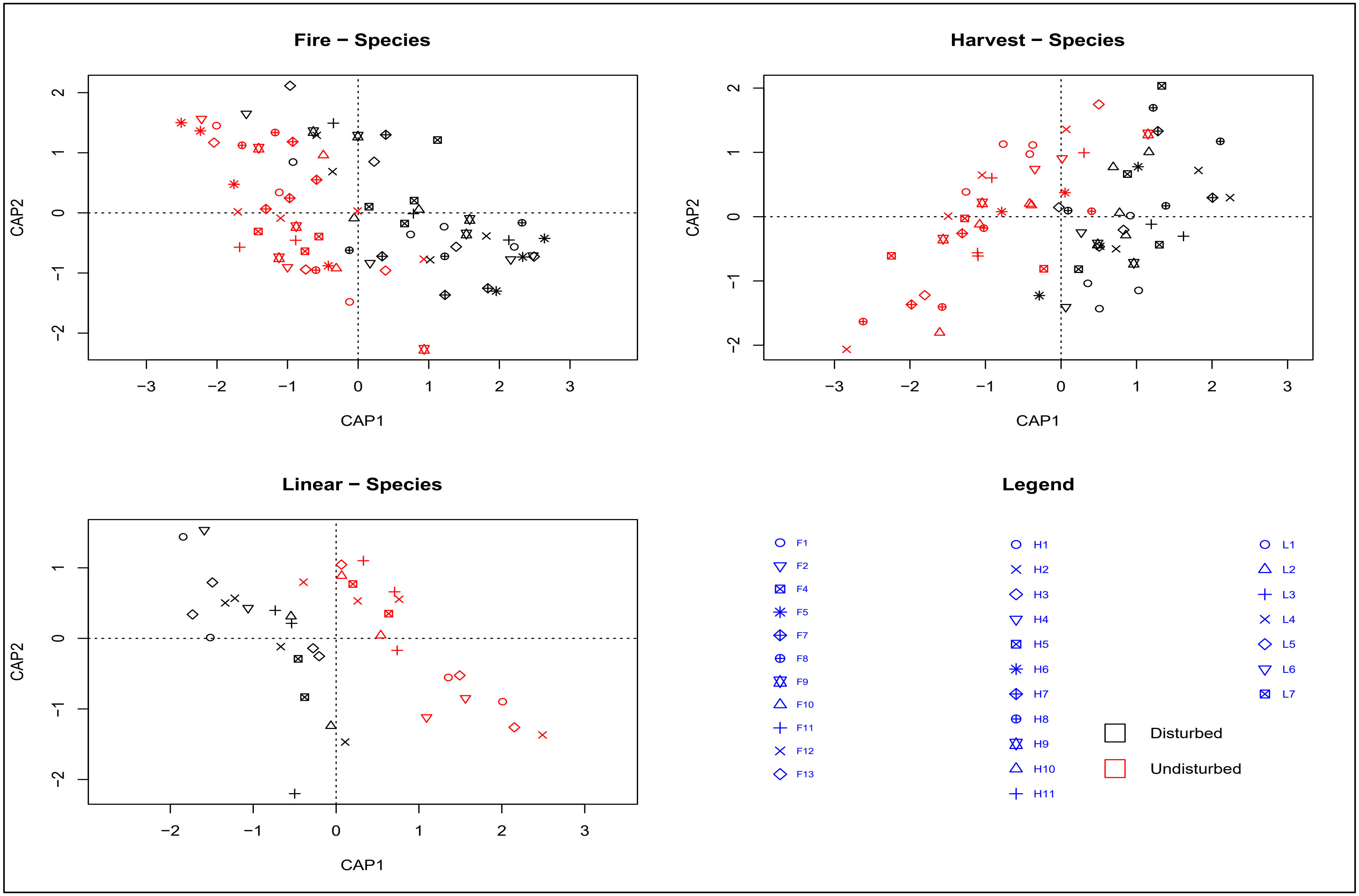

Figure 4-2. db-RDA plot of Mesostigmata assemblages showing both undisturbed and disturbed quadrants of fire (P = 0.04), harvest (P = 0.02) and linear (P = 0.03) disturbance for > 300 µm Mesostigmata , species-level. Points represents quadrants in site pairs, black points represent disturbed pairs, red points represent undisturbed site pairs. P = P value, NS = not significant.

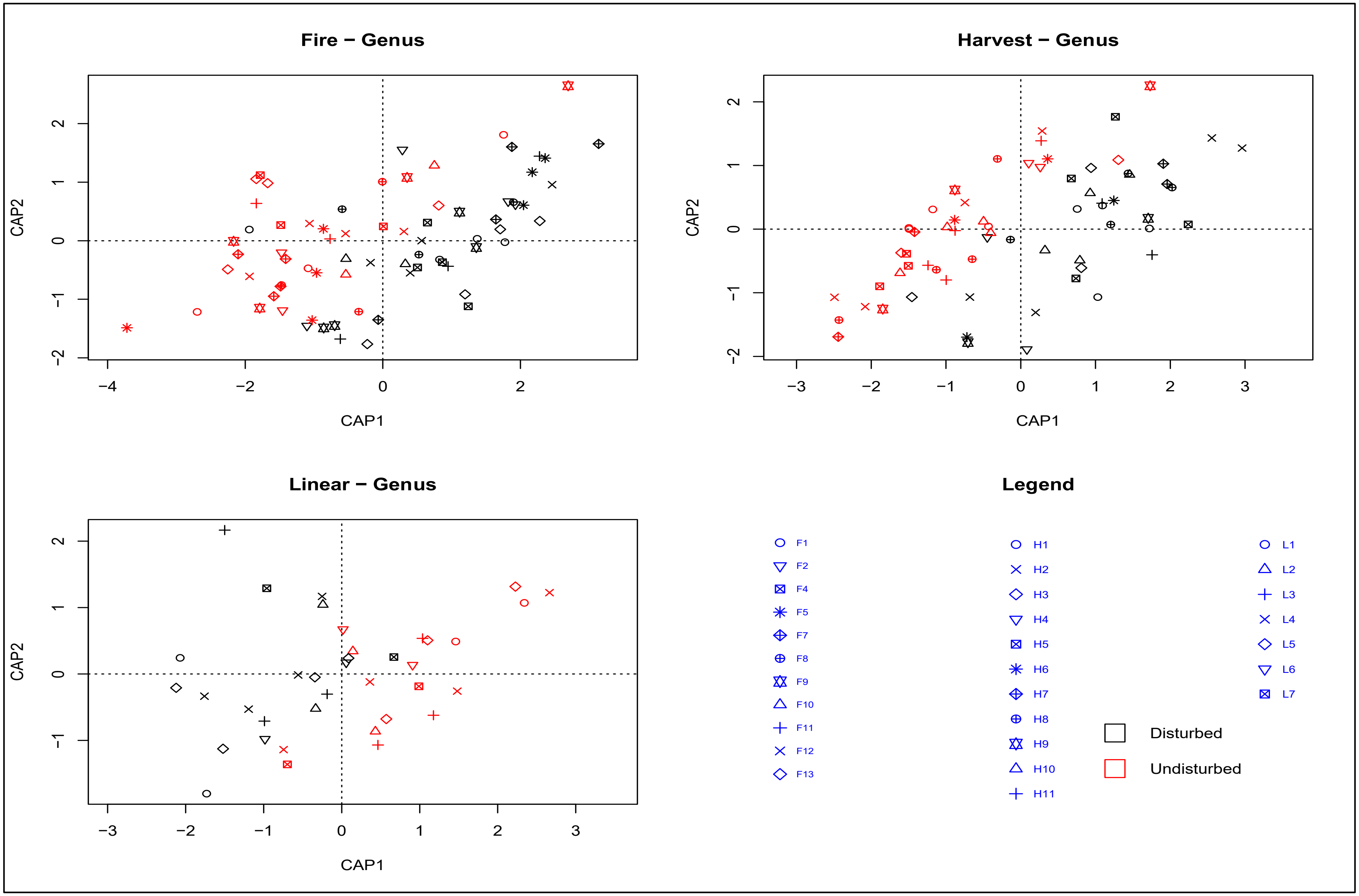

Figure 4-3. db-RDA plot of Mesostigmata assemblages showing both undisturbed and disturbed quadrants of NS), harvest (P = 0.03) and linear (NS) for > 300 µm Mesostigmata, genus-level. Points represents quadrants in site pairs, black points represent disturbed site pairs, red points represent undisturbed site pairs. P = P value, NS = not significant.

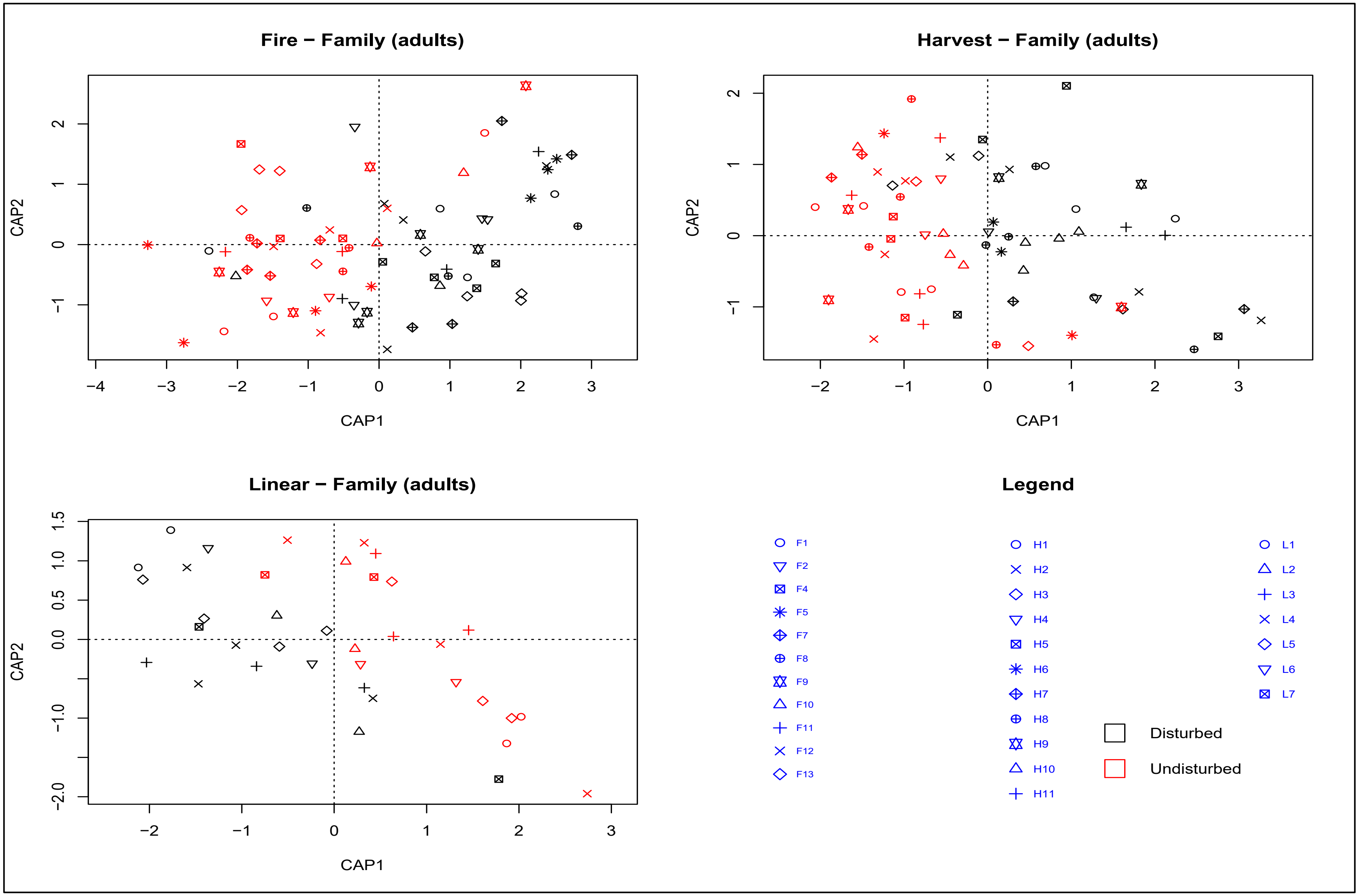

Figure 4-4. db-RDA plot of Mesostigmata assemblages showing both undisturbed and disturbed quadrants of fire (NS), harvest (P = 0.03) and linear (NS) disturbance for > 300 µm Mesostigmata, family (adults)-level. Points represents quadrants in site pairs, black points represent disturbed site pairs, red points represent undisturbed site pairs. P = P value, NS = not significant.

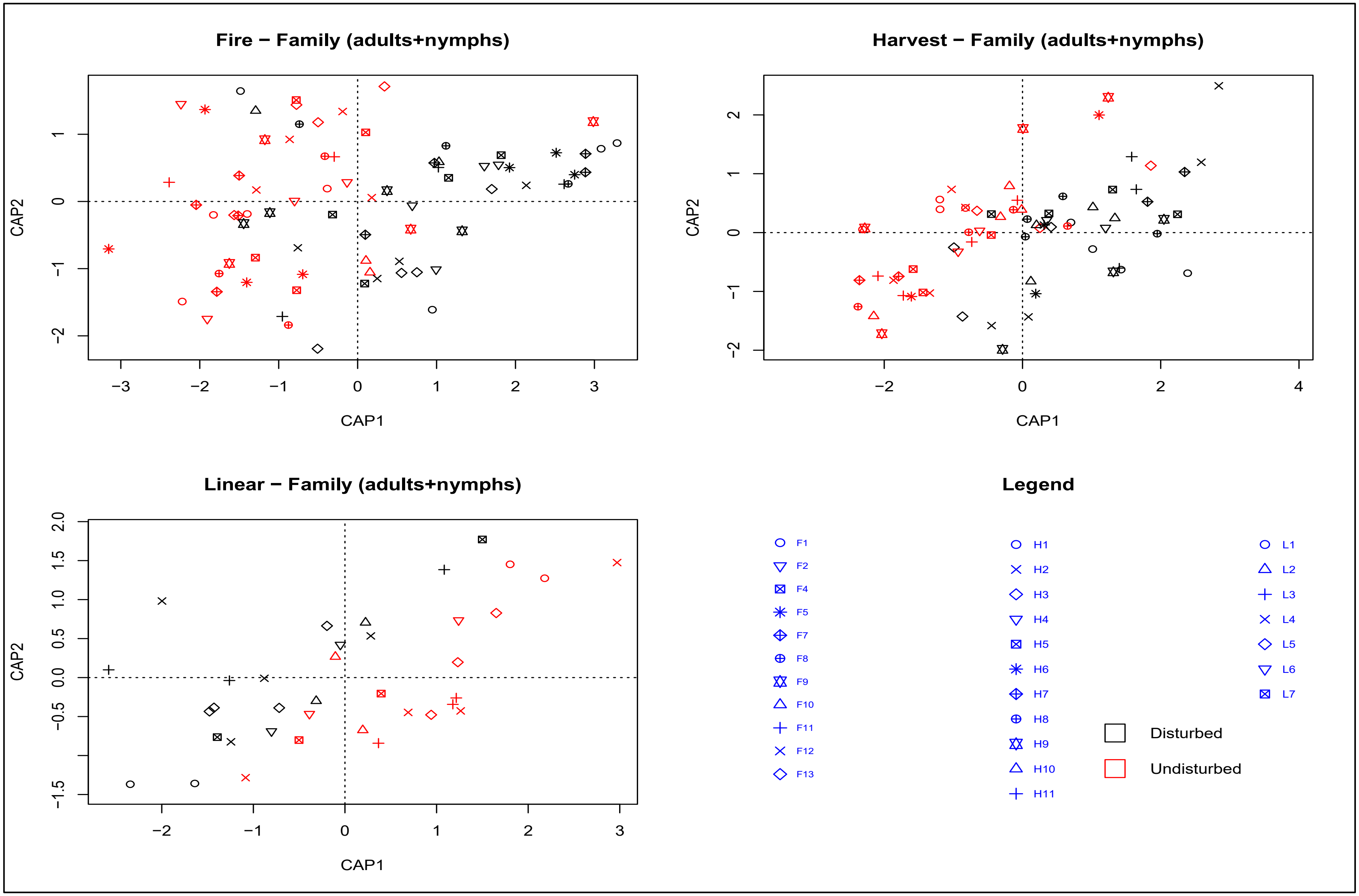

Figure 4-5. db-RDA plot of Mesostigmata assemblages showing both undisturbed and disturbed quadrants of fire (P = 0.01), harvest (P = 0.02) and linear (NS) disturbance for > 300 µm Mesostigmata, family (adults+nymphs)-level. Points represents quadrants in site pairs, black points represent disturbed site pair, red points represent undisturbed site pair. P = P value, NS = not significant.

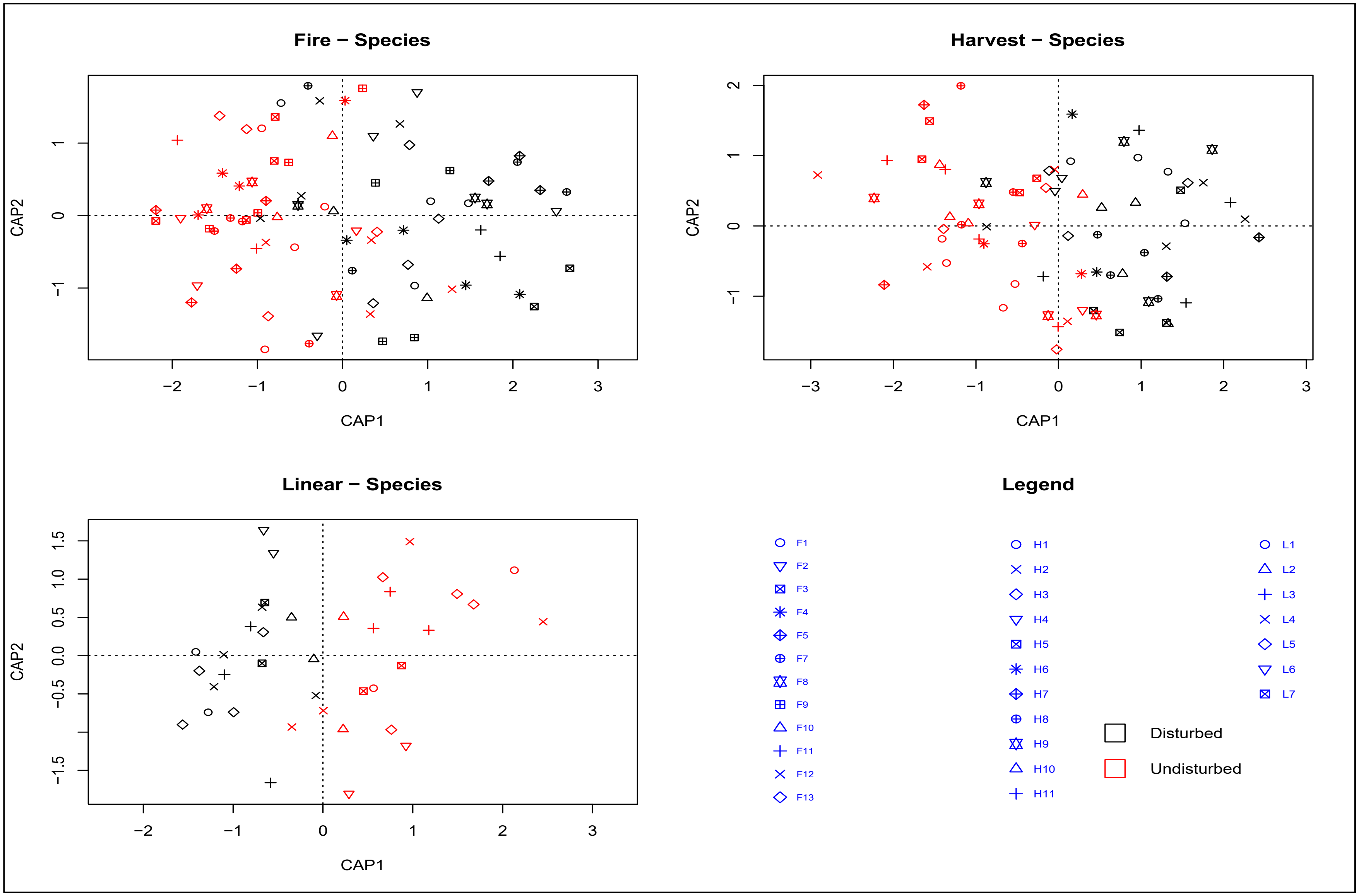

Figure 4-6. db-RDA plot of Mesostigmata assemblages showing both undisturbed and disturbed quadrants of fire ($P < 0.01$), harvest (NS) and linear ($P < 0.01$) disturbance for 50-300 + > 300 µm Mesostigmata , species-level. Points represents quadrants in site pairs, black points represent disturbed site pair, red points represent undisturbed site pair. P = P value, NS = not significant.

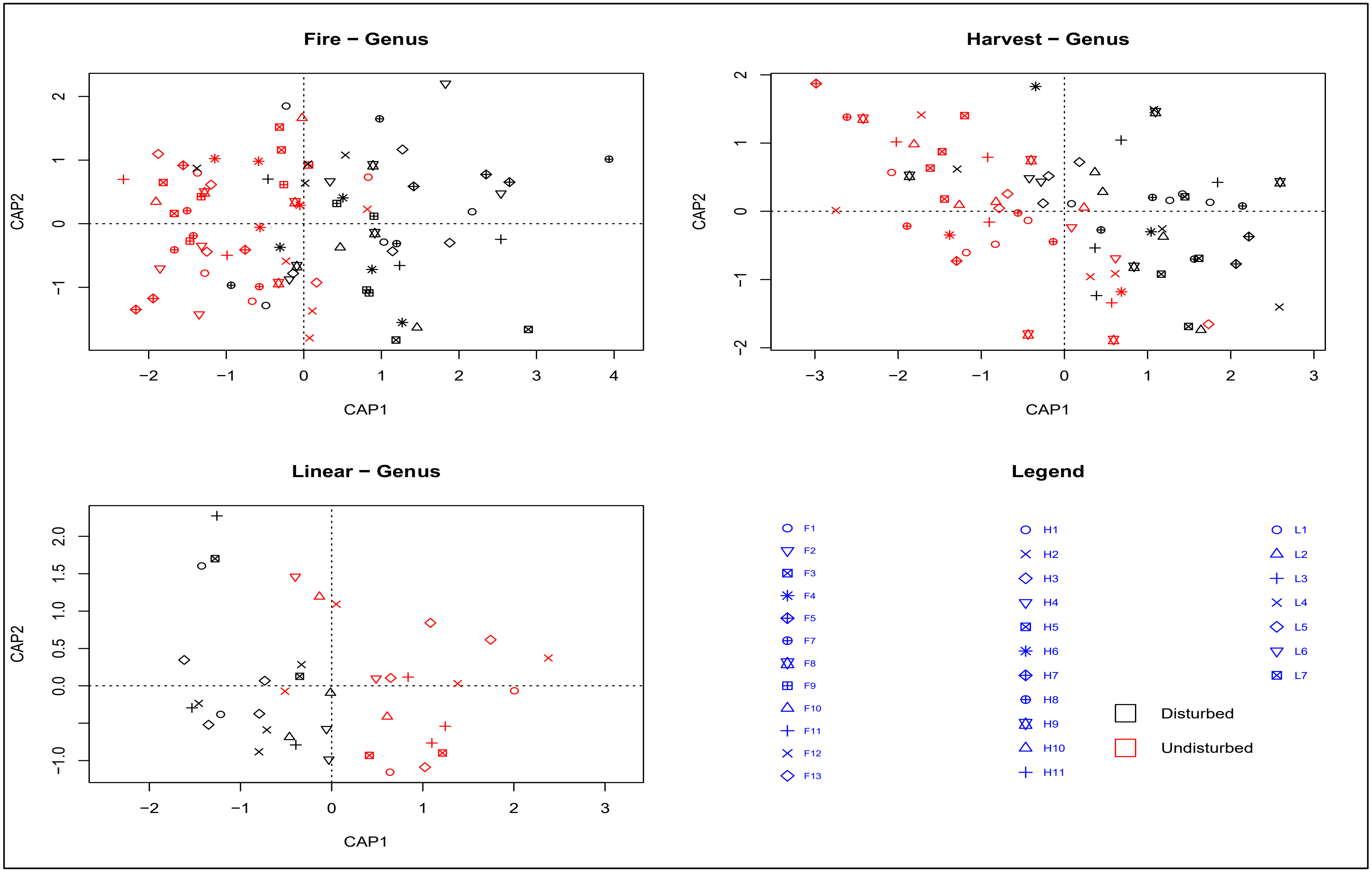

Figure 4-7. db-RDA plot of Mesostigmata assemblages showing both undisturbed and disturbed quadrants of fire ($P < 0.01$), harvest (NS) and linear ($P < 0.01$) disturbance for 50-300 + > 300 µm Mesostigmata , genus-level. Points represents quadrants in site pairs, black points represent disturbed site pair, red points represent undisturbed site pair. P = P value, NS = not significant.

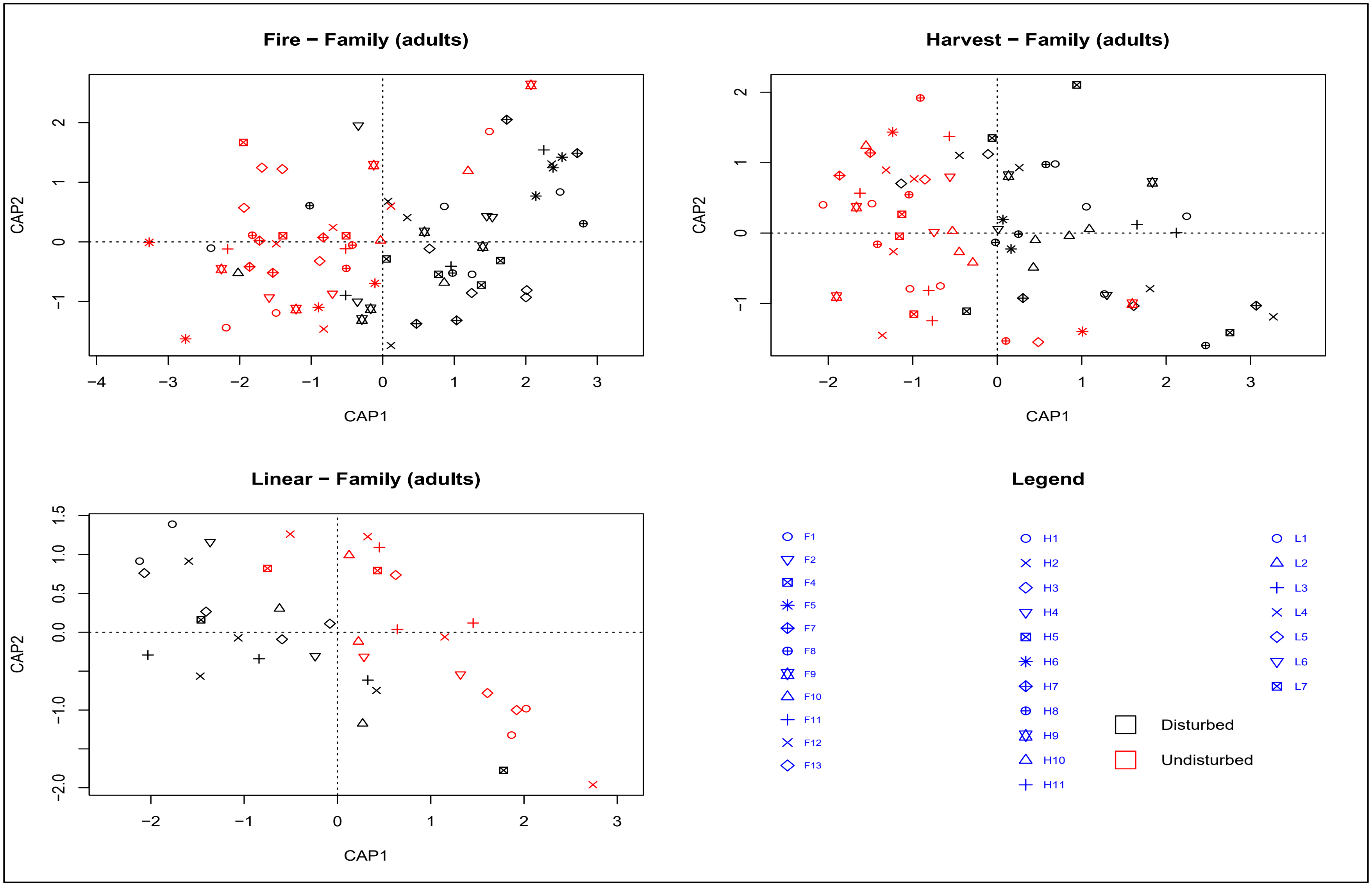

Figure 4-8. db-RDA plot of Mesostigmata assemblages showing both undisturbed and disturbed quadrants of fire ($P = 0.03$), harvest (NS) and linear ($P < 0.01$) disturbance for 50-300 + > 300 µm Mesostigmata, family (adults)-level. Points represents quadrants in site pairs, black points represent disturbed site pair, red points represent undisturbed site pair. P = P value, NS = not significant.

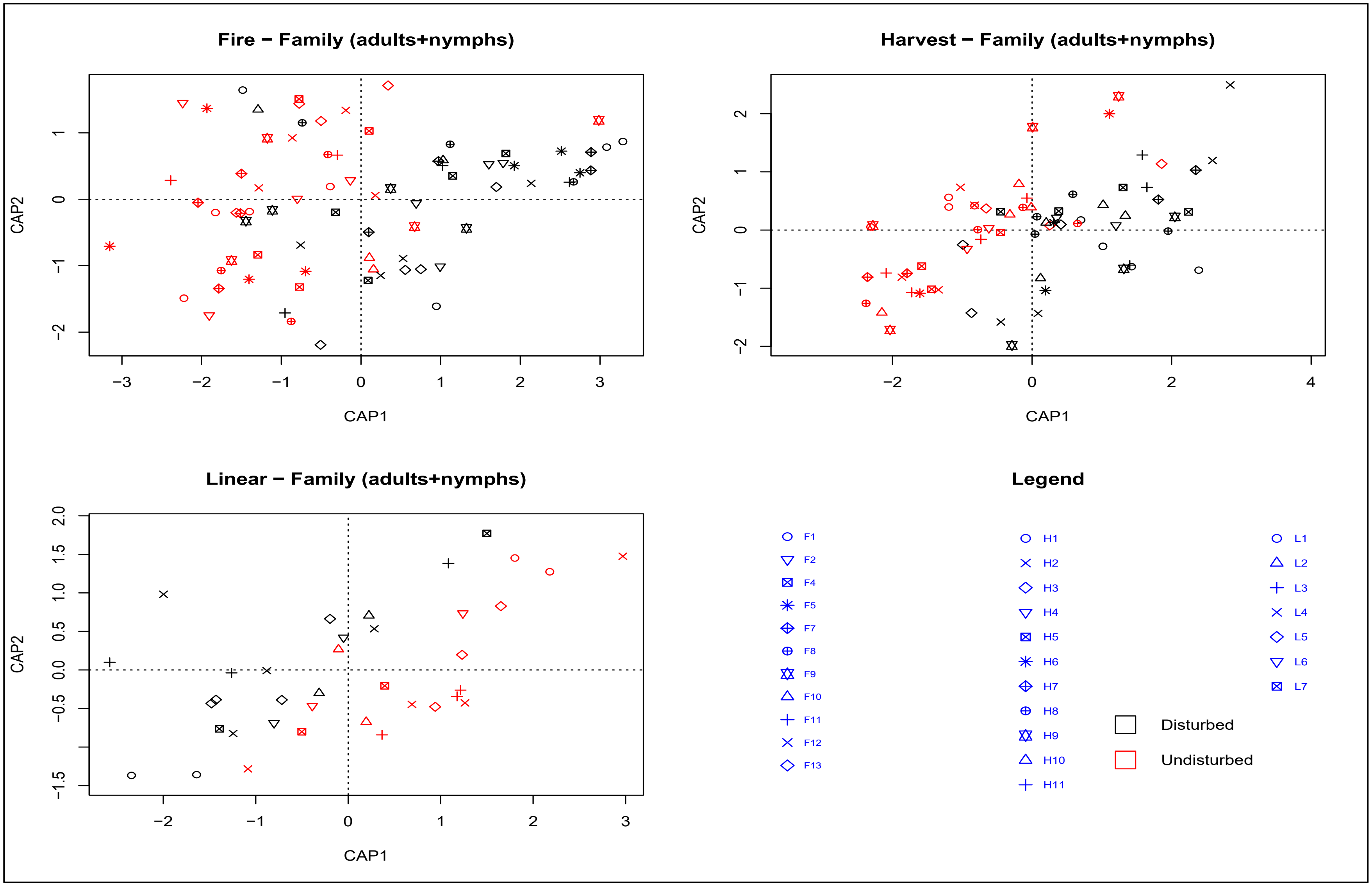

Figure 4-9. db-RDA plot of Mesostigmata assemblages showing both undisturbed and disturbed quadrants of fire ($P < 0.01$), harvest (NS) and linear ($P = 0.01$) disturbance for 50-300 + > 300 µm Mesostigmata, family (adults+nymphs)-level. Points represents quadrants in site pairs, black points represent disturbed site pair, red points represent undisturbed site pair. P = P value, NS = not significant

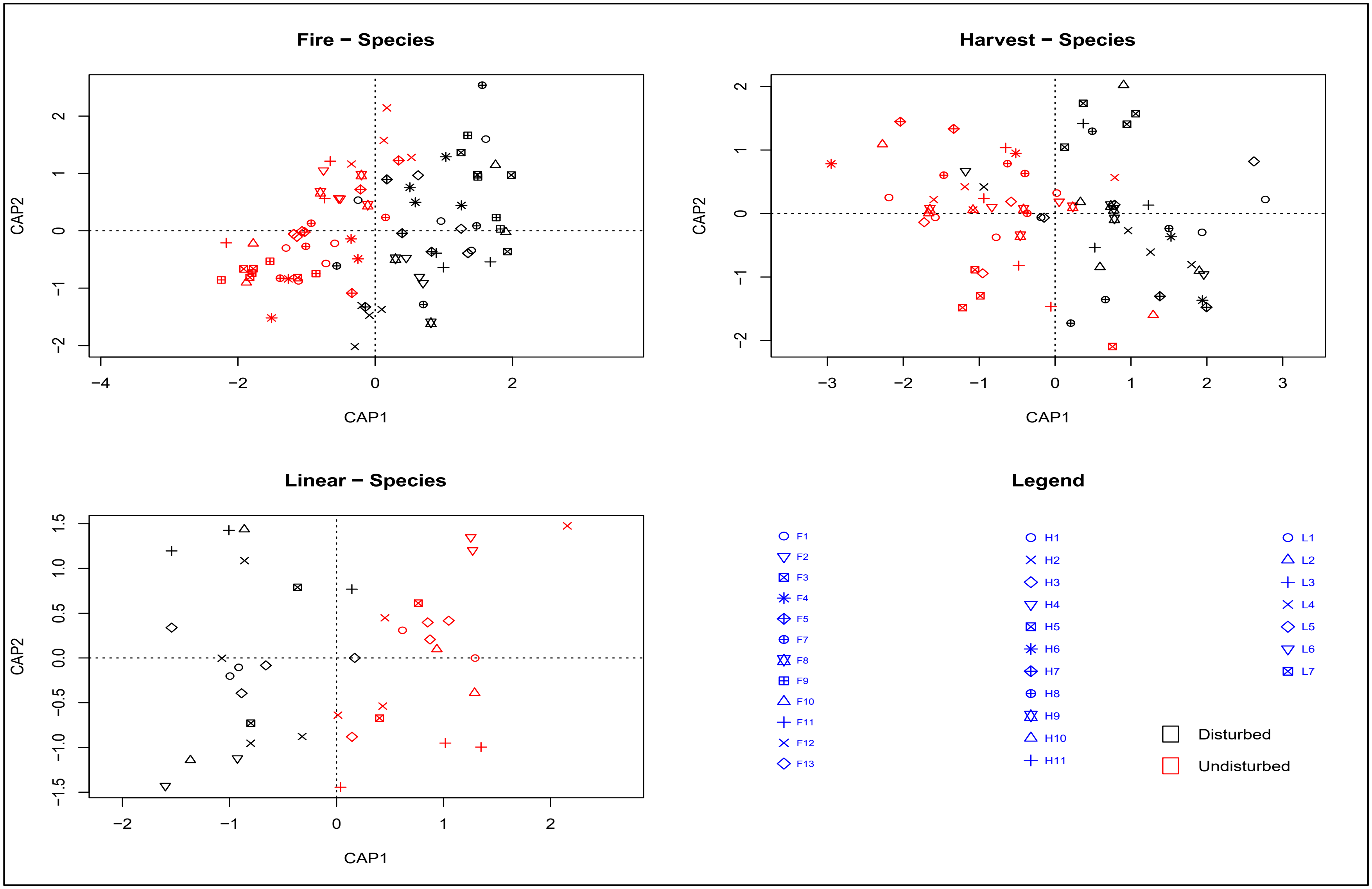

Figure 4-10. db-RDA plot of Oribatida assemblages showing both undisturbed and disturbed quadrants of fire ($P < 0.01$), harvest (NS) and linear (NS) disturbance for > 300 µm Oribatida, species-level. Points represents quadrants in site pairs, black points represent disturbed site pairs, red points represent undisturbed site pairs. P = P value, NS = not significant.

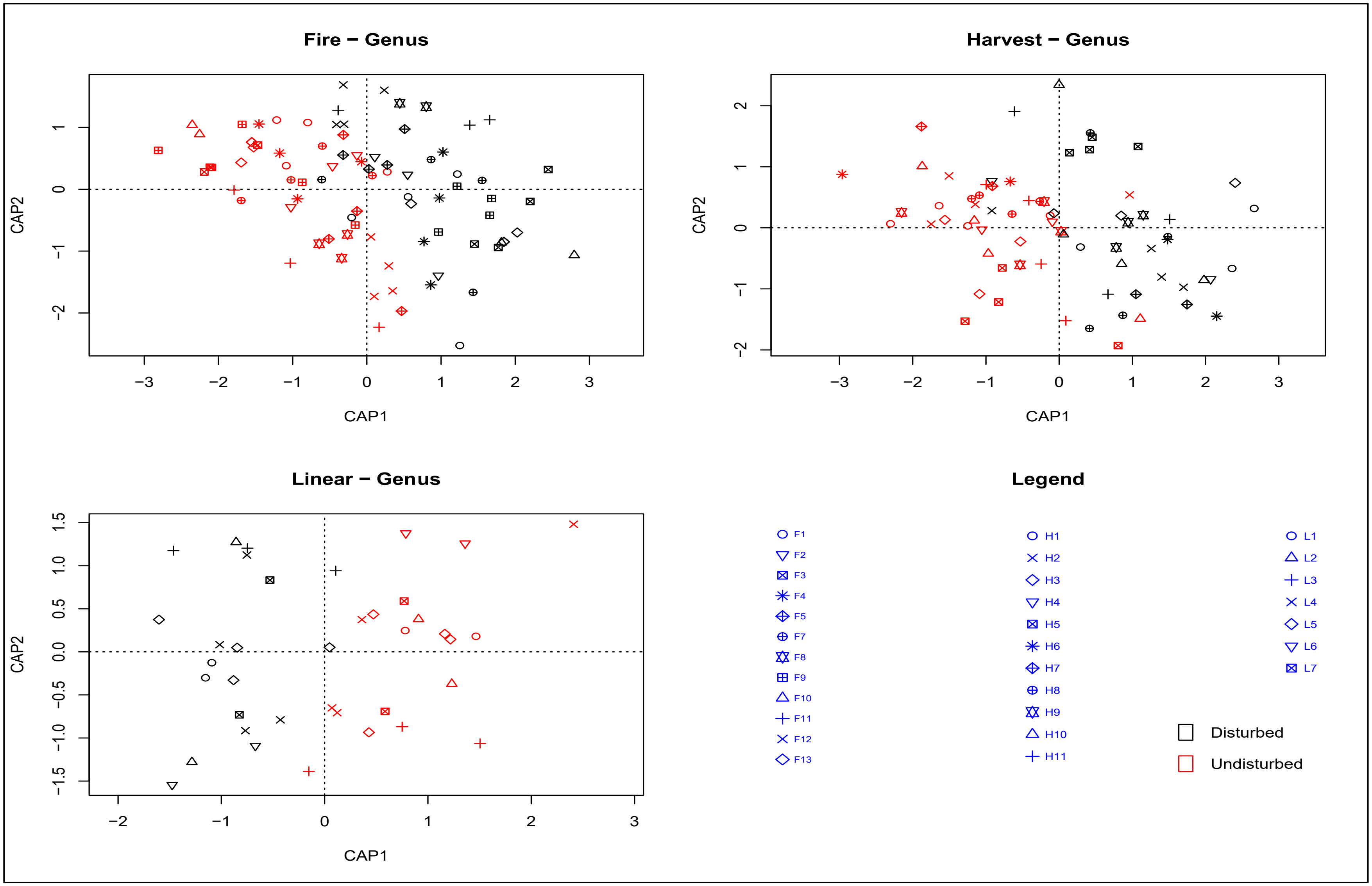

Figure 4-11. db-RDA plot of Oribatida assemblages showing both undisturbed and disturbed quadrants of fire (P = 0.02), harvest (NS) and linear (P = 0.03) disturbance for > 300 µm Oribatida, genus-level. Points represents quadrants in site pairs, black points represent disturbed site pairs, red points represent undisturbed site pairs. P = P value, NS = not significant.

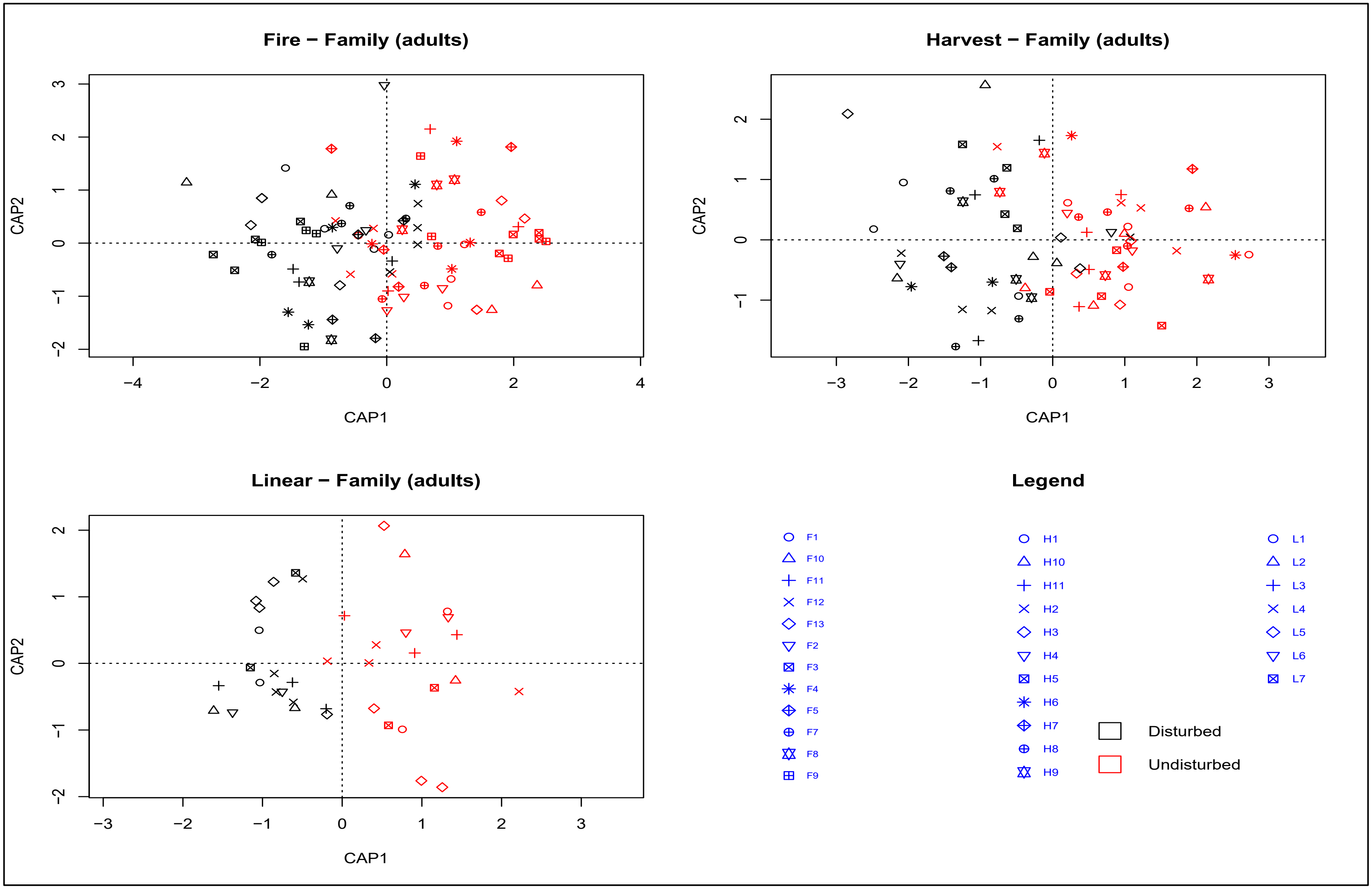

Figure 4-12. db-RDA plot of Oribatida assemblages showing both undisturbed and disturbed quadrants of fire (P = 0.03), harvest (NS) and linear (P < 0.01) disturbance for > 300 μm Oribatida, family (A)-level. Points represents quadrants in site pairs, black points represent disturbed site pairs, red points represent undisturbed site pairs. P = P value, NS = not significant.

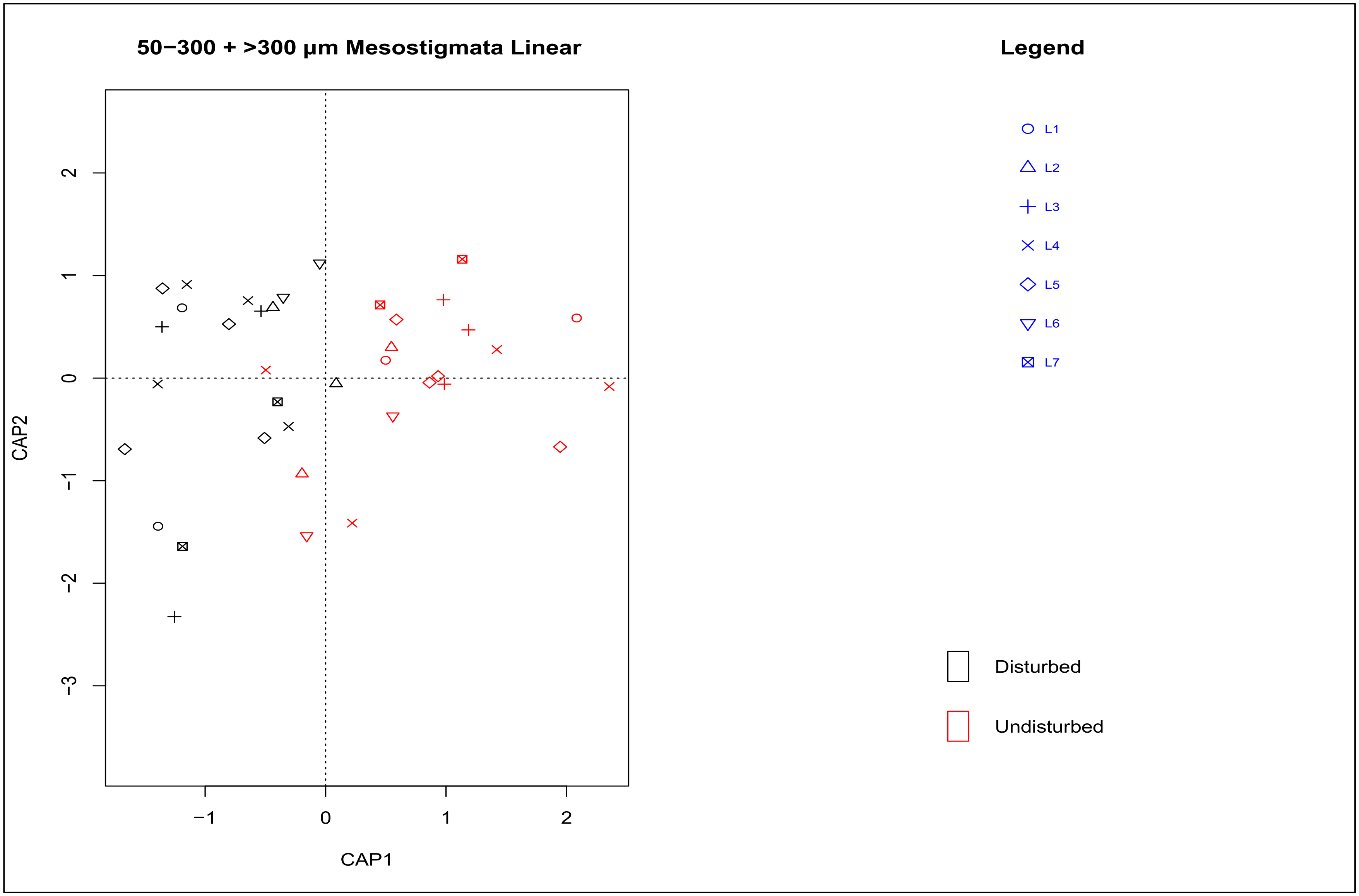

Figure 4-13. db-RDA plot of Mesostigmata assemblages showing both undisturbed and disturbed quadrants of linear disturbance (P = 0.01) for BestAgg datasets. Points represents quadrants in site pairs, black points represent disturbed site pair, red points represent undisturbed site pair.   P = P value.

5 Chapter 5: Conclusion and Summary

5.1 Research Summary

The objectives of my thesis were threefold: 1) catalogue species of soil-dwelling Mesostigmata found in northern Alberta; 2) determine how environmental factors (both abiotic and biotic) and spatial distance influence Mesostigmata assemblages; and 3) determine the utility of soil mesostigmatid and oribatid mites as bioindicators of forest fire, forest harvest and linear disturbance.

In Chapter 2, I created a public pictorial database of the 109 species/morphospecies found in the samples I examined. In total, these species represent 46 genera from 21 families of Mesostigmata. The majority of these species appear to be undescribed and new to science. Researchers, both experienced acarologists and those new to soil Mesostigmata taxonomy, can use this database to aid their identifications. I hope that this database will inspire others in soil acarology and entomology to further investigate the ecology of Alberta's microarthropod fauna, and perhaps, produce similar identification tools that can increase our understanding of these taxa.

In Chapter 3, I found that many environmental variables, such as moss, precipitation, and disturbance intensity, appear to greatly affect Mesostigmata assemblages. In addition, I found that spatial distance among samples could influence assemblages as strongly as environmental variables, with dissimilarity among assemblages increasing with geographic distance between quadrants.

In Chapter 4, I found that assemblages of mesostigmatid mites and of oribatid mites are effective bioindicators of fire, harvest and linear disturbance types. Restricting assemblage data to larger Mesostigmata (> 300 μm) proved to be a better indicator than the entire size spectrum (50-300 + > 300µm), as larger Mesostigmata were able to indicate all three-disturbance types, while the entire assemblage only indicated fire and linear disturbance. In addition, I found that mesostigmatid and oribatid mites could indicate disturbance at coarse taxonomic levels. This will ease the taxonomic burden of future researchers in boreal Alberta, as genus- and family-level identifications can be used for bioindication instead of species-level identification. As well, because large-bodied mesostigmatid and oribatid mites were strong indicators of disturbance, future studies can justify excluding smaller mites. This will undoubtedly allow for faster processing time, and will make identifications easier.

5.2 Reviewing Study Design

My results indicate that mesostigmatid mites had strong ties to environmental factors; however, it is probable that prey groups, and more indirectly the bacteria and fungi eaten by their prey, are governing their response. Although some studies have shown niche partitioning among Mesostigmata species with environmental variables (e.g., temperature) (Avdonin and Striganova 2004), undoubtedly, lower trophic organisms affect their assemblage composition. Studying different trophic levels simultaneously can provide more information on the nature of these groups, as there will likely be a causal relationship between different taxa (Ingimarsdóttir et al. 2012). As ABMI collects information on oribatid mites, I could have quantified whether oribatid mites influenced mesostigmatid mite assemblages, given that small, unsclerotized mites can be prey for Mesostigmata (Schneider and Maraun 2009). Similarly, I could have counted the number of collembolans within each quadrant I sampled; however, I would have had no information about the abundance and diversity of what is considered to be the main prey of most soil Mesostigmata, nematodes (Klarner et al. 2013).

5.3 Future Directions of Research

Classifying individuals according to ecological traits (e.g., diet and habitat) instead of morphological taxonomy is another approach to assess Mesostigmata assemblage composition in different environments. Although it is well known that soil mesostigmatid mites are predators of nematodes and collembolans (Klarner et al. 2013), there have been few studies of mesostigmatid mite feeding preferences within these broad taxonomic categories. Mouthpart morphology has been linked to trophic position in soil microarthropods (Perdomo et al. 2012), and Buryn and Brandl (1992) and Adar et al. (2012) noted weak correlation between cheliceral morphology and feeding preference of Mesostigmata. As DNA-based analysis of gut contents (e.g., Heidemann et al. 2014) can effectively reveal diets of Mesostigmata, studies should merge morphometric analysis with these analyses to determine the morphological traits that influence Mesostigmata diet preference. In addition, we should test whether mesostigmatid mites specialize on different functional groups in their prey. Nematodes for example have many functional groups, including plant feeders, fungal feeders, bacterial feeders, and predators (Bongers and Bongers 1998). This information combined with habitat preference (euedaphic vs. epedaphic) may be more informative than species richness, number of individuals, or assemblage composition.

5.4 Comments on biomonitoring and bioindicators

Researchers have used invertebrates as bioindicators for decades (Breure et al. 2005). When doing so, the stated preference is often to identify organisms to species-level (Lenat and Resh 2001); however, coarse taxonomic identifications (e.g., to genus- or family-level) have effectively assessed community composition (e.g. Terlizzi et al. 2009; Jiang et al. 2013; Jiang et al. 2017). However, coarse taxonomy may not be suitable for some taxa. Rosser (2017) suggested that coarse taxonomy could be applied when there is a low ratio of higher taxa (genus and family) to species, and when there is high evenness and turnover. These suggestions align well with the findings of my thesis: in Chapter 3 I found that Mesostigmata in my samples had a low genus-to-species ratio (1:2.37) and high turnover among quadrants, while in Chapter 4, I showed that mite assemblages identified at levels coarser than species can discriminate between disturbed and undisturbed areas.

Researchers have used richness of particular taxa as surrogates for overall species richness in an ecosystem. Sauberer et al. (2004) sought to use species richness from different taxonomic groups (e.g. bryophytes, vascular plants, gastropods, spiders, birds) to determine if grouping taxa together can provide information on total species richness for a habitat. They found that taxa with different functional traits and trophic levels were best to pair together; an example of such a pairing is gastropods and ants. Allen et al. (2001) also observed this trend, as they found that mammal and ant diversity were correlated with one another. For soil invertebrate assemblages, use of a single taxon to represent the entire invertebrate assemblage has only been weakly supported (Lovell et al. 2007); however, the inclusion of multiple, distinctly different taxa may well represent an assemblage. Future studies should test whether mesostigmatid and oribatid mites species richness can together estimate soil taxa diversity, given that they occupy different trophic levels and have different feeding preferences. In addition, as many disturbance types are present in Alberta (ABMI 2012), Mesostigmata + Oribatida species richness may indicate the effect disturbance is having on other soil taxa.

Excluding challenging taxonomic groups in bioindicator studies may be justified, if their exclusion still allows for an accurate portrayal of the ecosystem. Hawkins and Norris (1997) sampled aquatic invertebrates to determine if they could detect degradation of 'ecosystem health' in mountain streams. They tested this with two assemblages, one that contained all taxa, while the other left out chironomid midges (Diptera: Chironomidae). Chironomids are extremely abundant, and a taxonomically difficult group that are time-consuming to identify. When removed from analysis, similar results were attained giving credence to excluding this group in future studies. Subsampling could possibly be applied to mesostigmatid mites in the case of uropodines (Mesostigmata: Monogynaspida: Uropodina). The Uropodina is a difficult taxonomic group as relatively little research has been done on them, leaving many species and genera undescribed. In addition, classification of this group is not settled, as total number of families in the world ranges from 13 (Lindquist et al. 2009) to 35 (Beaulieu et al. 2011), depending on the source. One acarologist, Werner Hirschmann, has been the primary researcher of this group. His research articles are difficult to acquire and use, as most of his work was privately published, with a single key spanning multiple publications (Halliday 2015). In my thesis, uropodine mites made up 13% of total species/morphospecies and 11% of individuals identified. Removing them from future analysis will decrease sampling and processing time.

With the conclusion of my thesis, I have four recommendations for ABMI: 1) identify oribatid mites to genus-level instead of species-level if it further studies also find that similar results are attained with genus-level identifications; this will reduce identification time, and the number of individuals slide-mounted; 2) test whether other taxa studied (e.g. aquatic invertebrates) can indicate habitat health at genus-level, similar to the results seen in this thesis; 3) determine if combinations of taxa (amongst taxa already sampled by ABMI) can estimate total species richness in a site, this will validate ABMI's methodology and provide more information on the diversity of Alberta's fauna and flora; and 4) exclude difficult-to-identify taxa (e.g., Oribatida: Suctobelbidae) from analysis. These recommendations are based on the premise that ABMI's goal is to assess assemblage-level responses to environmental change. Using higher taxonomic levels and excluding difficult taxa can lead to similar results with faster processing speeds and greater cost-effectiveness. However, if ABMI's goals include tracking changes in total species richness, or assessing the responses of individual species, then species-level identification should be retained despite the higher cost.

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