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Article

Checklist of oribatid mites (Acari: Oribatida) from two contrasting boreal fens: an update on oribatid mites of Canadian peatlands

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Abstract

A checklist of the oribatid mite species from two boreal fens in Northern Ontario, Canada is presented. 174 peat soil samples, collected between 2015–2020, yielded a heterogeneous assemblage of 80 species, 57 genera and 33 families. Species richness and diversity were significantly higher in a *Sphagnum*-dominated fen (69 species) compared to a *Carex*-dominated fen (51 species), and although 40 species were found at both sites, overall composition was significantly different between the two sites. We also present an update to the seminal work of Behan-Pelletier and Bissett (1994) on Oribatida of Canadian peatlands with 45 new species records for peatlands. Records for the parthenogenetic families Brachychthoniidae Thor, 1934 and Suctobelbidae Jacot, 1938 were considerably expanded, but other families such as Punctoribatidae, Thor, 1937 remain poorly represented in Canadian peatlands. Taken together, species richness estimates range from 86–105 species based on our sampling and the number of undescribed species recorded suggests that the oribatid mite fauna still need further examination to encompass their actual biodiversity in peatlands. We report that the oribatid mite fauna of Canadian peatlands comprise 186 species that includes all published records as of February 2021 and species presented here.

Keywords: Canada, Acari, *Sphagnum*, *Carex*, NMDS, bog

Introduction

Oribatid mites (Acari: Oribatida) are commonly the dominant group of arthropods in terrestrial soils (Norton & Behan-Pelletier 2009) and are well represented in terms of diversity in wetlands such as peatlands (bogs and fens) (Belanger 1976; Behan-Pelletier & Bissett 1994; Lehmitz 2014; Lindo 2015; Barreto & Lindo 2018). Peatlands are defined as wetlands with organic soils over 40 cm deep, with high water table from precipitation (bogs) or precipitation and ground water connectivity (fens) (National Wetlands Working Group 1988). In Canada, peatlands cover ~13% (1,136,000 km^2) of the landscape (Tarnocai *et al.* 2011) with the vast majority in the boreal and subarctic ecozones. Peatlands are important for carbon cycling (Harenda *et al.* 2018) since they store 1/3 of the world's terrestrial carbon (Bragazza *et al.* 2013), but only cover ~3% of the globe (Gorham 1991). In Canada it is estimated that they store 147 Gt carbon, or 59% of Canada's stored soil organic carbon (Tarnocai & Lacelle 1996). Oribatid mites are an important component of detrital food webs, being responsible for secondary decomposition of organic matter (McBrayer *et al.* 1997; Hubert 2001) and nutrient cycling (Crossley 1977) suggesting they play an important role in carbon transformation in high carbon-storage ecosystems like peatlands.

Despite their importance, peatlands and other wetland systems are understudied with respect to oribatid mite fauna in Canada compared to other habitat types, and it has been more than 25 years since Behan-Pelletier and Bissett (1994) published data on the taxonomy and ecology of oribatid mites of Canadian peatlands. In that study, the authors listed 71 species (49 genera and 34 families) across four categories of peatland habitats (aquatic, mesic, xeric, epigeal). They also noted that parthenogenetic species are better represented in peatlands than in the general 'soil-dwelling' oribatid mite fauna, which was also recently noted in Maraun *et al.* (2019).

Since that work, only a handful of studies have directly examined oribatid mites in Canadian peatland habitats (bogs and fens) (Behan-Pelletier 1997; Lindo 2015; Barreto & Lindo 2018; and Markkula & Kuhry 2020 for subfossil), described species from peatlands (Behan-Pelletier & Eamer 2003; Norton & Behan-Pelletier 2007; Behan-Pelletier & Walter 2013; Walter & Latonas 2013), or provided records from non-specific *Sphagnum* moss habitats (McAdams *et al.* 2018; Meehan *et al.* 2020). In the United States recent studies of oribatid mites in peatland and/or *Sphagnum* moss habitats only include Donaldson (1996), Norton and Behan-Pelletier (2007), and Walter and Latonas (2013). The work of Belanger (1976) is still the most comprehensive study documenting 44 species in a *Sphagnum*-dominated fen in New York State, of which 25 species had been previously recorded from European peatlands. In Europe, however, oribatid mites in peatlands have been and continue to be much more intensively studied (Borcard & Matthey 1995; Borcard & Vaucher-von Ballmoos 1997; Ivan *et al.* 1997; Laiho *et al.* 2001; Ivan & Călugăr 2003; Starý 2006; Sidorchuk 2008; Mumladze *et al.* 2013; Markkula 2014; Lehmitz 2014; Melekhina *et al.* 2015; Minor *et al.* 2016, 2019; Seniczak *et al.* 2016, 2019, 2020; Lehmitz & Maraun 2016; George *et al.* 2017; Markkula *et al.* 2019; Juan-Ovejero *et al.* 2019; Lehmitz *et al.* 2020). In addition, subfossil oribatid fauna from European peatlands are also thoroughly investigated (Karppinen *et al.* 1979; Cañellas-Boltà *et al.* 2012; Markkula 1986; Markkula 2020; Markkula *et al.* 2018).

The objectives of this work are to: 1) characterize the oribatid mite fauna in two boreal peatlands: a nutrient-poor fen dominated by *Sphagnum* spp. mosses, and an intermediate nutrient level fen dominated by *Carex* spp. sedges using samples collected over five years, and 2) update the checklist of oribatid mites of Canadian peatlands using the species found in our sites, and published work since 1994. The checklist of Behan-Pelletier and Bissett (1994) was derived primarily from Marshall *et al.* (1987) and Behan-Pelletier (1989), and examination of specimens housed in the Canadian National Collection of Insects, Arachnids and Nematodes sampled from peatland sites in the Canadian provinces of Ontario, Quebec, Alberta, New Brunswick, and Newfoundland. Our updated data is mainly derived from Behan-Pelletier and Lindo (2019), which includes Alberta Biodiversity Monitoring Institute data and other published literature, and the specimens collected from objective 1.

Material & Methods

Study area

Sampling was conducted in two fen sites near White River, Ontario, Canada (48.21°N, 85.21°W) in the southern Boreal ecozone. These sites integrate a large boreal peatland complex that has been extensively studied by the Ontario Ministry of Natural Resources and Forestry for the past 17 years. The two sites are approximately 2 km apart and experience a continental climate strongly influenced by the proximity of Lake Superior, with mean annual temperature of 2.1°C and precipitation of 980 mm (~40% as snow). Temperatures can reach –40°C in the winter (ave. January temperature –14.2°C) and rarely exceed 30°C in the summer (ave. July temperature 14.7°C); the growing season is 70–100 days (see Webster & McLaughlin (2010) for a full site description).

Although in the same area, the two fens differ in terms of nutrient status, water table depth and dominant vegetation. The *Sphagnum*-dominated fen (hereafter SF) is a 4.5 ha nutrient-poor fen (pH ~4.1) covered by mixed *Sphagnum* mosses (*Sphagnum angustifolium* (C.E.P. Jensen ex Russow), *Sphagnum fuscum* (Schimp.) Klinggr., *Sphagnum girgensohnii* Russ., *Sphagnum magellanicum* Brid.) and other mosses (*Dicranum polysetum* Sw., *Pleurozium schreberi* (Michx.) Trevis), with sedges (*Carex disperma* Dewey, *Carex magellanica* Lam., *Carex oligosperma* Michx., *Carex pauciflora* Lightf.), and abundant shrubs such as leatherleaf (*Chamaedaphne calyculata* (L.) Moench), and Labrador tea (*Rhododendron groenlandicum* Oeder). The SF is sparsely treed with tamarack (*Larix laricina* (Du Roi) K. Koch) and black spruce (*Picea mariana* (Mill.) B.S.P.), bounded by a mixed-wood boreal forest and borders on a small lake. The water table at the SF is ~30 cm below the peat surface, depending on relative position considering the hummock-hollow topology that exists (see Asemaninejad *et al.* 2017); total peat depth is approx. 104–127 cm.

On the other hand, the *Carex*-dominated fen (hereafter CF) is a 10.2 ha mostly open fen surrounded by a mixed-wood forests, with two small streams that circle its edges, and has an intermediate nutrient status (pH ~5.4). The water table at this site is considerably higher than the SF, and it is not uncommon to have several centimeters of standing water at the surface for several months of the year. The vegetation at the CF is dominated by *Carex* sedges (*Carex lasiocarpa* Ehrh, *Carex oligosperma* Michx., *Carex stricta* Lamb.) and the shrub sweetgale (*Myrica gale* L.), alongside bog rosemary (*Andromeda polifolia* L.) and leatherleaf (*C. calyculata*). Patches of *S. angustifolium* are occasional and typically associated with sweetgale; the total peat depth is ~60 cm. For a complete description of plant communities at both sites, see Lyons *et al.* (2020).

Sampling design

To assess the oribatid fauna of these peatlands, peat soil samples (8.52g ± 0.26g SE dwt) were collected in August 2015 (five samples/fen), June 2017 (16 samples/fen), June 2018 (18 samples/fen), June 2019 (16 samples/fen), August 2019 (16 samples/fen) and June 2020 (16 samples/fen), totaling 174 samples. Soil samples were placed in plastic bags and kept cool until return to the laboratory. Within 72 hours of collection, samples were extracted using Tullgren funnels over three days into 75% EtOH using a low wattage (25W) bulb. Following microarthropod extraction, all oribatid mites (Acari: Oribatida), as the dominant group in our samples (72% of all microarthropods) were morphotyped under a stereomicroscope (Nikon SMZ 745T). Representative individuals were slide mounted in Hoyer's and identified to the family and genus level under a compound microscope (Nikon Eclipse Ni) using keys in Norton & Behan-Pelletier (2009) and literature provided by The Ohio State University Summer Acarology course. Final species level identifications were made using primary literature and confirmed where possible against reference material. Additional sampling at the SF occurred in September 2012 (see Lindo 2015) and from litterbags at the SF in June 2016 (see Barreto & Lindo 2018).

Descriptive statistics

All descriptive statistics were performed with R statistical program (R Core Team 2020) using functions within the base package and "vegan" package (Oksanen *et al.* 2019). For each soil sample, we quantified the species richness and calculated the Shannon-Weiner diversity (H') and compared those between fen types using ANOVA. Species accumulation curves for both fens were generated in order of sampling and rarefied with 1000 permutations of samples added in random order. Species richness for each fen was estimated using Chao, Jackknife 1, Jackknife 2, and Bootstrap estimators, and we compared the overall community composition between sites using PERMANOVA with Bray-Curtis dissimilarity and visualized using NMDS ordination. All analyses use an alpha of 0.05, and final plots were created in R with "ggplot2" package (Wichkam 2016).

Update on Oribatida of Canadian peatlands

Our updated checklist of the oribatid mite species of Canadian peatlands includes all the species records published in the previous checklist for Canadian peatlands (Behan-Pelletier & Bissett 1994), in the checklist of oribatid mites of Canada (Behan-Pelletier & Lindo 2019) and the species identified in this study. All species included are listed as found in one of the following habitats: peatland, bog, fen, *Sphagnum* moss (including non-specified peatland habitat), wetland, understory of Labrador tea (*Rhododendron* (*Ledum*) *groenlandicum*), temporary bog pool, *Sphagnum* area in swamp, and bog tundra.

Results

Oribatid mite fauna

In total, 80 species of oribatid mites distributed in 33 families were collected from the two fen sites (Table 1). Sample level species richness ($F_{1,172} = 404.91$, $P < 0.001$) and species diversity ($F_{1,172} = 223.00$, $P < 0.001$) were significantly higher in the SF (ave. richness = 23.48 (± 0.48 SE); ave. diversity H' = 2.45 (± 0.02 SE)) compared to the CF (ave. richness = 11.12 (± 0.37 SE); ave. diversity H' = 1.66 (± 0.04 SE)).

TABLE 1. Updated checklist of Oribatida of Canadian peatlands.

	Previously recorded[1]	SF	CF
Family Palaeacaridae Grandjean, 1932			
Palaeacarus hystricinus Trägårdh, 1932	+	+	+
Family Brachychthoniidae Thor, 1934			
Brachychthonius bimaculatus Willmann, 1936		+	
Brachychthonius sp.			+
Eobrachychthonius latior (Berlese, 1910)		+	
Liochthonius brevis (Michael, 1888)		+	+
Liochthonius forsslundi (Hammer, 1952)	†		
Liochthonius lapponicus (Trägårdh, 1910)		+	+
Liochthonius sellnicki (Thor, 1930)		+	+
Liochthonius sp.	+		+
Poecilochthonius spiciger (Berlese, 1910)		+	+
Sellnickochthonius lydiae (Jacot, 1938)	+		
Sellnickochthonius suecicus (Forsslund, 1942)		+	+
Sellnickochthonius zelawaiensis (Berlese, 1910)		+	+
Synchthonius crenulatus (Jacot, 1938)	+	+	
Family Eniochthoniidae Grandjean, 1947			
Eniochthonius mahunkai Norton and Behan-Pelletier, 2007	†	+	+
Eniochthonius minutissimus (Berlese, 1903)	+	+	+
Family Hypochthoniidae Berlese, 1910			
Hypochthonius rufulus C.L. Koch, 1835	+	+	+
Family Trichthoniidae Lee, 1982			
Gozmanyina majestus (Marshall and Reeves, 1971)		+	

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TABLE 1. (Continued)

	Previously recorded[1]	SF	CF
Family Gehypochthoniidae Strenzke, 1963			
Gehypochthonius rhadamanthus Jacot, 1936	†		
Family Parhypochthoniidae Grandjean, 1932			
Parhypochthonius aphidinus Berlese, 1904	+		
Family Eulohmanniidae Grandjean, 1931			
Eulohmannia ribagai (Berlese, 1910)	†		
Family Euphthiracaridae Jacot, 1930			
Acrotritia ardua (C.L. Koch, 1841)	+	+	+
Microtritia minima (Berlese, 1904)		+	
Microtritia simplex (Jacot, 1930)	†		
Family Phthiracaridae Perty, 1841			
Atropacarus striculus (C.L. Koch, 1835)	†		
Hoplophorella thoreaui (Jacot, 1930)		+	+
Hoplophthiracarus illinoisensis (Ewing, 1909)[2]	+		
Phthiracarus boresetosus Jacot, 1930		+	+
Phthiracarus globosus (C.L. Koch, 1841)	†		
Phthiracarus longulus (C.L. Koch, 1841)	†		
Phthiracarus sp.		+	+
Family Perlohmanniidae Grandjean, 1954			
Perlohmannia sp nr. *coiffaiti* Grandjean, 1961	†		
Family Crotoniidae Thorell, 1876 (incl. Camisiidae auct.)			
Camisia biurus (C.L. Koch, 1839)	+		
Camisia foveolata Hammer, 1955	†		
Camisia lapponica (Trägårdh, 1910)	†		
Camisia segnis (Hermann, 1804)	+		+
Camisia spinifer (C.L. Koch, 1835)	+		
Heminothrus longisetosus Willmann, 1925		+	
Platynothrus capillatus (Berlese, 1914)	†		
Platynothrus peltifer (CL Koch, 1839)	+		
Platynothrus punctatus (L. Koch, 1879)	†	+	
Platynothrus thori (Berlese, 1904)[3]	+		
Family Malaconothridae Berlese, 1916			
Malaconothrus mollisetosus Hammer, 1952		+	+
Tyrphonothrus foveolatus (Willmann, 1931)	†	+	
Tyrphonothrus maior (Berlese, 1910)[4]	+	+	+
Tyrphonothrus sp.	+		
Family Nanhermanniidae Sellnick, 1928			
Nanhermannia dorsalis (Banks, 1896)[5]	+	+	
Nanhermannia n. sp.	+		
Nanhermannia sp.	+		
Family Nothridae Berlese, 1896			

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TABLE 1. (Continued)

	Previously recorded[1]	SF	CF
Nothrus anauniensis Canestrini and Fanzago, 1876	+		
Nothrus borussicus Sellnick, 1928			+
Nothrus monodactylus (Berlese, 1910)		+	+
Nothrus palustris C.L. Koch, 1839	+		
Nothrus pratensis Sellnick, 1928	†		
Nothrus silvestris Nicolet, 1855	†		
Nothrus truncatus Banks, 1895	†		
Nothrus sp.	+		
Family Trhypochthoniidae Willmann, 1931			
Mainothrus badius (Berlese, 1905)	+	+	+
Trhypochthoniellus longisetus (Berlese, 1904)	†		
Trhypochthoniellus setosus canadensis Hammer, 1952	+		+
Trhypochthonius cladonicola (Willmann, 1919)	†		
Trhypochthonius tectorum (Berlese, 1896) *s.l.*	+		
Trhypothchonius sp.	+		
Family Hermanniellidae Grandjean, 1934			
Hermanniella robusta Ewing, 1918	+		
Family Neoliodidae Sellnick, 1928			
Platyliodes scaliger (C.L. Koch, 1839)	+		
Family Gymnodamaeidae Grandjean, 1954			
Pleodamaeus n. sp.		+	+
Family Damaeidae Berlese, 1896			
Epidamaeus arcticolus (Hammer, 1952)	†		
Epidamaeus bakeri (Hammer, 1952)	†		
Epidamaeus gibbofemoratus (Hammer, 1955)	†		
Epidamaeus kodiakensis Hammer, 1967	†		
Family Liacaridae Sellnick, 1928			
Dorycranosus parallelus (Hammer, 1967)	†		
Family Cepheidae Berlese, 1896			
Cepheus n. sp.		+	
Eupterotegaeus ornatissimus (Berlese, 1908)		+	
Family Astegistidae Balogh, 1961			
Cultroribula divergens Jacot, 1939	†		+
Cultroribula sp.	+		
Family Peloppiidae Balogh, 1943			
Ceratoppia bipilis (Hermann, 1804)	+	+	+
Ceratoppia quadridentata (Haller, 1882)	†		
Ceratoppia quadridentata arctica Hammer, 1955	+	+	
Ceratoppia sexpilosa Willmann, 1938	†		
Family Carabodidae C.L. Koch, 1837			
Carabodes granulatus Banks, 1895	†	+	+

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TABLE 1. (Continued)

	Previously recorded[1]	SF	CF
Carabodes labyrinthicus (Michael, 1879)	†		
Carabodes polyporetes Reeves, 1991	†	+	
Carabodes radiatus Berlese, 1916	†		
Family Oppiidae Grandjean, 1951			
Discoppia sp.		+	
Lasiobelba (*Antennoppia*) *rigida* (Ewing, 1909)	†		
Lauroppia maritima (Willmann, 1929)[6]	†		
nr. *Lauroppia* sp.		+	
Moritzoppia nr. *clavigera* (Hammer, 1952)		+	
Oppiella nova (Oudemans, 1902)	+	+	+
Oppiella (*Moritzoppia*) *translamellata* (Willmann, 1923)[7]	†		
Subiasella (*Lalmoppia*) *maculata* (Hammer, 1952)	†		
Family Quadroppiidae Balogh, 1983			
Quadroppia quadricarinata (Michael, 1885)	+	+	+
Quadroppia skookumchucki Jacot, 1939	†		
Family Thyrisomidae Grandjean, 1954			
Pantelozetes sp.[8]	†		
Pantelozetes alpestris (Willmann, 1929)	†		
Family Suctobelbidae Jacot, 1938			
Allosuctobelba sp. 1		+	
Allosuctobelba sp. 2		+	
Suctobelbella (*S.*) *arcana* Moritz, 1970	†	+	+
Suctobelbella hammerae (Krivolutsky, 1965)	†		
Suctobelbella hurshi Jacot, 1937		+	+
Suctobelbella laxtoni Jacot, 1937		+	+
Suctobelbella nr. *longirostris* (Forsslund, 1941)	†	+	
Suctobelbella palustris (Forsslund, 1953)		+	+
Suctobelbella nr. *palustris* (Forsslund, 1953)	†		
Suctobelbella nr. *sarekensis* (Forsslund, 1941)			+
Suctobelbella sp. 1		+	+
Suctobelbella sp. 2		+	+
Suctobelbella sp. 3		+	+
Suctobelbella sp. 4		+	+
Suctobelbella sp. 5		+	
Suctobelbella spp.	+		
Family Tectocepheidae Grandjean, 1954			
Tectocepheus sarekensis Trägårdh, 1910	†		
Tectocepheus velatus Trägårdh, 1905	+	+	+
Family Caleremaeidae Grandjean, 1965			
Veloppia pulchra Hammer, 1955	†		
Family Hydrozetidae Grandjean, 1954			

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TABLE 1. (Continued)

	Previously recorded[1]	SF	CF
Hydrozetes lacustris (Michael, 1882)	†		
Hydrozetes octosetosus Willmann, 1931	†		
Hydrozetes sp.	+		
Family Limnozetidae Grandjean, 1954			
Limnozetes atmetos Behan-Pelletier, 1989	+		
Limnozetes borealis Behan-Pelletier, 1989	+		
Limnozetes canadensis Hammer, 1952	+		
Limnozetes ciliatus (Schrank, 1803)	+		
Limnozetes guyi Behan-Pelletier, 1989	+	+	+
Limnozetes latilamellatus Behan-Pelletier, 1989	+		
Limnozetes lustrum Behan-Pelletier, 1989	+		
Limnozetes onondaga Behan-Pelletier, 1989			+
Limnozetes palmerae Behan-Pelletier, 1989	+		
Limnozetes sp.	+		
Family Ameronothridae Vitzthum, 1943			
Ameronothrus sp.	+		
Family Tegeocranellidae Balogh and Balogh, 1988			
Tegeocranellus muscorum Behan-Pelletier, 1997	†		
Family Cymbaeremaeidae Sellnick, 1928			
Scapheremaeus palustris (Sellnick, 1924)	+		
Family Phenopelopidae Petrunkevich, 1955			
Eupelops septentrionalis (Trägårdh, 1910)	+	+	
Propelops n. sp.		+	+
Family Unduloribatidae Kunst, 1971			
Unduloribates dianae Behan-Pelletier and Walter, 2009		+	
Family Achipteriidae Thor, 1929			
Achipteria coleoptrata (Linnaeus, 1758)	+	+	
Anachipteria sp.		+	+
Parachipteria nivalis (Hammer, 1952)	+		
Parachipteria travei Nevin, 1976	†		
Family Tegoribatidae Grandjean, 1954			
Tectoribates borealis Behan-Pelletier and Walter, 2013	†		
Tegoribates americanus Hammer, 1958	+		
Family Haplozetidae Grandjean, 1936			
Peloribates canadensis Hammer, 1952	†		
Peloribates pilosus Hammer, 1952	+		
Protoribates capucinus Berlese, 1908	†		
Protoribates haughlandae Walter and Latonas, 2013	†		
Protoribates lophotrichus (Berlese, 1904)		+	+
Protoribates sp.[9]	+		
Rostrozetes ovulum (Berlese 1908)[10]	+		

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TABLE 1. (Continued)

	Previously recorded[1]	SF	CF
Family Mochlozetidae Grandjean, 1960			
Podoribates longipes (Berlese, 1887)	+		+
Family Oribatulidae Thor, 1929			
Lucoppia nr. *apletosa* (Higgins and Woolley, 1975)		+	+
Oribatula tibialis (Nicolet, 1855)	+	+	
Phauloppia boletorum (Ewing, 1913)	+	+	
Zygoribatula bulanovae Kulijew, 1961	+		
Family Parakalummidae Grandjean, 1936			
Neoribates aurantiacus (Oudemans, 1914)	+		
Family Scheloribatidae Grandjean, 1933			
Dometorina plantivaga (Berlese, 1895)	+		
Liebstadia cf. *humerata* Sellnick, 1928		+	
Liebstadia similis Michael, (1888)	†		
Scheloribates laevigatus (C.L. Koch, 1835)	+		
Scheloribates pallidulus (C.L. Koch, 1841)	+	+	
Scheloribates sp.	†		
Family Ceratozetidae Jacot, 1925			
Ceratozetes parvulus Sellnick, 1922	+		+
Dentizetes ledensis Behan-Pelletier, 2000	†		
Diapterobates humeralis (Hermann, 1804)	+		
Diapterobates notatus (Thörell, 1871)	+		
Fuscozetes bidentatus Banks 1895	+		
Fuscozetes fuscipes (C.L. Koch, 1844)	+		
Ghilarovizetes longisetosus (Hammer, 1952)	†		
Lepidozetes singularis Berlese, 1910	+	+	
Melanozetes tanana Behan-Pelletier, 1986	†		
Neogymnobates luteus (Hammer, 1955)	†		
Svalbardia paludicola Thor, 1930	†		
Trichoribates copperminensis Hammer, 1952	†		
Trichoribates polaris Hammer, 1953	†		
Trichoribates n. sp.		+	
Trichoribates sp.	+		
Family Punctoribatidae Thor, 1937			
Mycobates incurvatus Hammer, 1952	†		
Mycobates yukonensis Behan-Pelletier, 1994	†		
Punctoribates palustris (Banks, 1895)	†	+	+
Punctoribates punctum (C.L. Koch, 1839)	†		
Family Zetomimidae Shaldybina, 1966			
Heterozetes aquaticus (Banks, 1895)	†		
Heterozetes minnesotensis (Ewing, 1913)	†		
Naiazetes n. sp.			+

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TABLE 1. (Continued)

	Previously recorded[1]	SF	CF
Zetomimus cooki Behan-Pelletier and Eamer, 2003	†		
Zetomimus francisi (Habeeb, 1974)	†		
Zetomimus setosus (Banks, 1895)	†		
Family Galumnidae Jacot, 1925			
Pergalumna emarginata (Banks, 1895)	+	+	+
Pilogalumna sp.		+	+

[1] Original record by Behan-Pelletier and Bisset (1994) denoted by + with updates from Behan-Pelletier and Lindo (2019) denoted by †
[2] as *Hoplophthiracarus paludis* Jacot, 1938
[3] as *Heminothrus thori* (Berlese, 1904)
[4] as *Trimalaconothrus novus* (Sellnick, 1921)
[5] probably *Nanhermannia coronata* Berlese, 1913
[6] as *Oppiella maritima* (Willmann, 1929)
[7] as *Oppiella translamellata* (Willmann, 1923)
[8] as *Gemmazetes* sp.
[9] as *Xylobates* sp.
[10] as *Rostrozetes foveolatus* Sellnick, 1925

At the SF site we collected 69 species from 22,252 sampled adult individuals, of which 29 were unique to that site, and eight collected as singletons. The two most abundant species at the SF were the cosmopolitan *Tectocepheus velatus* Trägårdh, 1910 and *Oppiella nova* (Oudemans 1902), followed by two known peatland species, *Malaconothrus mollisetosus* Hammer, 1952 and *Eniochthonius mahunkai* Norton and Behan-Pelletier, 2007. The estimated total species richness for the SF is between 74–85 species and new species records were still being added in our last year of sampling (Figure 1A) suggesting there are likely more species that were not collected.

At the CF we collected 51 species from 7,273 adult individuals of which 11 were unique to that site and not found in the SF, and four were singletons (*Cultroribula divergens* Jacot, 1939, *Liochthonius* sp., *Nothrus borussicus* Sellnick, 1928, *Trhypochthoniellus setosus canadensis* Hammer 1952). The two most abundant species at the CF were *Tyrphonothrus maior* (Berlese 1910) and *Mainothrus badius* (Berlese 1905), which contributed to >50% of all individuals collected at that site. The estimated richness for the CF is between 57–71 species, and several new species records were added in our last year of sampling at this site also (Figure 1B), suggesting there are more species that were not collected. Combined richness estimates for both these sites are 86–105 species.

In total, 40 species were shared between SF and CF sites (Supplementary Information Figure S1), but overall composition was significantly different between the two sites ($F_{1,172} = 104.60$, $P = 0.001$) (Figure 2). Notably, of the 40 shared species, 15 species were dominant (i.e., >10× more abundant) in the SF, of which five species had only one individual found in the CF (*Acrotritia ardua* (C.L. Koch 1841), *Carabodes granulatus* Banks, 1895, *Hoplophorella thoreaui* (Jacot, 1930), *Nothrus monodactylus* (Berlese, 1910), *Sellnickochthonius zelawaiensis* (Berlese, 1910)). On the other hand, there were four species in the CF that, although found in the SF, were more dominant in CF (*Anachipteria* sp., *Limnozetes guyi* Behan-Pelletier, 1989, *T. maior*, *Liochthonius sellnicki* (Thor1930)).

Update on Oribatida of Canadian peatlands

Behan-Pelletier and Bissett (1994) originally listed 71 species of oribatid mites for peatlands in Canada; we found 141 species recorded from peatland habitats (including those 71) with some listed as subfossils in the updated list of oribatid mites of Canada by Behan-Pelletier and Lindo (2019). Our work expands the number of oribatid mites in Canadian peatlands to 186 species (Table 1). From those, only 35 species are common to Behan-Pelletier and Lindo (2019) and this dataset (as indicated in Table 1).

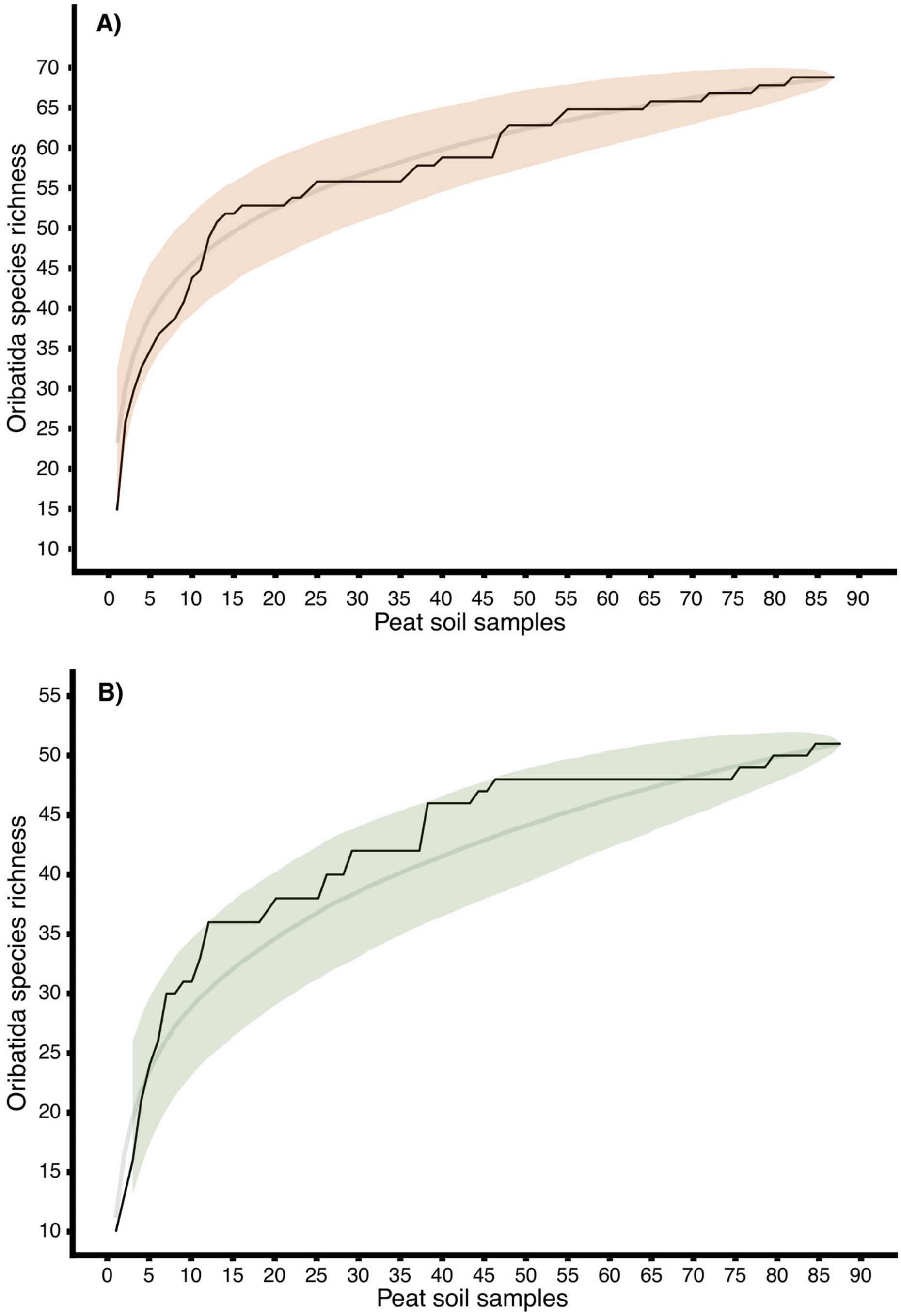

FIGURE 1. Species accumulation curves. (A) *Sphagnum*-dominated fen oribatid mite species (B) *Carex*-dominated fen oribatid mite species. Collector curves are in black for sampling effort over time on the X-axis (left to right 2015–2020). Rarefied accumulation curves (grey and brown/green) are plotted from means and standard deviation of 1000 permutations of samples in random order.

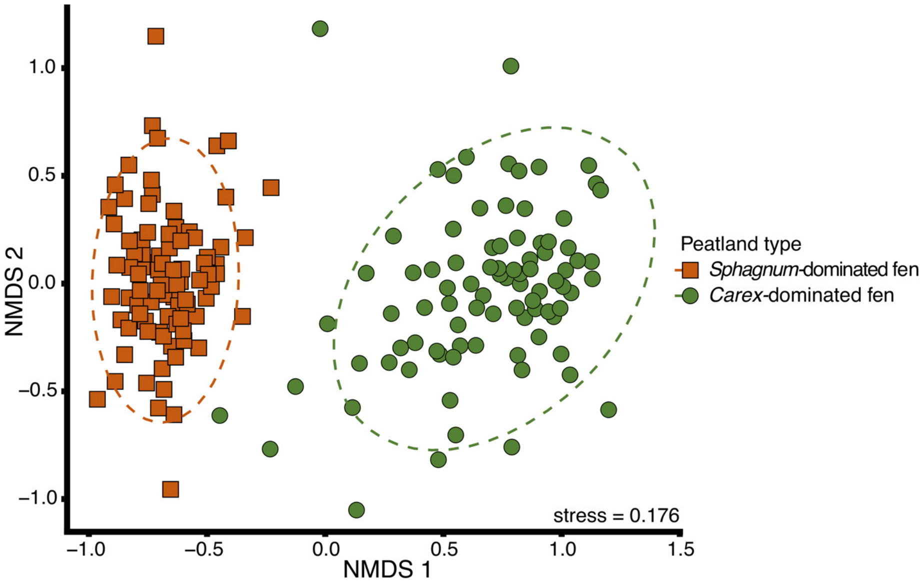

FIGURE 2. Non-metric multidimensional scaling (NMDS) plot depicting community assembly of oribatid mites in a *Sphagnum*-dominated (brown) and a *Carex*-dominated (green) fen. NMDS is based on Bray-Curtis percent similarity of species abundances for each species in 174 samples. Oribatida community composition was different between sites (PERMANOVA: $F_{1,172}$ = 104.60, P = 0.001).

Discussion

Extensive sampling over five years at two peatland sites collected 80 species of oribatid mites, of which 69 occurred in the *Sphagnum*-dominated fen and 51 occurred in the *Carex*-dominated fen. This sampling, along with the updated checklist of oribatid mites in Canada (Behan-Pelletier & Lindo 2019) brings the total known peatland oribatid mite fauna to 186 species, of which 45 species are newly recorded in peatlands in Canada. Among species previously recorded and collected at both our sampling sites, several have also been found in abundance in Europe such as *Hypochthonius rufulus* C.L. Koch, 1836, *A. ardua*, *T. maior*, and *O. nova* (Seniczak *et al.* 2019). Several of these are cosmopolitan species found in a variety of habitats, thus not strict peatland species. For instance, *O. nova* is a species found around the world, and possibly the most common and widespread arthropod in terrestrial environments (Norton & Palmer 1991), which indicates that the oribatid mite fauna of peatlands also comprises non-peatland specialized species. Donaldson (1996) similarly suggests that there are only a few highly specialised species that occur in very high abundances in natural peatlands. Specifically, Donaldson (1996) found high abundance of the genus *Limnozetes* Hull, 1916, and particularly *L. palmerae* Behan-Pelletier, 1989, which they attributed to a semi-aquatic habitat association, preference for acidic environments, and its small size.

The SF in particular had a greater number of generalist (i.e., non-peatland specialist) species. For example, among the 29 species unique to the SF, *Gozmanyina majestus* (Marshall & Reeves 1971) was highly abundant, although previously recorded primarily in acidic forest soil (Cianciolo & Norton 2006), which might suggest that habitat associations are driven by pH (Kaneko & Kofuji 2000). Alternatively, the presence of non-peatland specialist species at the SF could be explained by wind dispersal of oribatid mites from the adjacent forest, a phenomenon seen for other oribatid mites (Behan-Pelletier & Winchester 1998). We also record several species previously not documented for peatlands including members of Cepheidae Berlese, 1896 (*Cepheus* n. sp., *Eupterotegaeus ornatissimus* (Berlese 1908)) and Gymnodamaeidae Grandjean, 1954 (*Pleodamaeus* n. sp.) that are typically found in drier environments. As a result, the SF had higher species richness and diversity compared to the CF because of these unique species and species that appear to be peatland specialists, such as *E. mahunkai*, *M. badius*, and *L. guyi* that were also present. While we note that several mesophilous peatland species were found at the SF, some species were more commonly (e.g., *T. maior*, *L. guyi*) or solely (*T. setosus canadensis*, *L. onondaga* Behan-Pelletier, 1989) collected at the wetter CF that were typically semi-aquatic species. In addition to differences in water table that explain distributions of aquatic species, the SF site has greater vascular plant and moss species richness (Lyons *et al.* 2020), leading to heterogeneous microhabitats such as hummock/hollow topography (Barreto & Lindo 2018), and greater saprophytic fungal biomass (Lyons & Lindo 2020), and diverse fungal (Asemaninejad *et al.* 2017) and bacterial (Asemaninejad *et al.* 2019) communities that provide food resources for many oribatid mite species (Schneider & Maraun 2005; Lehmitz & Maraun 2016). We will also note that we observed a relatively high frequency of the zygomycete fungi *Basidiobolus* on slide mounted specimens, and two specimens parasitized with the non-photosynthetic algae *Helicosporidium*. *Basidiobolus* attaches to external surfaces of small arthropods for dispersal, while *Helicosporidium* was observed inside body cavities. Whether these observations reflect greater abundance of these microbial groups in peatlands or some enhanced synecological association warrants further investigation.

Peatland records for the entirely parthenogenetic Brachychthoniidae Thor, 1934 were considerably expanded, with nine new species added to the checklist. As important was the update on Suctobelbidae Jacot, 1938, whose members are predominantly asexually reproducing species. Until Behan-Pelletier and Lindo (2019), only four named species of Suctobelbidae were listed for peatlands; here we add eleven more species in two genera (*Allosuctobelba* Moritz, 1970 and *Suctobelbella* Jacot, 1937), although with relatively lower taxonomic resolution as we were not able to confirm all species identities. While there are 12 described species of *Suctobelbella* in Canada (Behan-Pelletier & Lindo 2019), there are still many undescribed species. For instance, Beaulieu et al. (2019) estimate 48 undescribed or unrecorded *Suctobelbella* species but note that based on molecular barcode information this number may be an underestimate.

It has been noted that both the number of parthenogenetic species as well as their individual abundances are higher in peat bogs than other habitats (e.g., forest floor soils) (Maraun *et al*. 2019); while this was not overly evident for species richness in the SF (39 parthenogenetic vs. 30 sexual species), more than 2/3 of the species in the CF were parthenogenetic (36 parthenogenetic vs. 15 sexual species). Overall, the abundance of individuals of parthenogenetic species, however, was about 10-fold greater than that of sexual species at both fens. One possible explanation for higher richness of parthenogenetic species in the CF might be related to a lower efficacy of free-standing spermatophores produced by males in wet habitats (Norton & Palmer 1991), resulting in taxonomic groups like Brachychthonidae and Eniochthonidae Grandjean, 1947 within the Enarthronota being preadapted to these wet habitats (Behan-Pelletier & Bisset 1994).

Notably missing from the peatland fauna in Canada compared to other boreal systems (Behan-Pelletier 1999) are species in the predominantly sexually reproducing Punctoribatidae Thor, 1937, many of which are found in dry microhabitats. However, while the family is present in all ecozones of Canada (Beaulieu *et al.* 2019), different genera exhibit different habitat preferences. For example, two of the five described *Punctoribates* Berlese, 1908 in Canada (*P. palustris* (Banks, 1895) and *P. punctum* (C.L. Koch, 1839)) are reported from *Sphagnum* in peat bog and wet *Sphagnum* habitats, respectively, while only two of the 17 described *Mycobates* Hull, 1916 (*M. incurvatus* Hammer, 1952 and *M. yukonensis* Behan-Pelletier, 1994) are recorded from bog tundra or peat habitats (Behan-Pelletier & Lindo 2019). That said, while there are 35 described species in Punctoribatidae, there are an estimate 30 additional unrecorded or undescribed species in Canada (Beaulieu *et al.* 2019).

Among the 45 species as new records for Canadian peatlands, at least five species from our sampling are confirmed as undescribed (*Pleodamaeus* n. sp., *Cepheus* n. sp., *Propelops* n. sp., *Trichoribates* n. sp., *Naiazetes* n. sp.), suggesting great potential for more species to yet be described, and clearly more taxonomic studies are needed on peatlands in North America. For example, despite *Protoribates haughlandae* Walter and Latonas, 2013 being widely distributed across the province of Alberta (Walter & Latonas 2013), this species has only recently been collected by the systematic sampling of peatland sites. Even though the oribatid mite fauna in Europe is considerably more studied than in Canada, many studies still list species as morphospecies, which could also potentially translate to new species or new records for peatlands worldwide (e.g., Sidorchuk 2008; Markkula 2014; Seniczak *et al.* 2020).

Embedded in the expanded checklist of Canadian peatland oribatid mites are geographical as well as habitat factors that dictate the presence and distribution of these mites. Prior to 1994, the vast majority of peatland records were for eastern Canada and within the boreal ecozone. The addition of records from western Canada and the subarctic will continue to increase the number of known peatland species, as does extensive and repeated sampling at single locations. Thus we suggest that future studies focus more on these sites with repeated sampling and/or more consideration of habitat specific associations. For instance, Donaldson (1996) found significantly different oribatid mite species assemblages across three different *Sphagnum* moss habitats within a single location, while at the same time, the abundance and dominance of particular species changed over one growing season. Taken together, this work highlights that, despite the importance of peatlands as soil reservoirs for carbon and biodiversity, peatlands and other wetland systems remain understudied with respect to oribatid mite fauna in Canada compared to other habitat types.

Disclosure statement

No potential conflict of interest was reported by the authors.

Author contributions

Both authors contributed to the sampling, identifications, and written work; CB performed sample processing and data analysis, while the project was conceived and funded by grants to ZL.

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References

Asemaninejad, A., Thorn, R.G., Branfireun, B.A. & Lindo, Z. (2019) Vertical stratification of peatland microbial communities follows a gradient of functional types across hummock-hollow microtopographies. *Écoscience*, 26, 249–258.
https://doi.org/10.1080/11956860.2019.1595932

Asemaninejad, A., Thorn, R.G. & Lindo, Z. (2017) Vertical distribution of fungi in hollows and hummocks of boreal peatlands. *Fungal Ecology*, 27, 59–68.
https://doi.org/10.1016/j.funeco.2017.02.002

Barreto, C. & Lindo, Z. (2018) Drivers of decomposition and the detrital invertebrate community differ across a hummock-hollow microtopology in Boreal peatlands. *Écoscience*, 25, 39–48.
https://doi.org/10.1080/11956860.2017.1412282

Beaulieu, F., Knee, W., Nowell, V., Schwarzfeld, M., Lindo, Z., Behan-Pelletier, V.M., Lumley, L., Young, M.R., Smith, I., Proctor, H.C., Mironov, S. V., Galloway, T.D., Walter, D.E. & Lindquist, E.E. (2019) Acari of Canada. *ZooKeys*, 819, 77–168.
https://doi.org/10.3897/zookeys.819.28307

Behan-Pelletier, V. & Winchester, N. (1998) Arboreal oribatid mite diversity: Colonizing the canopy. *Applied Soil Ecology*, 9, 45–51.
https://doi.org/10.1016/S0929-1393(98)00052-3

Behan-Pelletier, V. (1999) Oribatid mite fauna of northern ecosystems: a product of evolutionary adaptations or physiological constraints? *In*: Needham, G.R., Mitchell, R., Horn, D.J. & Welbourn, C. (Eds.), *Acarology IX: Vol. 2*, Symposia. Columbus, Ohio, Ohio Biological Survey, pp. 87–105.

Behan-Pelletier, V.M. & Bissett, B. (1994) Oribatida of Canadian peatlands. *Memoirs-Entomological Society of Canada*, 169, 73–88.
https://doi.org/10.4039/entm126169073-1

Behan-Pelletier, V.M. & Eamer, B. (2003) Zetomimidae (Acari: Oribatida) of North America. *In*: Smith, I.M. (Ed.), *An Acarological Tribute to David Cook,* Indira Publishing House, pp. 21–56.

Behan-Pelletier, V.M. & Lindo, Z. (2019) Checklist of oribatid mites (Acari: Oribatida) of Canada and Alaska. *Zootaxa*, 4666, 1–180.
https://doi.org/10.11646/zootaxa.4666.1.1

Behan-Pelletier, V.M. & Walter, D.E. (2013) Phylogenetic relationships of *Tectoribates*: nymphal characters of new North American species place the genus in Tegoribatidae (Acari, Oribatida). *Zootaxa*, 3741, 459–489.
https://doi.org/10.11646/zootaxa.3741.4.2

Behan-Pelletier, V.M. (1989) Limnozetes (Acari: Oribatida: Limnozetidae) of Northeastern North America. *The Canadian Entomologist*, 121, 453–506.
https://doi.org/10.4039/Ent121453-6

Behan-Pelletier, V.M. (1997) Oribatid mites (Acari: Oribatida) of the Yukon. *In*: Danks, H.V. & Downes, J.A. (Eds.), *Insects of the Yukon*. Biological Survey of Canada Monograph Series No. 2. Ottawa, pp. 115–149.

Belanger, S.D. (1976) *The microarthropod community of Sphagnum moss with emphasis on the Oribatei*. State University of New York, 180 pp.

Borcard, D. & Matthey, W. (1995) Effect of a controlled trampling of *Sphagnum* mosses on their oribatid mite assemblages (Acari, Oribatei). *Pedobiologia*, 39, 219–230.

Borcard, D. & Vaucher-von Ballmoos, C. (1997) Oribatid mites (Acari, Oribatida) of a primary peat bog-pasture transition in the Swiss Jura mountains. *Écoscience*, 4, 470–479.
https://doi.org/10.1080/11956860.1997.11682426

Bragazza, L., Parisod, J., Buttler, A. & Bardgett, R.D. (2013) Biogeochemical plant-soil microbe feedback in response to climate warming in peatlands. *Nature Climate Change*, 3, 273–277.
https://doi.org/10.1038/nclimate1781

Cañellas-Boltà, N., Rull, V., Sáez, A., Margalef, O., Giralt, S., Pueyo, J.J., Birks, H.H., Birks, H.J.B. & Pla-Rabes, S. (2012) Macrofossils in Raraku Lake (Easter Island) integrated with sedimentary and geochemical records: Towards a palaeoecological synthesis for the last 34,000 years. *Quaternary Science Reviews*, 34, 113–126.
https://doi.org/10.1016/j.quascirev.2011.12.013

Cianciolo, J.M & Norton, R.A. (2006) The ecological distribution of reproductive mode in oribatid mites, as related to biological complexity. *Experimental and Applied Acarology*, 40, 1–25.
https://doi.org/10.1007/s10493-006-9016-3

Crossley, D.A.J. (1977) Oribatid mites and nutrient cycling. *In*: Dindal, D.A. (Eds.), *Biology of Oribatid mites*. State Univ. N.Y., Syracuse, 71–85.

Donaldson, G.M. (1996) Oribatida (Acari) associated with three species of *Sphagnum* at Spruce Hole Bog, New Hampshire, U.S.A. *Canadian Journal of Zoology*, 74, 1706–1712. https://doi.org/10.1139/z96-188

George, P.B.L., Keith, A.M., Creer, S., Barrett, G.L., Lebron, I., Emmet, B.A., Robinson, D.A. & Jones, D.L. (2017) Evaluation of mesofauna communities as soil quality indicators in a national-level monitoring programme. *Soil Biology & Biochemistry*, 115, 537–546. https://doi.org/10.1016/j.soilbio.2017.09.022

Gorham, E. (1991) Northern Peatlands: role in the carbon cycle and probable responses to climatic warming. *Ecological Applications*, 1, 182–195. https://doi.org/10.2307/1941811

Harenda, K.M., Lamentowicz, M., Samson, M. & Chojnicki, B.H. (2018) The role of peatlands and their carbon storage function in the context of climate change. *In*: Zielinski, T., Sagan, I. & Surosz, W. (Eds.), *Interdisciplinary Approaches for Sustainable Development Goals*. GeoPlanet, Earth and Planetary Sciences, Springer, pp. 169–187.

Hubert, J. (2001) The influence of *Scheloribates laevigatus* (Acari: Oribatida) on decomposition of *Holcus latanus* litter. *Acta Societatis Zoologicae Bohemicae*, 65, 77–80.

Ivan, O. & Călugăr, A. (2003) The fauna of edaphic mites (Acari, Gamasida, Oribatida) in some peat bogs–protected areas in North Moldavia (Romania). *Anuarul Complexului Muzeal Bucovina*, 16–17, 127–150.

Ivan, O., Vasiliu, N. & Vasiliu, M. (1997) The fauna and structure of the oribatid mites communities from height peat bogs in the Eastern Carpathians (Romania). The Poiana Sampa and Lucina nature reserves. *Anuarul Muzeului National al Bucovinei*, 14, 35–42.

Juan-Ovejero, R., Benito, E., Barreal, M.E., Rodeiro, J. & Briones, M.J.I. (2019) Tolerance to fluctuating water regimes drives changes in mesofauna community structure and vertical stratification in peatlands. *Pedobiologia*, 76, 150571. https://doi.org/10.1016/j.pedobi.2019.150571

Kaneko, N. & Kofuji, R. (2000) Effects of Soil pH gradient caused by stemflow acidification on soil microarthropod community structure in a Japanese Red Cedar plantation: an evaluation of ecological risk on decomposition. *Journal of Forestry Research*, 5, 157–162. https://doi.org/10.1007/BF02762395

Karpinnen, E., Krivolutsky, D.A., Koponen, M., Kozlovskava, L.S., Laskova, L.M. & Viitasaari, M. (1979) List of subfossil oribatid mites (Acarina, Oribatei) of northern Europe and Greenland. *Annales Entomologicae Fennicae*, 45, 103–108.

Laiho, R., Silvan, N., Cárcamo, H. & Vasander, H. (2001) Effects of water level and nutrients on spatial distribution of soil mesofauna in peatlands drained for forestry in Finland. *Applied Soil Ecology*, 16, 1–9. https://doi.org/10.1016/S0929-1393(00)00103-7

Lehmitz R. & Maraun, M. (2016) Small-scale spatial heterogeneity of stable isotopes signatures (δ15N, δ13C) in *Sphagnum* sp. transfers to all trophic levels in oribatid mites. *Soil Biology & Biochemistry*, 100, 242–251. https://doi.org/10.1016/j.soilbio.2016.06.005

Lehmitz, R. (2014) The oribatid mite community of a German peatland in 1987 and 2012–effects of anthropogenic desiccation and afforestation. *Soil Organisms*, 86, 131–145.

Lehmitz, R., Haase, H., Otte, V. & Russell, D. (2020) Bioindication in peatlands by means of multi-taxa indicators (Oribatida, Araneae, Carabidae, Vegetation). *Ecological Indicators*, 109, 105837. https://doi.org/10.1016/j.ecolind.2019.105837

Lindo, Z. (2015) Warming favours small-bodied organisms through enhanced reproduction and compositional shifts in belowground systems. *Soil Biology & Biochemistry*, 91, 271–278. https://doi.org/10.1016/j.soilbio.2015.09.003

Lyons, C.L. & Lindo, Z. (2020) Above- and belowground community linkages in boreal peatlands. *Plant Ecology*, 221, 615–632. https://doi.org/10.1007/s11258-020-01037-w

Lyons, C.L., Branfireun, B.A., McLaughlin, J. & Lindo, Z. (2020) Simulated climate warming increases plant community heterogeneity in two types of boreal peatlands in north-central Canada. *Journal of Vegetation Science*, 31, 908–919. https://doi.org/10.1111/jvs.12912

Maraun, M., Caruso, T., Hense, J., Lehmitz, R., Mumladze, L., Murvanidze, M., Nae, I., Schulz, J., Seniczak, A. & Scheu, S. (2019) Parthenogenetic vs. sexual reproduction in oribatid mite communities. *Ecology and Evolution*, 9, 7324–7332.
https://doi.org/10.1002/ece3.5303

Markkula, I. & Kuhry, P. (2020) Subfossil oribatid mite communities indicate Holocene permafrost dynamics in Canadian mites. *Boreas*, 49, 730–738.
https://doi.org/10.1111/bor.12444

Markkula, I. (1986) Comparison of present and subfossil oribatid faunas in the surface peat of a drained pine mire. *Annales Entomologici Fennici*, 52, 39–41.

Markkula, I. (2014) Permafrost dynamics structure species compositions of oribatid mite (Acari: Oribatida) communities in sub-Arctic palsa mires. *Polar Research*, 33, 1–10.
https://doi.org/10.3402/polar.v33.22926

Markkula, I. (2020) *Oribatid mites (Acari: Oribatida) in sub-arctic peatlands*. A multidisciplinary investigation into climate change, permafrost dynamics and indicator values of subfossils. University of Turku, 100 pp.

Markkula, I., Cornelissen, J.H.C. & Aerts, R. (2019) Sixteen years of simulated summer and winter warming have contrasting effects on soil mite communities in a sub-Arctic peat bog. *Polar Biology*, 42, 581–591.
https://doi.org/10.1007/s00300-018-02454-4

Markkula, I., Oksanen, P. & Kuhry, P. (2018) Indicator value of oribatid mites in determining past permafrost dynamics in northern European sub-Arctic peatlands. *Boreas*, 47, 884–896.
https://doi.org/10.1111/bor.12312

Marshall, V.G., Reeves, R.M. & Norton, R.A. (1987) Catalogue of the Oribatida (Acari) of Continental United States and Canada. *Memoirs of the Entomological Society of Canada*, 119, 1–418.
https://doi.org/10.4039/entm119139fv

McAdams, B.N., Quideau, S.A., Swallow, M.J.B & Lumley, L.M. (2018) Oribatid mite recovery along a chronosequence of afforested boreal sites following oil sands mining. *Forest Ecology and Management*, 422, 281–293.
https://doi.org/10.1016/j.foreco.2018.04.034

McBrayer, J.F., Ferris, J.M., Metz, L.J., Gist, C.S., Cornaby, B.W., Kitazawa, Y., Kitazawa, T., Wernz, J.G., Krantz, G.W. & Jensen, H. (1977) Decomposer invertebrate populations in U.S. forest biomes, *Pedobiologia*, 17, 89–96.

Meehan, M.L., Barreto, C., Turnbull, M.S., Bradley, R.L., Bellenger, J.P., Darnajoux, R. & Lindo, Z. (2020) Response of soil fauna to simulated global change factors depends on ambient climate conditions. *Pedobiologia*, 83, 150672.
https://doi.org/10.1016/j.pedobi.2020.150672

Melekhina, E.N., Markarova, M.Y., Shchemelinina, T.N., Anchugova, E.M. & Kanev, V.A. (2015) Secondary successions of biota in oil-polluted peat soil upon different biological remediation methods. *Eurasian Soil Science*, 48, 643–653.
https://doi.org/10.1134/S1064229315060071

Minor, M.A., Ermilov, S.G. & Philippov, D. (2019) Hydrology-driven environmental variability determines abiotic characteristics and Oribatida diversity patterns in a *Sphagnum* peatland system. *Experimental and Applied Acarology*, 77, 43–58.
https://doi.org/10.1007/s10493-018-0332-1

Minor, M.A., Ermilov, S.G., Philippov, D.A. & Prokin, A.A. (2016) Relative importance of local habitat complexity and regional factors for assemblages of oribatid mites (Acari: Oribatida) in *Sphagnum* peat bogs. *Experimental and Applied Acarology*, 70, 275–286.
https://doi.org/10.1007/s10493-016-0075-9

Mumladze, L., Murvanidze, M. & Behan-Pelletier, V. (2013) Compositional patterns in Holarctic peat bog inhabiting oribatid mite (Acari: Oribatida) communities. *Pedobiologia*, 56, 41–48.
https://doi.org/10.1016/j.pedobi.2012.10.001

National Wetlands Working Group (1988) *Wetlands of Canada*. Canada Committee on Ecological Land Classification, Environment Canada, Ecological Land Classification Series, 454 pp.

Norton, R.A. & Behan-Pelletier, V.M. (2007) *Eniochthonius mahunkai* sp. n. (Acari: Oribatida: Eniochthoniidae), from North American peatlands, with a redescription of Eniochthonius and a key to North American species. *Acta Zoologica Academiae Scientiarum Hungaricae*, 53, 295–333.

Norton, R.A. & Behan-Pelletier, V.M. (2009) Suborder Oribatida. *In*: Krantz, G.W. & Walter, D.E. (Eds.), *A Manual of Acarology*, 3rd Edition. Texas, Texas Tech University Press, pp. 430–564.

Norton, R.A. & Palmer, S.C. (1991) The distribution, mechanisms and evolutionary significance of parthenogenesis in oribatid mites. *In*: Schuster, R. & Murphy, P.W. (Eds.), *The Acari*. Chapman and Hall, London, pp. 107–136.

Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, P., Legendre, P., McGlinn, D., Minchin, P. R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.H., Szoecs, E. & Wagner, H. (2019) vegan: Community Ecology Package. R package version 2.5–6.

R Core Team (2020) Computing, R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Schneider, K. & Maraun, M. (2005) Feeding preferences among dark pigmented fungal taxa ("Dematiacea") indicate limited trophic niche differentiation of oribatid mites (Oribatida, Acari). *Pedobiologia*, 49, 61–67.
https://doi.org/10.1016/j.pedobi.2004.07.010

Seniczak, A., Seniczak, S., Graczyk, R., Waldon-Rudzionek, B., Nowicka, A. & Pacek, S. (2019) Seasonal dynamics of oribatid mites (Acari, Oribatida) in a bog in Poland. *Wetlands*, 39, 853–864.
https://doi.org/10.1007/s13157-019-01125-2

Seniczak, A., Seniczak, S., Iturrondobeitia, J.C., Solhøy, T. & Flatberg, K.I. (2020) Diverse *Sphagnum* mosses support rich moss mite communities (Acari, Oribatida) in mires of Western Norway. *Wetlands*, 40, 1339–1351.
https://doi.org/10.1007/s13157-019-01236-w

Seniczak, A., Seniczak, S., Maraun, M., Graczyk, R. & Mistrzak, M. (2016) Oribatid mite species numbers increase, densities decline and parthenogenetic species suffer during bog degradation. *Experimental and Applied Acarology*, 68, 409–428.
https://doi.org/10.1007/s10493-016-0015-8

Sidorchuk, E.A. (2008) Oribatid mites (Acari, Oribatei) of three fens in the northern part of European Russia. *Entomological Review*, 88, 485–490.
https://doi.org/10.1134/S0013873808040118

Starý, J. (2006) Contribution to the knowledge of the oribatid mite fauna (Acari: Oribatida) of peat bogs in Bohemian Forest. *Silva Gabreta*, 12, 35–47.

Tarnocai, C. & Lacelle, B. (1996) The soil organic carbon digital database of Canada. Research Branch, Agriculture and Agri-Food Canada, Ottawa, Ontario.

Tarnocai, C., Kettles, I. & Lacelle, B. (2011) Peatlands of Canada. Geological survey of Canada, Open File 6561 (digital database), Ottawa, Ontario.
https://doi.org/10.4095/288786

Walter, D.E. & Latonas, S. (2013) A review of the ecology and distribution of *Protoribates* (Oribatida, Oripodoidea, Haplozetidae) in Alberta, Canada, with the description of a new species. *Zootaxa*, 3620, 483–499.
https://doi.org/10.11646/zootaxa.3620.3.9

Webster, K.L. & McLaughlin, J.W. (2010) Importance of the water table in controlling dissolved carbon along a fen nutrient gradient. *Soil Science Society of America Journal*, 74, 2254–2266.
https://doi.org/10.2136/sssaj2009.0111

Wickham, H. (2016) ggplot2: elegant graphics for data analysis.

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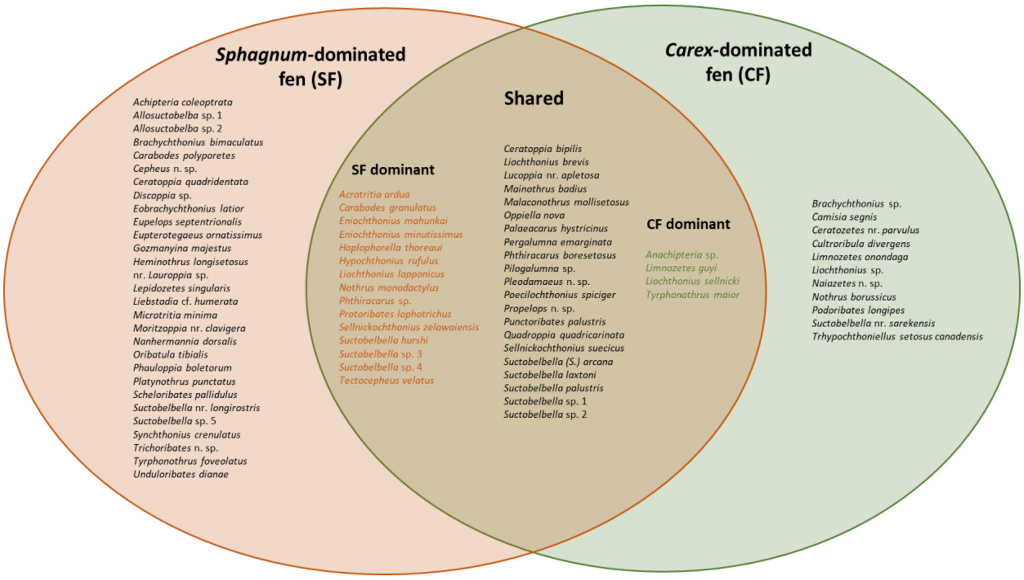

FIGURE S1. Venn diagram showing the overlap between species extracted from peat soil samples collected in a *Sphagnum*-dominated fen (SF) and a Carex-dominated fen (CF) between 2015–2020 near White River Ontario, Canada. Shared species that were dominant (i.e., >10× more abundant) in either fen have different colours.