

## Chapter 7

# Acari in Grassland Soils of Canada

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**Abstract.** Members of the arachnid subclass Acari (mites) are the most diverse and abundant arthropods in Canadian grasslands. Mites are notable for their small size, diverse feeding habits, often complex life histories, and the range of habitats in which they live. This chapter provides a descriptive overview of the state of our knowledge of the ecology of these arthropods in grassland soils, reviews the literature on their biology and ecology, and highlights research challenges.

**Résumé.** Les acariens (Acari), une sous-classe d'arachnides, constituent le groupe d'arthropodes le plus diversifié et le plus abondant des prairies canadiennes. Ils se caractérisent par leur petite taille, leurs modes d'alimentation diversifiés, leurs cycles biologiques souvent complexes et la gamme des habitats dans lesquels ils vivent. Ce chapitre présente un aperçu descriptif de l'état de nos connaissances sur l'écologie de ces arthropodes dans les sols des prairies, examine la documentation portant sur leur biologie et leur écologie, et met en lumière les enjeux de la recherche les concernant.

### Introduction

Grasslands are one of the major biomes in Canada, representing about 5% of the country's land base. Grasslands are among the most productive biomes, the rate of energy turnover is high, and about 90% of their net primary productivity is decomposed in situ (Coleman *et al.* 2004). Grassland vegetation develops extensive root systems, extending to depths of over 2 m in tallgrass prairie, to over 1.5 m in the Moist Mixed Grassland Ecoregion, and to approximately 1 m in the Mixed Grassland Ecoregion and Palouse grasslands of southern British Columbia (Schenk and Jackson 2002). These root systems have distinct architecture and rhizospheres that affect below-ground biodiversity and ecology. Rooting depth in grassland soils is greater than in boreal forests and is only slightly less than that of temperate forests (Schenk and Jackson 2002).

Typical soils of Canadian prairie are Chernozemic, with decomposing grass parts that produce a dark, rich A horizon underlain by a sharp B horizon where minerals are deposited at the line of deepest water penetration (see Chapter 3). Chernozems are classified as Brown, Dark Brown, or Black depending on the colour of the A horizon. The colour darkens along an organic matter gradient, reflecting moisture supply. Dark

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Gray Chernozems are found in prairie–forest transition areas (Danks 1979). However, in forest–grassland transition zones, where the mean annual temperature is lower than 5.5 °C, soils are in the Luvisolic order (Berg and Pawluk 1984).

Mites (Acari) in these grassland soils are the most diverse and abundant arthropods (Willard 1974; Leetham and Milchunas 1985; O’Lear and Blair 1999). Mites living in grassland soils encompass a broad range of feeding guilds, including both specialized and polyphagous predators, parasites, herbivores, fungivores, microbivores, detritivores, scavengers, and omnivores (Krantz and Lindquist 1979; Lindquist 1979; Walter 1987a). Mites catalyze primary decomposition and nutrient cycling in soils, activating fungi and bacteria (Moore *et al.* 1988). The contribution of mites to these and other processes, such as biocontrol and soil formation in various soils, has been reviewed by a number of authors, including Seastedt (1984a), Crossley *et al.* (1992), Brussaard *et al.* (1997), and Coleman *et al.* (2004).

The mite fauna of grassland soils in Canada is remarkably poorly known. Mite studies in grasslands have emphasized species associated with the grass canopy (e.g., Jeppson *et al.* 1985) or with stored grains (e.g., Sinha and Wallace 1973; Mills 1990) rather than the fauna of litter and soil. Faunistic studies on soil mites in Canada have concentrated on habitats other than grasslands, such as forest, alpine, and arctic ecosystems, or agroecosystems in central and eastern Canada, as is reflected in catalogues (e.g., Marshall *et al.* 1987) and reviews (e.g., Behan-Pelletier 1993a; Smith *et al.* 1996, 1999; Behan-Pelletier 2003). For example, we know more about the mite fauna of forest soil in the Winnipeg area (Oswald and Minty 1970, 1971) than of its unique tallgrass prairie refuge. Taxonomists have conducted surveys in the alpine grasslands of Waterton Lakes National Park; the Palouse grasslands of the Okanagan Valley; and the tallgrass, Moist Mixed Grassland, and Mixed Grassland ecoregions on the prairies. Voucher specimens with associated habitat data also exist in the Canadian National Collection (CNC). However, most of these data are unpublished. Until recently, studies of the soil fauna in specific grassland types in Canada have focused on the small-scale and often short time-frame changes that occur specifically in response to soil management, such as changes in species richness or population abundance in response to different agricultural practices, and placing such studies within the context of more broadly defined native grassland types, such as tallgrass prairie, is premature. Recently, surveys by the Alberta Biodiversity Monitoring Institute between 2007 and 2009 provided new information on Albertan Oribatida, many from grassland habitats, data captured in the impressive and user friendly *Almanac of Alberta Oribatida* (Walter 2009).

Our objectives in this chapter are to provide a descriptive overview of (a) the mite taxa that occur in Canadian grassland soils, with relevant ecological data; and (b) the mite fauna associated with particular grassland types, as defined in Chapters 2 and 3, this volume. We use these data to compare patterns of mite distribution and ecology in Canadian grassland soils with data from similar grasslands in the United States and to address possible causes for these patterns. Finally, we suggest research questions that need to be addressed to understand the ecology of this grassland fauna.

### Descriptive Taxonomic Overview

Mites comprise the subclass Acari of the class Arachnida, which is also represented in Canadian grasslands by the spiders (order Araneae), harvestmen (order Opiliones), and pseudoscorpions (order Pseudoscorpionida). The higher classification used in this chapter follows that proposed for the new edition of *A Manual of Acarology* (Krantz and Walter 2009).

The Acari includes two superorders: the Parasitiformes represented in Canadian grassland soils by the suborder Monogynaspida in the order Mesostigmata, and the Acariformes represented by the suborders Prostigmata and Sphaerolichida in the order Trombidiformes and the suborders Endeostigmata and Oribatida in the order Sarcoptiformes. The Oribatida includes the cohort Astigmatina (Norton 1998). Endeostigmatans have been included in Prostigmata in most ecological studies (Seastedt 1984*b*; O’Lear and Blair 1999). In the classification used herein, components of this assemblage, the Lordalychioidea and Sphaerolichoidea, remain in Trombidiformes, whereas all other endeostigmatans are considered members of the Sarcoptiformes. These changes in classification affect interpretation of prostigmatan abundance in studies where taxonomy was treated at the subordinal level.

### **Parasitiformes: Order Mesostigmata: Suborder Monogynaspida**

Mesostigmatic mites are numerically dominant predators in soil and litter of Canadian agroecosystems. They primarily feed on nematodes, Collembola, soft-bodied mites, insect larvae, and small insects, and they respond rapidly to increased prey in the habitat. Their role as bioindicators in agriculture was reviewed by Koehler (1999).

Representatives of the following superfamilies occur or are expected to occur in Canadian grassland soils.

#### ***Uropodoidea***

Saprophagous and predaceous members of this superfamily occur commonly in edaphic and dung habitats and can be part of the cattle dung food web. Cattle dung is an important but often overlooked by-product of cattle on pasture, and the many arthropods, including Uropodidae, that colonize this detrital source accelerate its breakdown and incorporation into soil by feeding on fungi and rotting plant material (Krantz and Lindquist 1979). Some uropodoids are predators of nematodes, fly larvae, and collembolans (Walter and Proctor 1999). Most species of Uropodoidea are associated with insects and disperse as phoretic deutonymphs on their hosts.

#### ***Parasitoidea***

These generally large, predatory mites occur in various edaphic habitats in grasslands. Many species of Parasitidae are associated with animal nests, carrion, and dung. Their deutonymphs disperse by phoresy on mammals and more commonly on insects (Smith *et al.* 1999). These mites are among the top predators in the cattle dung food web.

#### ***Veigaiioidea***

These large, predatory mites occur in edaphic habitats, especially forest soils. The family Veigaiidae in grasslands is represented by relatively few species compared with the fauna of eastern forests (Smith *et al.* 1996, 1999).

#### ***Rhodacaroidea***

Representatives of two families of this superfamily are known from Canadian grassland soil. Species of Rhodacaridae and Ologamasidae are predators in soil and compost habitats and below-ground nests of insects and mammals. Walter (1987*a*) noted that Rhodacaridae include top predators that feed on bacterial, fungal, and plant-feeding nematodes, as well as on mites, collembolans, and the eggs and young of insects. Walter (1987*a*) recorded

the rhodacarid *Rhodacarellus* from deep in the grassland soil profile. Undoubtedly, representatives of Digamasellidae and Halolaelapidae are represented in Canadian grassland soil and litter, but there are no published records of these taxa.

### ***Eviphidoidea***

Species of Eviphididae and Macrochelidae are known from edaphic habitats in grassland soil, including cattle dung. Eviphididae are strictly nematode predators (Walter 1987a). Some species of Macrochelidae are prevalent in compost, manure, and carrion, where they are associated with insects that act as carriers during a phoretic stage of the mite's life cycle. Species of Parholaspididae and Pachylaelapidae are anticipated to occur in Canadian grassland soils but have not been recorded to date.

### ***Zerconoidea***

Members of the family Zerconidae represent one of the two most numerically abundant mite families in fescue prairie (Clapperton *et al.* 2002). These slow-moving mites, with well-sclerotized adults, are more typically associated with humus and litter habitats in forests (Smith *et al.* 1996).

### ***Ascoidea***

This large, diverse group is represented by two families in Canadian grassland soils (Table 1). Species of Ascidae are often closely associated with insects and disperse by phoresy as adult females on these hosts. Most members of Ascidae found in grassland soils are top predators, feeding on both nematodes and arthropods (Walter 1987a); however, some species of *Proctolaelaps* feed on pollen and fungi (Krantz and Lindquist 1979). Representatives of several species of the family Ameroseiidae occur in litter and nidicolous habitats in grasslands. As with a few species of Ascidae, these mites are atypical among Mesostigmata in that they feed on fungal spores and pollen grains.

### ***Phytoseioidea***

Members of the Phytoseiidae found in grassland soils are generally top predators, feeding on both nematodes and arthropods (Walter 1987a). However, certain species include fungi, pollen, and leaf sap in their diet and are facultatively non-predatory (Krantz and Lindquist 1979). Phytoseiid mites are the most important predators of spider mites (Prostigmata: Tetranychioidea).

### ***Dermanyssoidea***

This group is also well represented in grassland soils. The family Laelapidae (including the subfamily Hypoaspidae, which is sometimes treated as a separate family) includes predatory species in edaphic habitats. Walter (1987a) recorded hypoaspidines as the most abundant top predators in soils of shortgrass prairie in Colorado. As he points out, these, and many other Mesostigmata, can develop from egg to adult in less than two weeks when food is abundant and soil temperature is favourable for development.

## **Acariformes: Order Trombidiformes: Suborder Prostigmata**

Members of this large, extremely diverse suborder of mites are mostly soft bodied, with adults varying in size from 100  $\mu\text{m}$  to 10 mm. This is the dominant acarine group in most grassland habitats, whether arctic–alpine, temperate, or tropical (Kethley 1990), and it may

represent up to 95% of the total mite fauna in Palouse grasslands of Canada (Battigelli *et al.* 2003). There are few data from Canadian grasslands, but an annual average abundance of 31,920, and 94,700 m<sup>-2</sup>, representing 46.3% and 66.8% of the mite fauna, respectively, is known from prairie in Wisconsin (Lussenhop 1972) and from shortgrass prairie in Colorado (Leetham and Milchunas 1985), respectively. Species richness can also be high, with 21 and 35 species from the Wisconsin and Colorado sites, respectively. Data from a range of grassland habitats in a number of countries indicate that population density of Prostigmata increases following periods of heavy rainfall (Kethley 1990 and included references). Where documented, peaks in population density of predaceous Prostigmata correspond with those of prey.

Species can be algivores, bacterivores, fungivores, phytophages, predators, parasites, and parasitoids. Unlike most Oribatida that have shredding and grinding mouthparts, the chelicera of most prostigmatan mites pierce tissue and suck up cell contents or other subepidermal substances. Many species of Prostigmata have a high metabolism, high fecundity, and a short lifespan, in comparison with oribatid mites, and can therefore respond rapidly to nutrient pulses in the environment (Kethley 1990, and included references; Walter and Proctor 1999). Obligately phytophagous Prostigmata that feed on above-ground plant tissue fluid, such as members of the Tetranychioidea, can occasionally be abundant in soil and litter samples in grasslands because of their dislodgement from vegetation, their downward movement into the upper litter layers as a result of environmental conditions (Kethley 1990), or their feeding on grasses near the soil interface. In addition, soil and litter represent the contact zone for parasitic larvae of terrestrial Parasitengona seeking vertebrate or invertebrate hosts that move across or through the habitat (Kethley 1990).

Representatives of the following superfamilies occur in Canadian grassland soils.

### ***Eupodoidea***

Many species of these usually soft-bodied mites, representing fungivorous Eupodidae, predaceous Rhagidiidae, and Penthalodidae, are thought to feed on algae, lichens, and mosses (Krantz and Lindquist 1979) and occur in edaphic habitats in grasslands. Eupodines can be highly abundant in shortgrass prairie (Walter 1987a). Species of *Eupodes* will eat soil algae, and Walter (1987a) speculated that they opportunistically feed on higher plants. The related penthaleid mite, *Penthaleus major* (Dugès), feeds on plants and is an occasional pest of legume crops.

### ***Tydeoidea***

Two families are well represented in grasslands. Species of primarily fungivorous Tydeidae are among the most common mites in grassland soil and litter (Clapperton *et al.* 2002). Walter (1987a) observed *Tydeus* feeding on algae and sucking fluids from fungi. Santos and Whitford (1981) reported some Tydeidae feeding on eggs and inactive instars of nematodes. Most species of Ereyenetidae are considered predators in edaphic habitats, but some are ectodermal cavity parasites of gastropods (Smith *et al.* 1999).

### ***Bdelloidea***

Species of Bdellidae and Cunaxidae are among the common predatory mites in litter and herbaceous ground-cover habitats in grasslands. Walter (1987a) reported that bdelloids were the most common prostigmatan predators in shortgrass prairie of Colorado, with smaller cunaxid predators occurring lower in the soil profile.

### ***Trochometridioidea***

The trochometridiid genus *Trochometridium* has an intimate association with a variety of ground-nesting bees in North America (Cross and Bohart 1979). Although they are fungivorous, these mites may also function as egg parasitoids of bees (Kaliszewski *et al.* 1995). One species of this genus is associated with halictid bees in the Okanagan Valley. This is the most northern record of the family in North America (Smith *et al.* 1999).

### ***Scutacaroida***

Species of Scutacaridae occur commonly in edaphic habitats in grasslands where they feed as mycophages.

### ***Pygmephoroida***

Pygmephorid and siteroptid mites in the genera *Siteroptes*, *Pediculaster*, and *Bakerdania* include mycophages and herbivores and are common inhabitants of the upper layers of prairie soil in Colorado (Walter 1987a). Species of *Siteroptes* feed on cereal grasses and other plants and are implicated in the malformation and stunting of plants (Evans *et al.* 1961). These mites are also vectors of fungal pathogens of plants and may feed preferentially on these phytopathogenic fungi rather than on plant tissue (Krantz and Lindquist 1979).

### ***Pyemotoidea***

Adult females of *Pyemotes*, the only described genus of Pyemotidae, are parasitoids of Coleoptera, Lepidoptera, Hymenoptera, Diptera, and Homoptera (Kaliszewski *et al.* 1995) and are found in shortgrass prairie (Walter 1987a). Capable of a population-doubling time of 1.1 days, they have been estimated as the most fecund of arthropods yet known (Wrensch and Bruce 1991).

### ***Tarsonemoidea***

The ecologically diverse family Tarsonemidae is represented by numerous genera and species in grassland soil. They are primarily mycophages, but feed on algae and fungi. They can also be phytophagous and cause crop damage (Walter 1987a; Krantz and Lindquist 1979). *Tarsonemus* spp. can be opportunistic predators of eriophyid eggs on foliage, and they may also be opportunistic predators in soil. A species of *Steneotarsonemus* has been found to a depth of 10 cm in the prairies of Colorado and is assumed to be feeding on grass roots or the lower sheaths of grasses (Walter 1987a).

### ***Cheyletoidea***

Species of free-living, predaceous Cheyletidae can be common in litter in shortgrass prairie (Walter 1987a).

### ***Raphignathoidea***

Most members of this superfamily, including the Stigmaeidae, are free-living predators in soil and herbaceous ground-cover habitats in grasslands of Moist Mixed, Fescue, and Mixed Grassland ecoregions (Willard 1974; Walter 1987a; Clapperton *et al.* 2002) (Table 1). Species of the moderately large stigmaeid genus *Eustigmaeus* feed on mosses on bare patches on the soil surface. Lindquist (1979) recorded a species in the Camerobiidae genus *Neophyllobius*, likely also a predator, from prairie grass and sod in southern Alberta.

### ***Tetranychoida***

All species of Tetranychoida are obligately phytophagous, and several of them reach the northern limit of their distribution along with their host plants in Canadian grasslands. Although these mites feed in the sheaths of the above-ground parts of grasses, they are often collected in soil cores associated with the lower parts of the plants (Leetham and Milchunas 1985). Females of some species lay their eggs in soil, for example, the brown wheat mite *Petrobia latens* (Müller). The feeding sites of some species are unknown and they may feed on below-ground parts of plants (Walter 1987a). Species of Linotetranae and Tuckerellidae probably feed on the roots of plants, and the latter are common in prairie soils (Walter 1987a). A species of *Linotetranus* has been found to at least 60 cm in soil (Leetham and Milchunas 1985). Specimens of a *Linotetranus* species were collected from grassland soils in southern Alberta, and the tenuipalpid genera *Aegyptobia* and *Dolichotetranychus* are anticipated to occur in grassland soils in southern Canada (Lindquist 1979).

### ***Anystoidea***

Known as whirligig mites, these are highly active predators of phytophagous and other soft-bodied mites in edaphic habitats and herbaceous ground cover. The most conspicuous are members of the family Anystidae, but members of the Barbutiidae and Paratydeidae, which do not move as rapidly as Anystidae, are also predators in litter and soil habitats. Lindquist (1979) recorded representatives of two genera of the anystid subfamily Erythracarinae running over open ground in the Milk River Valley, Saskatchewan, and noted that these taxa were not expected to occur in Canada from their known distribution.

### ***Erythraeoida***

Species of Erythraeidae are common in litter and herbaceous ground-cover habitats and are among the dominant arthropod predators in grasslands and deserts (Lindquist 1979). Their larvae typically parasitize various insects, but those of the erythraeid genus *Leptus* are also frequently found on other arachnids. Larvae of *Balaustium* are unusual in that they can feed as predators or as facultative parasites (Krantz and Lindquist 1979). Lindquist (1979) recorded the predatory erythraeid genus *Tepoztlana*, previously known only from Mexico, from the Milk River Valley, Alberta.

### ***Trombidioidea***

These mites are among the most conspicuous in litter and edaphic habitats in grassland. Larvae of Johnstonianidae, Trombellidae, and Trombidiidae parasitize a wide variety of insects, whereas those of Trombiculidae are the infamous chigger mites that parasitize vertebrates and occasionally attack humans (Smith *et al.* 1999). Chiggers are not known from Canadian grasslands.

## **Acariformes: Order Sarcoptiformes: Suborder Endeostigmata**

Endeostigmata are one of the dominant groups in grassland soils and have been included as a component of Prostigmata in most studies (e.g., Willard 1974; Leetham and Milchunas 1985). Bimichaellidae and Alicorhagiidae are primarily nematode predators (Walter 1988a, 1988b). Although Walter (1988b) found that *Alicorhagia fragilis* Berlese will consume fungi and algae, he maintained thriving cultures with only nematodes as food. Members of the Terpnacaridae are particulate-feeding fungivores, consuming hyphae and their contents, whereas Nanorchestidae, which feed on fungi and algae, do not ingest particulate

matter (Walter 1988b). Recently, a species of *Alycosmesis* (Terpnacaridae) was recovered by one of us (DK) from an active area of sand dunes at Onefour in the Milk River Valley of Alberta, the first report of this genus for Canada.

### **Acariformes: Order Sarcoptiformes: Suborder Oribatida**

Oribatida (also called Cryptostigmata) are one of the most numerically dominant arthropod groups in the organic horizons of most soils, where their densities can reach several hundred thousand individuals per square metre (Norton 1986). The five active postembryonic instars feed on a wide variety of particulate matter, including living and dead plant and fungal material, lichens, and carrion. Some of these mites are predaceous, none are parasitic, and feeding habits may differ between immatures and adults of the same species (Siepel 1990). Oribatid mites generally have low metabolic rates, slow development, and low fecundity compared with many prostigmatan and mesostigmatan taxa (Norton 1986). Species are iteroparous, with adults living from weeks to a year in grasslands (Walter 1987a).

Oribatida influence decomposition and soil structure in several ways. One is by shredding and feeding on fungi and dead organic matter. Their fecal pellets provide a large surface area for primary decomposition by bacteria and fungi and are an integral component of soil structure in grasslands (Berg and Pawluk 1984). Oribatida also disperse bacteria and fungi, either externally on their body surface, or by feeding, with subsequent survival of spores after passage through their alimentary tracts. Seastedt (1984a) and Norton (1986) reviewed the role of Oribatida in decomposition and nutrient cycling, and Behan-Pelletier (1999) reviewed Oribatida as bioindicators in agriculture.

Oribatida are the best known mite group in Canadian grassland soils (Table 1), and representatives of the following superfamilies occur or are expected to occur in them.

#### ***Brachychthonioidea***

These small mites, generally less than 250 µm, are found in soil, moss, and litter. They are microphytophagous, feeding on fungi, algae, and possibly also bacteria (Luxton 1991). Members of the Brachychthoniidae dominate the oribatid mite fauna in fescue grassland of southern Alberta (Clapperton *et al.* 2002; Osler *et al.* 2008). This fauna is rich at the species and genus level, and includes mainly undescribed species in the genera *Brachychthonius*, *Sellnickochthonius*, and *Liochthonius*. Species of *Brachychthonius* are also abundant in shortgrass steppe in the United States (Walter 1987a, 1987b) and are known to feed on fungi and algae.

#### ***Eremaeioidea***

Species in this superfamily are primarily found in dry habitats, where they live in the litter layer or in moss and lichens on the soil surface. Occasionally, a large percentage of the population may be found lower in the soil profile (Mitchell 1978). Species of Eremaeidae are known fungivores (Mitchell and Parkinson 1976). Walter (1987a) found Eremaeioidea rare in shortgrass prairie, but species of *Eueremaeus* are found in shortgrass prairie of southern Alberta (Osler *et al.* 2008; Walter 2009) and the Milk River Valley, Saskatchewan (Behan-Pelletier 1993b).

#### ***Oppioidea***

Members of this superfamily are consistent components of the grassland soil fauna. The cosmopolitan *Oppiella nova* (Oudemans) feeds on a range of fungi and algae (Walter



1987a; Kaneko *et al.* 1995). This can complete the development of this species in three to five weeks under laboratory conditions (Walter 1987a), but in prairie soils there are probably at most two generations per year, similar to that recorded from eastern forests (Reeves 1969).

### ***Cymbaeremaeoidea***

Species in the cymbaeremaeid genus *Ametroproctus* are restricted to dry, primarily alpine habitats in western North America. These species are probably fungivorous. On south-facing outcrops in the Palouse grassland habitat, for example, the summit of Kobau Mountain in the southern interior of British Columbia, they can be the numerically dominant oribatid mites.

### ***Oripodoidea***

Members of three families, Oribatulidae, Scheloribatidae, and Haplozetidae, are found in all grassland soils in North America (e.g., Leetham and Milchunas 1985; Walter 1987a; Clapperton *et al.* 2002). Oripodoid mites are primarily mycophagous but also consume pollen. Some species of *Haplozetes* and *Peloribates* feed on nematodes (Walter 1988a), and arthropod fragments were noted in the guts of *Liebstadia humerata* Sellnick (Wunderle 1992).

### ***Ceratozetoidea***

Members of the Ceratozetidae seem more common in mesic tallgrass prairie (unpublished records from CNC and DK), whereas species of the mycobatid genus *Mycobates* are known from drier foothill and alpine grasslands in western Canada. Species in the ceratozetid genus *Ceratozetes* are omnivores that feed on fungi, algae, and nematodes (Walter 1987a, 1987b). Some *Ceratozetes* species are intermediate hosts of anoplocephalan tapeworms (Denegri 1993). Diurnal vertical movement of these and other anoplocephalan hosts from soil to litter and the base of vegetation may be a modification of their behaviour by the tapeworm to increase the probability of transmission to the final vertebrate host (Lindquist 2001).

### ***Galumnoidea***

The galumnid *Pilogalumna cozadensis* Nevin is among the most common oribatid mites in dry prairie in Canada (unpublished records from CNC) and shortgrass steppe in Colorado. This species is omnivorous on fungi, algae, and nematodes, and adults double the size of their egg clutches when nematodes are added to the diet (Walter 1987a).

### ***Cohort Astigmatina***

The life history traits of this group differ significantly from those of other Oribatida (Norton 1998). The life cycle of Astigmatina often includes a heteromorphic deutonymph (hypopus), which is a non-feeding instar morphologically and physiologically adapted for phoresy and survival in conditions unsuitable for development. Astigmatina that are free-living in soil feed on plant material, fungi, and algae, preferably of high-protein content, and also consume the liquified products of decaying organic material (Philips 1990). For example, species of Acaridae (Acaroidea) are the most common astigmatine mites in Canadian grassland soils, in particular, members of the genus *Tyrophagus* (unpublished records from CNC), which will feed on any easily subdued organic material, including fungi, algae, nematodes, eggs of Collembola, and eggs of corn rootworm (Walter 1987a).

Few soil astigmatine mites are phytophagous, but species of *Tyrophagus* and *Rhizoglyphus* can be significant plant pests, feeding on bulbs and roots (Philips 1990).

Free-living Astigmatina in grassland soils include colonizing species, with the phoretic stage usually dispersed by insects. These mites have higher fecundity, faster development, and much higher reproductive rates than other oribatid mites (Norton 1994). Many species can complete their life cycle in eight days to three weeks, depending on relative humidity and temperature (Philips 1990). Under laboratory conditions, females can lay up to 800 eggs in a month (Philips 1990, and included references). This fecundity, combined with rapid development and an effective phoretic stage, means that Astigmatina can respond rapidly to nutrient availability.

### Soil Mite Fauna of Grassland Types in Canada

The importance of the grassland element for mite biodiversity in Canada was recognized by Lindquist (1979) with the acknowledgement that the mite fauna of these habitats is virtually unknown. Here we compare the sparse data about mites from Canadian grassland types, as defined by Shorthouse (Chapter 3, this volume), with data from corresponding grasslands in the United States. Oribatid records from grassland sites in the Alberta Biodiversity Monitoring Institute (Walter 2009) are difficult to associate with a particular grassland type at this time, and thus are not ascribed to a particular type in Table 1.

#### Tallgrass Prairie

Knowledge of the mite fauna of this rare vegetation type in Canada is limited in comparison to the extensive studies on the soil mite fauna of tallgrass prairie in the United States (Seastedt 1984b; O'Lear and Blair 1999; St. John *et al.* 2006). The only Canadian study with a bearing on tallgrass prairie is that of Aitchison (1979), who looked at winter-active mites in aspen parkland at Fort Whyte, Manitoba (97°13'N, 49°49'W) by using pitfall traps, a collecting method that selects for actively moving edaphic fauna. As a result, the few taxa represented were almost exclusively litter-dwelling members of the Prostigmata and Mesostigmata (Table 1). She recorded more families that were active in autumn than in winter or spring. Prostigmatans were the dominant winter-active group, with the families Eupodidae (*Eupodes* spp., *Linopodes* spp.) and Rhagidiidae (*Rhagidia* spp.) dominant among them. Other mites present in moderate numbers were *Pergamasus crassipes* L. (Mesostigmata: Parasitidae). St. John *et al.* (2006) used modified Berlese extractors in their study of mites in tallgrass prairie at the Konza Prairie Long-Term Ecological Research site, Kansas, and recorded 162 species of mites with an average density of 84,344 m<sup>-2</sup> to a depth of 10 cm. This species richness is the highest recorded from grassland soil in the world, and similar diversity can be expected in Canadian tallgrass prairie soils.

Fire is a recurrent perturbation in grassland that is required to maintain tallgrass prairie. However, almost no studies have been done on the effects of fire on the soil mite community in North American grasslands. White (2001) looked at the effect of a grassland fire on a prairie arthropod community in Canada by using pan traps and pitfall traps. The total abundance of mites on burned sites was significantly decreased in comparison with unburned sites. These results were consistent with those from the Konza tallgrass prairie (Seastedt 1984b), where mite density in the 0–5 cm layer of soil was significantly lower on a one-year burn site in comparison with a site unburned for five years. However, this effect was significant for only Mesostigmata and Oribatida, whereas prostigmatan abundance

remained unchanged and representatives of Tydeidae were the dominant prostigmatans at both sites. Also, mite densities at the 5–10 cm depth were not different between burned and unburned sites (Seastedt 1984b). Seastedt (1984b), who identified specimens only to the family level, observed no major difference in family composition between burned and unburned sites.

### Mixed Grasslands (“Shortgrass Prairie”)

The Matador Project, part of the Canadian contribution to the International Biological Programme during 1967–1972, was a total ecosystem study of natural shortgrass prairie at the Matador Field Station (50°43′–51°30′N, 107°30′–108°00′W) in southwestern Saskatchewan (Willard 1974). This area comprised a stand of *Agropyron-Koeleria* vegetation and moraines covered with *Stipa-Agropyron-* to *Stipa-Bouteloua-Agropyron*-type vegetation (Coupland 1973). The main objective of this project was to establish baseline population and biomass data for the major groups of soil invertebrates (Willard 1974). Because the soils were fine-textured clays, with 68% clay content, the Salt-Hollick washing method was used to extract soil arthropods for four years from depths of 0–30 cm and in November 1968 to a depth of 150 cm (Willard 1972). Efficiency of extraction was estimated at 20% (Willard 1972), and all results for Acari (and Collembola) from the Matador Project were corrected for this estimated efficiency. Mites were found to a depth of 50 or 60 cm in all months sampled (Willard 1973). Average acarine density was 36,901 m<sup>-2</sup> to a depth of 30 cm, and 7,316 m<sup>-2</sup> at a depth of 30–60 cm (Willard 1973). Approximately 65–80% of mites were found in the upper 30 cm of soil, with almost 80% of these in the top 10 cm; however, mites were found to a depth of 150 cm (Willard 1974). Mite density was higher in natural grassland than in adjacent grazed, burned, irrigated, fertilized, or cultivated grassland plots, but the difference was not significant (Willard 1974). In contrast with most studies of grassland soil arthropods where Acari are more abundant than Collembola (e.g., Fyles *et al.* 1988), at Matador, Collembola were more abundant than Acari (Willard 1973). This result may reflect a bias of the Salt-Hollick extraction technique, where soil is washed through a series of sieves of decreasing mesh size, although this has not been tested. Furthermore, in contrast with other studies in shortgrass prairie (e.g., Walter 1987a), Oribatida dominated the Matador mite fauna, representing almost 55% of the mite fauna in natural grasslands, and 45% and 76% in irrigated and wheat-cultivated grasslands, respectively (Willard 1973). Numbers for Prostigmata for the same habitats were 23–25%, 22%, and 3%, respectively.

### Moist Mixed Grasslands

Studies on this type of grassland are mainly associated with effects of management practices on fauna or the fauna associated with a particular soil type. Berg and Pawluk (1984) compared mite abundance on Gray Luvisol soil planted with either fescue or alfalfa (Table 1). Populations were highest under fescue (9,000 m<sup>-2</sup>), and species richness of brachyphylinae Oribatida was lower than that of other mite groups (Table 1). Microthin soil sections showed much more fecal material of oribatid mites and Collembola under fescue than they did under alfalfa (Berg and Pawluk 1984). Fyles *et al.* (1988), who compared microarthropod populations under oat and alfalfa at a site with Gray Luvisol soil, found that populations were significantly higher under oat than under alfalfa, that mites accounted for 60–95% of the microarthropod fauna, and that their population was positively correlated with soil moisture. The authors considered that these differences in abundance may be attributed to the different root systems of the two crop plants. Alfalfa has a single tap root bearing few lateral branches, whereas oat has a fibrous root system concentrated in the

surface layers that would provide a larger rhizosphere. Subsequently, Rutherford and Juma (1989) compared faunal populations in different prairie soil types, a Black Chernozem versus a Gray Luvisol, with both sites cropped to barley for at least two years prior to sampling and with no significant difference in root mass between sites. Mite populations in the 0–10 cm layer were greater in Black Chernozem (47,200 m<sup>-2</sup>) compared with the Gray Luvisol (19,700 m<sup>-2</sup>). This result was expected because Chernozems have higher organic carbon content and a deeper A horizon. Martin (1985) looked at the effect of cultivated grass systems on microarthropods in the aspen parkland ecotone on Gray Luvisolic soils near Winfield, Alberta. He recorded that old stands (26 and 49 years) of Kentucky bluegrass pasture had developed a distinct 2–4 cm thick turf layer and that oribatid abundance in soils at these sites was comparable to that in native white spruce–trembling aspen forest in the same area.

### Fescue Grasslands

Changes in abundance and diversity of mite families associated with light (1.2 animal unit months (AUMs) ha<sup>-1</sup>) or very heavy (4.8 AUMs ha<sup>-1</sup>) grazing regimes or in a grazing enclosure in fescue prairie at Stavely, Alberta, showed clearly that prostigmatan mites were the most abundant microarthropod fauna in this vegetation type, whereas oribatid mites were the most family rich (Clapperton *et al.* 2002). Soils at this site are Black Chernozemic, the vegetation type was affected by the grazing regime, and there was more exposed soil under heavy grazing (Clapperton *et al.* 2002). Mites were collected from the 0–4 and 4–8 cm depths. There were significantly more families of Mesostigmata, Prostigmata, Endeostigmata, and Oribatida represented under light and no-grazing regimes than under the heavy grazing regime (Table 1). In grazing enclosures, Prostigmata and Oribatida were more abundant in the 4–8 cm depth than in the upper soil layer. Among Mesostigmata, Phytoseiidae and Zerconidae were the most abundant families, with Zerconidae most abundant at the 4–8 cm layer. Among Prostigmata, Tydeidae were the most abundant under all treatments at both depths (Clapperton *et al.* 2002). Brachychthoniidae were the most abundant oribatid family under all treatments and at both depths, whereas representatives of the families Eremaeidae, Galumnidae, and Trhypochthoniidae were found in soils of only the heavily grazed site (Clapperton *et al.* 2002).

Similarly, Osler *et al.* (2008) studied changes in abundance and diversity of Acari associated with organic and low-input rotations in a site under agricultural production for 50 years, but surrounded by fescue prairie, at Lethbridge, Alberta. They recorded 27 species of Oribatida, most representatives of Brachychthoniidae, which is among the highest species richness in arable agricultural soils globally (Table 1).

### Palouse Grasslands

The mite fauna of this grassland type was reviewed as part of the biodiversity assessment of the Montane Cordillera Ecozone (Smith *et al.* 1999). The Oribatida of the grasslands of the Haynes' Lease Ecological Reserve in the southern Okanagan was briefly outlined by Behan-Pelletier (1987), and species recorded are listed in Table 1. This fauna includes some interesting northern records for Canada, for example, *Passalozetes californicus* Wallwork, previously known only from dry habitats in California (Wallwork 1972). Oribatid species richness (34 species) is low in comparison with that of adjacent forested habitats, where more than 50 species may be found in a single sample of 100 cm<sup>3</sup>. However, species richness is comparable to data from shortgrass steppe in Colorado (Walter 1987a) and desert and semi-desert habitats in New Mexico (Kamil *et al.* 1985).

Prostigmata were numerically dominant in a study on bunchgrass prairie soils at the Lac du Bois Range of British Columbia (50°45'N 120°25'W), with soils classified as Dark Brown Chernozem (Battigelli and McIntyre 1999; Battigelli *et al.* 2003). Prostigmata represented 94.5% of the total microarthropods, including ants, a figure similar to that from tundra, desert, and tropical grassland sites where Prostigmata represent up to 75% of the microarthropod fauna (Petersen and Luxton 1982). In these Palouse grassland soils, the density of Prostigmata was significantly higher at the 4–8 cm layer than at the 0–4 cm layer (Battigelli *et al.* 2003). Cattle grazing at the rate of 2 AUMs ha<sup>-1</sup> had a significant negative effect on populations of Prostigmata (Battigelli and McIntyre 1999). On high-elevation coal mine spoils in southeastern British Columbia seeded with a mixture of grasses and legumes, mites were the most abundant microarthropods, with Prostigmata comprising 96–98% of the total mite fauna (Lawrence 1985). On adjacent alpine meadows, Prostigmata comprised 79% of the mite fauna (Lawrence 1985).

## Patterns of Distribution and Ecology

### Vertical and Seasonal Abundance

Densities of mites in grassland soils can exceed 120,000 m<sup>-2</sup> (O'Lear and Blair 1999), but are generally lower than those in forest soils and soils in more mesic habitats (Wood 1966; Coleman *et al.* 2004). However, mites in grassland soils may have deeper vertical penetration than in forest soils. They have been recorded from depths of 150 cm at Matador (Willard 1973) and routinely to depths of 60 cm (Willard 1974; Leetham and Milchunas 1985). The latter authors found 50% of the fauna below 30 cm. However, in most ecological studies, mites are sampled only to depths of 0 to 10–20 cm in most habitats (Coleman *et al.* 2004). Mites were sampled seasonally at the shortgrass prairie at Matador (Willard 1974) and the shortgrass steppe in Colorado (Leetham and Milchunas 1985). At both sites, seasonal changes were of low amplitude, though there was a trend for the endeostigmatan Nanorchestidae and the oribatid Oribatulidae to be deeper in the profile in the warm season (Leetham and Milchunas 1985).

Leetham and Milchunas (1985) noted two peaks in mite populations through the soil profile, associated with surface concentrations of root biomass and stability of soil water at depth, factors that may help explain why prostigmatans do so well in prairie soil. Prairie soils are characterized by frequent rapid wetting and drying cycles, and with their rapid life cycles, phytophagous and mycophagous prostigmatans can capitalize on feeding on root biomass and associated fungal biomass during these wet periods (Kethley 1990). Nematodes are enormously important in grassland soils (Ingham *et al.* 1989) and also rapidly increase in numbers under good conditions, but, as Walter *et al.* (1988) observed, Prostigmata do not prey on nematodes, even though many are voracious predators on arthropods.

### Collembola: Acari Ratios

In most grassland studies in North America, mites substantially outnumber Collembolans, as they do in most soil ecosystems. Seastedt (1984a) had Collembola:Acari ratios of 0.20 and 0.21 for burned and unburned sites on tallgrass prairie, respectively, and Leetham and Milchunas (1985) presented Collembola:Acari ratios of 0.09, 0.17, and 0.13 for shortgrass steppe, mixedgrass prairie, and tallgrass prairie, respectively. Thus, the Collembola:Acari ratio of 2.41 for the Matador shortgrass prairie study (Willard 1973) would appear to be an anomaly.

**Table 1.** Acari taxa by grassland type recorded from published studies on Canadian grassland soils.<sup>1</sup> Abbreviation: ABMI = Alberta Biodiversity Monitoring Institute.

Acari Taxa	Tallgrass Prairie	Mixedgrass Prairie	Mixedgrass Prairie	Dry Mixed Prairie	Fescue Prairie	Fescue Prairie	Fescue Prairie	Fescue Prairie	Palouse Grassland	ABMI Grassland Sites	
		Fescue	Alfalfa		Grazing – very heavy	Grazing – light	Grazing – none	Rotation			
<b>Suborder Monogynaspida</b>											
<b>Uropodidae</b>											
					e	e	e				
<b>Zerconidae</b>											
					e	e	e				
<i>Zercon</i> sp. nr. <i>peltatus</i> Koch				c							
<b>Parasitidae</b>											
<i>Gamasodes bispinosus</i> Halbert		a									
<i>Parasitus</i> sp. nr. <i>fimetorum</i> Berlese		a									
<i>Pergamasus crassipes</i> L.		a									
<b>Veigaiidae</b>											
<i>Gorirossia</i> sp.		a									
<i>Veigaia cerva</i> Kramer		a									
<b>Rhodacaridae</b>											
<i>Rhodacarellus</i> spp.		b	c						i		
						e	e				
<b>Ologamasidae</b>											
						e	e				

<b>Eviphididae</b>		c		e	e	
<i>Eviphis</i> sp.		c				
<b>Ascidae</b>		c	e	e	e	
<i>Arctoseius cetratus</i> (Sellnick)		c				
<i>Arctoseius</i> sp.						i
<i>Cheiroseius</i> sp.						i
<i>Protogamasellus</i> sp.						i
<b>Melicharidae</b>						
<i>Proctolaelaps hypudaei</i> (Oudemans)		c				
<b>Ameroseiidae</b>			e	e	e	i
<i>Ameroseius</i> spp.			b			
<b>Phytoseiidae</b>			e	e	e	
<i>Amblyseius</i> sp.						i
<b>Laelapidae</b>			e	e	e	i
<i>Androlaelaps casalis</i> Berlese	a					
<i>Hypoaspis</i> sp. nr. <i>angusta</i> (Karg)			b			
<i>H. nollii</i> Karg			c			
<i>H.</i> sp. nr. <i>aculeifer</i> (Canestrini)			c			

Table 1 (continued)

Acari Taxa	Tallgrass Prairie	Mixedgrass Prairie	Mixedgrass Prairie	Dry Mixed Prairie	Fescue Prairie	Fescue Prairie	Fescue Prairie	Fescue Prairie	Palouse Grassland	ABMI Grassland Sites
		Fescue	Alfalfa		Grazing – very heavy	Grazing – light	Grazing – none	Rotation		
<i>H. nr. praesternalis</i> (Willmann)		b								
<i>Hypoaspis</i> spp.				c						
<b>Suborder Prostigmata</b>										
<b>Bdellidae</b>	a			c	e	e	e	i		
<i>Bdella</i> sp.	a									
<i>B. longicornis</i> Hermann	a									
<i>B. muscorum</i> Ewing				c						
<b>Cunaxidae</b>					e	e	e	i		
<b>Eupodidae</b>	a				e	e	e	i		
<i>Eupodes</i> sp.	a									
<i>Linopodes</i> sp.	a									
<b>Rhagidiidae</b>	a				e	e	e	i		
<i>Rhagidia</i> sp.	a									
<b>Tydeidae</b>					e	e	e	i		
<i>Tydeus</i> spp.		b	b							
<b>Ereynetidae</b>						e	e			
<b>Paratydeidae</b>								i		



<b>Eriophyidae</b>		e	e	e	i
<b>Anystidae</b>					
<i>Anystis</i> sp.	a				
<b>Barbutiidae</b>			e	e	
<b>Erythraeidae</b>	c	e	e	e	
<i>Abrolophus</i> sp.	c				
<i>Tepoztlana</i> sp.	d				
<b>Trombidiidae</b>	c				
<i>Microtrombidium</i> sp.	c				
<b>Stigmaeidae</b>	c	e	e	e	i
<i>Eustigmaeus rhodomela</i> (Koch)	c				
<b>Camerobiidae</b>					
<i>Neophyllobius</i> sp.	d				
<b>Tetranychidae</b>		e	e	e	i
<b>Linotetranidae</b>					
<i>Linotetrans</i> sp.	d				
<b>Trochometridiidae</b>					
<i>Trochometridium</i> sp.	d				
<b>Pomerantziidae</b>	c				

Table 1 (continued)

Acari Taxa	Tallgrass Prairie	Mixedgrass Prairie	Mixedgrass Prairie	Dry Mixed Prairie	Fescue Prairie	Fescue Prairie	Fescue Prairie	Fescue Prairie	Palouse Grassland	ABMI Grassland Sites
		Fescue	Alfalfa		Grazing – very heavy	Grazing – light	Grazing – none	Rotation		
<i>Pomerantzia charlesi</i> Baker				c						
<b>Pygmephoridae</b>		b	b		e	e	e	i		
<i>Bakerdania</i> spp.		b	b							
<b>Tarsonemidae</b>					e	e	e	i		
<b>Scutacaridae</b>		b	b		e	e	e	i		
<i>Scutacarus</i> spp.		b	b							
<b>Suborder Endeostigmata</b>										
<b>Nanorchestidae</b>		b			e	e	e	i		
<i>Nanorchestes collinus</i> (Hirst)		b								
<b>Bimichaelidae</b>						e	e	i		
<b>Oehserchestidae</b>								i		
<b>Terpnacaridae</b>						e	e	i		
<b>Alicorhagiidae</b>		b	b		e	e	e	i		
<i>Alicorhagia</i> spp.		b	b							
<b>Suborder Oribatida</b>										
<b>Brachychthoniidae</b>					e	e	e			

<i>Brachychthonius berlesei</i> Willmann	i	
<i>B. bimaculatus</i> Willmann	i	
<i>B. pius</i> Moritz	i	
<i>Brachychthonius</i> spp.	i	
<i>Liochthonius lapponicus</i> (Trägårdh)	i	
<i>L. leptaleus</i> Moritz	i	
<i>Liochthonius</i> spp.	i	
<i>Neoliochthonius piluliferus</i> (Forsslund)	i	
<i>Sellnickochthonius furcatus</i> (Weis-Fogh)	i	
<i>S. nr. jugatus</i> (Jacot)	i	
<i>S. nr. suecicus</i> (Forsslund)	i	
<i>Sellnickochthonius</i> sp.	i	
<i>Verachthonius montanus</i> (Hammer)	i	
<b>Hypochthoniidae</b>	c	
<i>Hypochthonius rufulus</i> C.L. Koch		j
<i>Hypochthonius</i> sp.	c	
<b>Haplochthoniidae</b>		



<i>Nothrus anauniensis</i> Canestrini & Fanzago					j
<b>Camisiidae</b>		e	e	f	
<i>Camisia biverrucata</i> (C.L. Koch)					j
<i>Camisia</i> sp.				f	
<b>Gymnodamaeidae</b>	c			f	
<i>Gymnodamaeus</i> sp.	c				
<i>Joshuella agrosticula</i> Paschoal					j
<i>Odontodamaeus</i> sp.				f	
<b>Damaeidae</b>	c	e	e	f	
<i>Epidamaeus</i> spp.	c			f	
<i>Dyobelba</i> sp.				f	
<i>Lanibelba</i> sp.					j
<b>Eremaeidae</b>	c	e		f	
<i>Eremaeus walteri</i> Behan-Pelletier					j
<i>Eremaeus</i> sp.	c			f	
<i>Eueremaes masinasin</i> Behan-Pelletier	h				j
<i>Eu. tetrosus</i> (Higgins)	h				
<i>Eueremaes</i> sp.				i	



<i>Exochocepheus</i> sp.					f
<b>Passalozetidae</b>					f
<i>Passalozetes californicus</i> Wallwork					f
<b>Achipteriidae</b>	c		e	e	
<i>Anachipteria howardi</i> (Berlese)					j
<i>Anachipteria</i> sp.	c				
<i>Tectoribates</i> sp.	c				
<b>Tegoribatidae</b>					f
<i>Lepidozetes</i> sp.					f
<b>Phenopelopidae</b>	c	e	e	e	f
<i>Peloptulus</i> sp.	c				j
<i>Propelops canadensis</i> (Hammer)					j
<i>Propelops</i> sp.					f
<b>Oribatulidae</b>	c		e	e	f
<i>Jornadia</i> sp.					j
<i>Oribatula</i> sp.	c				f j
<i>Zygoribatula bulanovae</i> Kulijew					j





<i>Trichoribates striatus</i> Hammer					j
<b>Mycobatidae</b>					
<i>Guatemalozetes danos</i> Behan-Pelletier & Ryabinin			g		
<b>Oribatellidae</b>					
<i>Oribatella</i> sp.					f
<b>Galumnidae</b>					
<i>Galumna</i> sp.			g		j
<b>Oribatida: Astigmatina</b>					
<b>Histiostomatidae</b>					
<i>Histiostoma</i> spp.	b	b			
<b>Acaridae</b>					
<i>Mycetoglyphus fungivorus</i> Oudemans			c		
<i>Rhizoglyphus echinopus</i> (F. & R.)	b	b			

<sup>1</sup> References: a, Aitchison (1979); b, Berg and Pawluk (1984); c, Willard (1974); d, Lindquist (1979); e, Clapperton *et al.* (2002); f, Behan-Pelletier (1999); g, Behan-Pelletier and Eamer (2004); h, Behan-Pelletier (1993b); i, Osler *et al.* (2008); j, Walter (2009).

### Relative Abundance of Different Mite Taxa

In the soils of most forest ecosystems, abundance values for total Acari usually reflect the abundance of Oribatida. In contrast, total Acari in many grassland types reflect the abundance of Prostigmata (e.g., Osler *et al.* 2008). Furthermore, the drier bunchgrass soils show the highest relative abundance of prostigmatans (93%) (Battigelli *et al.* 2003). In the Great Plains of the United States, Prostigmata represented 67% and 77% of the mite fauna in shortgrass steppe of Colorado and mixedgrass prairie, respectively (Leetham *et al.* 1981; Leetham and Milchunas 1985). Oribatida at the same sites represented 25% and 18% of the mite fauna, respectively. These data suggest that relative abundance of Prostigmata (23–25%) at the shortgrass prairie Matador site was underestimated, possibly because of the extraction method used. Prostigmata (including endeostigmatans) also dominate the mite fauna in Konza tallgrass prairie (Seastedt 1984b; O’Lear and Blair 1999), but this may reflect the inclusion of endeostigmatans with Prostigmata. St. John *et al.* (2006) showed endeostigmatans comprised 19% of mite specimens collected at this Konza tallgrass prairie site. In turn, Oribatida were slightly more abundant than Prostigmata (1.14:1) in this study (St. John *et al.* 2006).

The number of families of Oribatida represented at the fescue prairie site studied by Clapperton *et al.* (2002) and the rotation site in fescue prairie studied by Osler *et al.* (2008) was higher than that of Prostigmata, but the difference was not significant. Oribatida (including Astigmatina) are more species rich than were Prostigmata in tallgrass prairie soils that have been studied. For example, numbers of species of Mesostigmata, Prostigmata (including endeostigmatans), and Oribatida recorded from tallgrass prairie were 11, 27, and 43 from Kansas (Seastedt 1984b); 18, 21, and 23 from Wisconsin (Lussenhop 1972); and 10, 5, 13 from Oklahoma (Stepanich 1975). St. John *et al.* (2006) identified all adult mites to species and found species richness of Mesostigmata, Prostigmata, Endeostigmata, and Oribatida to be 25, 41, 10, and 67, respectively. Thus, species richness of Prostigmata *sensu* Krantz and Walter (2008) may have been lower in the studies of Seastedt (1984b), Lussenhop (1972), and Stepanich (1975).

### Research Needs

Key components of biogeochemical cycles (e.g., carbon and nitrogen cycles) that occur in soil affect local soil fertility and global climate. Perennial grassland soils, with continual root turnover, and with additions of above-ground plant litter, develop rich mite communities. Root browsing by root-feeding mites increases the amount of carbon and nitrogen in the rhizosphere. However, knowledge of the role of soil microarthropod biodiversity in maintaining the functional properties of soils in Canadian grasslands is still rudimentary because there have been few attempts to address this issue. The paucity of species-specific biological and ecological data for mites found in these soils limits the interpretation of how changes in community composition (species richness and composition) of mites per se might affect ecosystem processes such as nutrient cycling and soil formation. Similarly, studies addressing mediation of mite assemblage structure by plant community composition are just beginning (St. John *et al.* 2006).

No studies have examined changes in community composition across the grassland landscape, for example, between river banks, riparian forest soils, and grassland per se. The [Alberta Biodiversity Monitoring Institute](#) provides a framework for doing this in the future, at least for oribatid mites, with the *Almanac of Alberta Oribatida* (Walter 2009). Studies on interactions between plant diversity, rhizosphere architectural diversity and

litter quality, and soil mite diversity in prairie landscapes, similar to that of Hansen (2000) for forest-dwelling mites, need to be addressed in Canada. Although soils are buffered by their biophysical properties that have developed over a long time (Anderson 2000), research is particularly critical in Canadian grasslands subject to grazing pressure, where rapid changes in grazing intensity and manure application can alter both soil biodiversity and soil biophysical properties over the short term.

At the outset though, there is a fundamental need for alpha-level taxonomy on the mite fauna of grassland soils of North America, together with data on species distributions and feeding habits. As Lindquist (2001) noted, this is a basic necessity for major projects on biodiversity and mites as rangeland pests, indicators of environmental and climate change, and biocontrol agents. Basic taxonomy and biology will allow adequate description of the community composition of mites in our grassland soils and will provide the baseline for biodiversity assessments at spatial scales from local to landscape to regional levels and for changes in biodiversity over time.

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