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Diversity and Distribution of Oribatid Mites (Acari: Oribatida) Associated with Arboreal and Terrestrial Habitats in Interior Cedar-Hemlock Forests, British Columbia, Canada

Abstract

We assessed oribatid mite abundance, species richness and community composition in arboreal and terrestrial habitats associated with 12 western redcedar trees in the Interior Cedar-Hemlock biogeoclimactic zone of British Columbia, Canada. We extracted microarthropods from 36 canopy litter samples, 36 epiphytic lichen samples from three different lichen functional groups, and 36 soil core samples of the forest floor litter layer. Oribatid mites dominated microarthropod assemblages in all habitats. Total microarthropod and oribatid mite abundances were significantly greater in forest floors and foliose (leaf-like) lichens compared to canopy litter accumulations, and alectorioid (hair-like) and cyanolichen (lobed) groups. Sixty-one species of oribatid mites were identified from the study area. The ten species collected from canopy litter and 14 species collected from epiphytic lichens shared five species in common, whereas only three of the 45 species collected from the forest floor also were found within the canopy system. Principal components analysis and discriminant function analysis differentiated three distinct assemblages of oribatid mites corresponding to the canopy litter accumulations, epiphytic lichens and forest floor habitats. Low abundance of oribatid mites in canopy litter accumulations is attributed to low microhabitat structural complexity, low food resources and low desiccation resistance in these habitats compared to canopy lichen habitats and the forest floor. Epiphytic lichens are the dominant habitat for arboreal oribatid mites in the ICH forest zone, and contribute to the overall biodiversity of the forest system by containing distinct oribatid mite assemblages.

Introduction

The Interior Cedar-Hemlock (ICH) biogeoclimactic zone of British Columbia, Canada contains some of the most productive forests of the province's interior, and more tree species than any other ecological zone in British Columbia (Meidinger and Pojar 1991). The zone is characterised by cool, wet winters and a prolonged period of snowmelt, which helps to maintain soil moisture during the warm, dry summers (Meidinger and Pojar 1991). Forest fires are important regulators of ecosystem processes in drier portions of the ICH, as in much of the rest of the British Columbia interior. In wetter portions of the ICH, however, wildfires occur infrequently, and large areas are dominated by stands of old-growth western redcedar (*Thuja plicata* Donn ex D. Don) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) (Sanborn et al. 2006).

These old-growth trees are rich in epiphytic lichens, composed mainly of three functional groups: fruticose alectorioids (e.g. *Alectoria*, *Bryoria*), foliose chlorolichens (e.g. *Hypogymnia*), and cyanolichens (e.g. *Lobaria*), which differ in their morphology and vertical positioning within the canopy (McCune 1993, Benson and Coxson 2002, Campbell and Fredeen 2004). Alectorioid lichens in the ICH zone provide an important winter food resource for mountain caribou (Simpson et al. 1985, Rominger et al. 2000, Stevenson et al. 2001), cyanolichens fix atmospheric nitrogen (Campbell and Fredeen 2004) and all functional groups contribute to forest biodiversity (Goward 1994, Campbell and Fredeen 2004, Radies and Coxson 2004). Furthermore, we hypothesise that epiphytic lichens in old-growth trees of the ICH zone in central BC will also contribute significantly to forest biodiversity by providing habitat for arboreal microarthropods, in particular, oribatid mites (Acari: Oribatida).

Oribatid mites are the dominant component of the microarthropod fauna in most forest floor

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systems (Petersen and Luxton 1982), and are species rich and numerically dominant in temperate forest canopies (Behan-Pelletier and Walter 2000). Canopy oribatid mite assemblages contribute to overall forest biodiversity, as they are characteristically distinct from forest floor assemblages (Wunderle 1992, Winchester et al. 1999, Lindo and Winchester 2006). Oribatid mites are observed in many arboreal habitats, including bark and trunks of trees (Nicolai 1993, Proctor et al. 2002), leaf domatia and stems (Spain and Harrison 1968, Walter and O'Dowd 1995), suspended soils (Wunderle 1992, Behan-Pelletier et al. 1993, Lindo and Winchester 2006), and epiphytic cover including lichens (Seyd and Seaward 1984, André 1985).

Habitat heterogeneity and complexity has been shown to be important in shaping arboreal mite communities (Spain and Harrison 1968, Walter and O'Dowd 1995, Wardle et al. 2003, Yanoviak et al. 2004, Lindo and Winchester 2007a), with the dominance, abundance and species richness of oribatid mites linked to the quality and quantity of habitat within the canopy system. Thus different epiphytic lichen functional groups displaying different morphologies and vertical preferences within the canopy system are expected to differ in oribatid mite assemblages. Furthermore, since most microarthropod fauna are distributed based on microhabitat associations, and the main factor influencing canopy distributions is the availability of suitable habitat (Anderson 1977), we hypothesise that canopy litter accumulation will provide additional habitat for arboreal assemblages of oribatid mites. Accordingly, in this paper we compare the abundance, species richness and composition of oribatid mite assemblages in canopy litter accumulations, epiphytic lichen functional groups, and forest floors associated with old-growth western redcedar trees in the ICH zone, British Columbia, Canada.

Methods

Site Description and Experimental Design

The Isaiah Creek study site was located in the Central Cariboo Forest District on the North Arm of Quesnel Lake, British Columbia, Canada (52°39'N, 120°57'W) in the wet cool subzone of the ICH (ICHwk2) (Steen and Coupé 1997). The 73-ha site is located at an elevation of 1100-1240 m, and includes an experimental group selection harvesting area and an uncut control area. Western redcedar and western hemlock are the dominant canopy tree species, with lesser amounts of Douglas-fir (*Pseudotsuga menziesii*), hybrid spruce (*Picea glauca* x *engelmannii*) and subalpine fir (*Abies lasiocarpa*). Stand age is estimated at 325-425 years (E. Phillips, FPInnovations, FERIC Division, unpubl. data).

Sampling of Isaiah Creek microarthropods associated with canopy habitats was performed 25-30 June 2006, prior to forest harvesting. We sampled a total of 12 western redcedar trees from the uncut control area, using single rope climbing techniques to access the canopy. Nine trees were randomly selected from a larger set of candidate trees that had been identified for an arboreal lichen study; these nine trees were sampled for canopy litter accumulations and forest floor soils. Four replicate samples of litter accumulations were collected within the mid-upper canopy (ave. height 26.2 m above ground) of each of the nine trees. Litter accumulation samples (ave. 7 g d.w.), which were collected at branch/trunk interfaces, were not well-developed or associated with epiphytes, and composed mainly of unconsolidated cedar needles and bark flakings. Lichens were purposely avoided in the canopy litter sampling. We collected four replicate soil samples from the surrounding forest floor of each tree, 1.5 m away from the base of the trunk to a depth of 5 cm. Forest floor samples (ave. 9 g d.w.) were also mostly cedar needle litter in the early stages of decay (L/F). We collected a total of 72 soil and litter samples (9 trees × 2 habitats × 4 samples) for this component of the study. Three additional trees were used to sample microarthropod diversity associated with canopy lichen habitats. We collected four replicate lichen samples (ave. 2.5 g d.w.) from each of three lichen functional groups (alectorioid (A), foliose (F), cyanolichen (C)) in each tree for a total of 36 lichen samples collected (3 trees × 3 lichen types × 4 samples).

Soil, litter and lichen samples were taken back to the laboratory. We extracted soil and litter samples for microarthropods using modified Berlese-type funnels over 75% EtOH for 48 hr. We soaked lichen samples for 48 hr in a dilute KCl solution before rinsing through a 2 mm sieve. Lichen washings were further filtered through a micropore filter to collect the microarthropods, which we then rinsed into sample vials and preserved them in 75% EtOH. We oven dried (70°C) the lichen samples for 48 hr to establish dry weights.

Specimen Identification and Data Analyses

We sorted the extracted and washed microarthropods into the following taxonomic groups: mites (Acari), springtails (Collembola) and other microarthropods, which included booklice (Psocoptera), thrips (Thysanoptera), wasps (Hymenoptera), flies and fly larvae (Diptera), pseudoscorpions (Pseudoscorpiones), and spiders (Araneae). We further identified the Acari to suborder (Mesostigmata, Prostigmata, Astigmata and Oribatida) and all the adult oribatid mites to species. Nomenclature follows Marshall et al. (1987). Microarthropod and oribatid mite abundance is expressed as number of individuals g^{-1} d.w. substrate. Oribatid mite voucher specimens are in preparation for deposition at the Canadian National Collection, Ottawa, Canada, and for the Pacific Forestry Centre, Victoria, British Columbia, Canada.

We used separate full-factorial Analysis of Variance (ANOVA) tests with Scheffe post-hoc comparisons to test the main effect of tree and habitat (forest floor vs. canopy litter, or lichen functional group) on the abundance of major microarthropod groups, and oribatid mite species richness. These analyses were performed using Statistica 7.0 (Statsoft, Inc. 2004) with a significance level of $\alpha = 0.05$. Theoretical species richness for canopy (litter, lichen, litter plus lichen) and forest floor habitats was calculated using first and second-order Jackknife, Chao 1 and Chao 2 estimators in EstimateS at 50 randomized permutation tests without sample replacement (Colwell 2005). We analysed oribatid mite community compositional data using Principal Components Analysis (PCA) and Discriminant Function Analysis (DFA). PCA and DFA were conducted on the 10 most abundant species using standardized abundance data (# ind. g^{-1} d.w.). PCA ordinates the species to maximise variation within the data set, whereas DFA results in canonical discriminant functions that separate *a priori* determined groups, in this case 5 groups based on habitat (canopy litter, lichen type (A, F, C), forest floor). We used factor coordinates based on species correlations to interpret the PCA, whereas standardized discriminant function coefficients for species, and correlations of species with discriminant scores were used to determine the contribution of species to the separation of groups in the DFA. PCA and DFA were carried out in Statistica 7.0 (StatSoft, Inc. 2004).

Results

Oribatid mites were the most abundant group of microarthropods in all habitats (Figure 1); their

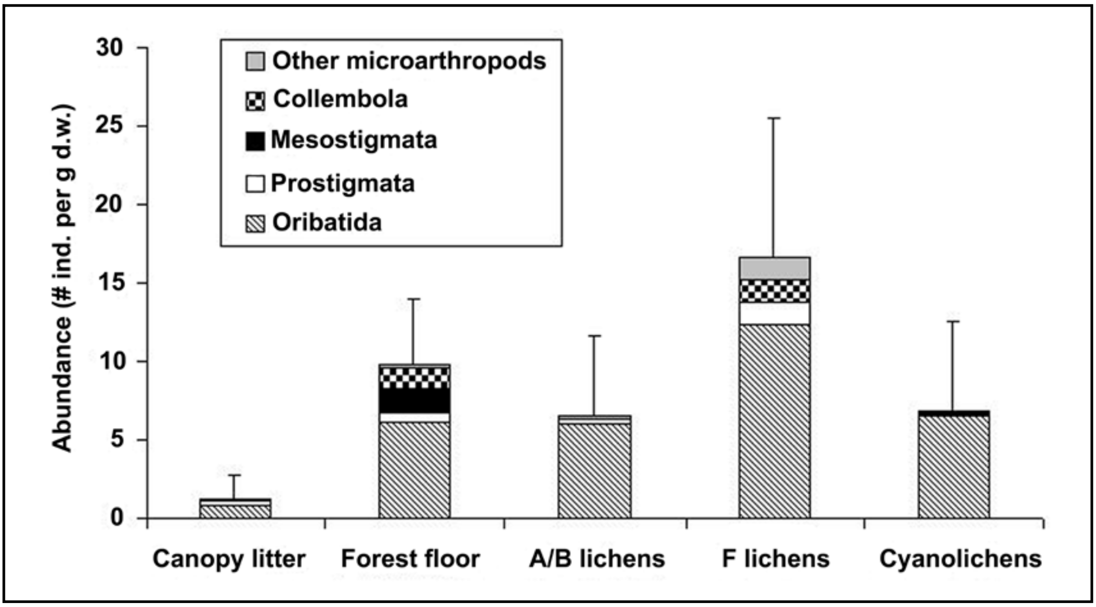

Figure 1. Average microarthropod abundance (# individuals g^{-1} d.w. substrate) collected from canopy litter, forest floor soil, and three arboreal lichen functional types associated with western redcedar trees in the Interior Cedar-Hemlock biogeoclimactic zone of British Columbia, Canada.

average relative abundance was 70% in canopy litter accumulations, 84% in canopy lichens, and 62% in forest floors. When compared to canopy litter, forest floor soils had significantly greater abundance (# g^{-1} d.w. substrate) of mites (all groups) and springtails (Figure 1) (total microarthropods: $F_{1,54} = 119.66$, $P < 0.001$; oribatids: $F_{1,54} = 115.57$, $P < 0.001$; prostigmatids: $F_{1,54} = 4.20$, $P = 0.045$; mesostigmatids: $F_{1,54} = 106.41$, $P < 0.001$; astigmatids: $F_{1,54} = 10.01$, $P = 0.003$; collembola: $F_{1,54} = 7.67$, $P = 0.008$). Differences in microarthropod abundance between lichen functional groups also existed for all microarthropod groups except Mesostigmata, with foliose lichens having significantly higher abundances than alectorioid and cyanolichens (total microarthropods: $F_{2,27} = 9.52$, $P < 0.001$; oribatids: $F_{2,27} = 4.91$, $P = 0.015$; prostigmatids: $F_{2,27} = 7.37$, $P = 0.003$; collembola: $F_{2,27} = 5.59$, $P = 0.009$) (Figure 1). No astigmatid mites were collected from lichen samples. Different trees sampled had no significant effect on abundance of microarthropod groups.

We identified 61 species of oribatid mites from 2117 adult specimens collected from the Isaiah Creek study site (Table 1). Species richness of oribatid mites was greatest on the forest floor with 45 species collected in this habitat, significantly greater than the oribatid mite species richness collected in canopy litter accumulations ($F_{1,54} = 264.51$, $P < 0.001$; ave. forest floor richness: 10.06 ± 3.13 (# g^{-1} d.w.), ave. canopy litter richness: 1.42 ± 1.40 (# g^{-1} d.w.)). Only 10 species were collected from canopy litter accumulations, and all canopy habitats combined (litter plus three lichen types) yielded 19 species. Foliose lichens had significantly greater richness than alectorioid lichens ($F_{2,27} = 6.73$, $P = 0.004$; ave. A: 2.33 ± 1.37, ave. F: 5.00 ± 2.04, ave. C: 3.83 ± 1.75). Theoretical species richness using first and second-order Jackknife, Chao 1 and Chao 2 estimates are higher in the forest floor compared to canopy habitats, even when all canopy habitats (litter plus three lichen types) are combined (Table 2).

Three species of oribatid mite, *Gymnodamaeus* sp., *Eueremaeus marshalli*, and *Autogneta longilamellata*, were found in both canopy and forest floor habitats. The most abundant species were *Oppiella nova* (forest floor), *Quadroppia quadricarinata* (forest floor), *Phauloppia* sp. (all lichens), *Ceratozetes thienemanni* (forest floor), *Neogymnobates marilynae* (all lichens), *Neobrachychthonius* sp. 1 (canopy litter) and *Camisia segnis* (F and C lichens). Three PC factors had eigenvalues >1, which accounted for 74.6% of the cumulative variation in the data set (Table 3). The species drivers of PC 1 based on the species correlations with the factor coordinates were *Oppiella nova*, *Ceratozetes thienemanni*, and *Suctobelbella* sp. 5. Species driving PC 2 were *Phauloppia* sp., *Neobrachychthonius* sp. 1, *Neogymnobates marilynae*, and factor 3 were *Banksinoma* sp. nr. *setosa*, *Liochthonius* sp. 1 and *Quadroppia quadricarinata* (Figure 2). Discriminant Function Analysis (DFA) could statistically predict sampling habitats from the individual species abundances of oribatid mites. Forward stepwise selection based on partial F statistics and Wilk's lambda criterion selected 5 of the top 10 species as contributing significantly to the canonical discriminant functions used to separate community groups and were used in subsequent analyses. Four discriminant functions were significantly modeled (Wilk's $\lambda < 0.001$, approx. $F_{40,51} = 11.780$, $P < 0.001$) and accounted for most of the explainable variation in the data set (Table 3). The first function explained 75.27% of the variance with a canonical correlation coefficient of $R = 0.993$. Standardized coefficient and factor structure value for the first and second functions indicated that *Liochthonius* sp. 1 and *Neogymnobates marilynae* abundance contribute most to the habitat group separation. The first two canonical discriminant functions jointly account for 96.2% of the total variance.

Discussion

The high proportion of oribatid mites collected from arboreal lichens, canopy litter accumulations and forest floor habitats is consistent with previous studies of microarthropods (Peterson and Luxton 1982, Behan-Pelletier and Walter 2000). In particular, studies of microarthropods in lichen systems report oribatid mites as the dominant microarthropod taxa, whether this be a system of arboreal lichens (Smrž and Kocourková 1999), lichens on boulders (Maturna 2000, Sjursen and Sømme 2000), the forest floor (Seyd 1992) or in the arctic tundra (Seniczak and Plichta 1978). The high prevalence of oribatid mites associated with lichens is attributed to lichenivorous-specific species of oribatid mites (Seyd and Seaward 1984). Feeding habits of lichenivorous oribatid mites include cropping fungal mycelia and grazing on fungal fruiting bodies within the lichen, or feeding on organic matter debris that is captured

TABLE 1. Oribatid mites collected from canopy litter, arboreal lichens and forest floors associated with western redcedar trees in the Interior Cedar-Hemlock forest zone of British Columbia, Canada.

Family	Species	Canopy Litter	Total Lichens	Forest Floor
Palaeacaridae	*Palaeacarus hystricinus* Trägårdh, 1932	0	0	2
Atopochthoniidae	*Atopochthonius artiodactylus* Grandjean, 1948	0	0	2
Pterochthoniidae	*Pterochthonius angelus* (Berlese, 1910)	0	0	26
Brachychthoniidae	*Brachychthonius* sp. nr. *berlesei* Willmann, 1928	0	0	1
	Liochthonius sp. nr. *muscorum* Forsslund, 1964	0	0	56
	Liochthonius sp. nr. *brevis* (Michael, 1888)	0	0	3
	Neobrachychthonius sp. 1	110	0	0
	Neobrachychthonius sp. 2	0	0	1
	Sellnickochthonius suecica (Forsslund, 1942)	0	0	2
	Synchthonius crenulatus (Jacot, 1938)	0	0	40
	Synchthonius elegans Forsslund, 1957	0	0	1
Phthiracaridae	*Archiphthiracarus* sp.	0	0	15
Oribotritiidae	*Protoribotritia* sp.	0	0	7
Euphthiracaridae	*Euphthiracarus cernuus* Walker, 1965	0	0	14
Camisiidae	*Camisia segnis* (Hermann, 1804)	0	109	0
	Heminothrus sp.	0	0	2
	Platynothrus peltifer (C.L. Koch, 1839)	0	0	26
	Platynothrus sp. nr. *septentrionalis* Sellnick, 1944	0	0	32
Nanhermanniidae	*Nanhermannia elegantula* Berlese, 1913	0	0	1
Hermanniellidae	*Hermanniella occidentalis* Ewing, 1918	0	0	6
Gymnodamaeidae	*Gymnodamaeus* sp.	29	11	4
Damaeidae	*Epidamaeus* sp.	0	0	42
Cepheidae	*Sphodrocepheus anthelionus* Woolley and Higgins, 1968	0	0	2
	Eupterotegaeus sp.	0	0	1
Caleremaeidae	*Veloppia kananaskis* Norton, 1978	0	0	37
Eremaeidae	*Eueremaeus acostulatus* Behan-Pelletier, 1993	10	5	0
	Eueremaeus higginsi Behan-Pelletier, 1993	2	0	0
	Eueremaeus marshalli Behan-Pelletier, 1993	7	0	3
Megeremaeidae	*Megeremaeus kootenai* Behan-Pelletier, 1990	0	6	0
Astegistidae	*Cultroribula* sp. nr. *bicultrata* (Berlese, 1905)	0	0	3
Tectocepheidae	*Tectocepheus velatus* (Michael, 1880)	0	0	9
Oppiidae	*Lauroppia* sp.	0	0	1
	Multioppia sp.	0	0	2
	Oppiella nova (Oudemans, 1902)	0	0	365
	Oppiella washburni (Hammer, 1952)	0	0	9
Quadroppiidae	*Quadroppia quadricarinata* (Michael, 1885)	0	0	271
Suctobelbidae	*Suctobelbella* sp. 1	0	0	40
	Suctobelbella sp. 2	0	0	19
	Suctobelbella sp. 3	0	0	8
	Suctobelbella sp. 4 nr. *longicuspis* Jacot, 1937	0	0	3
	Suctobelbella sp. 5	0	0	66
	Suctobelbella sp. 6	0	0	25
	Allosuctobelba sp.	0	0	21
Autognetidae	*Autogneta longilamellata* (Michael, 1885)	36	0	1
Thrysomidae	*Banksinoma* sp. nr. *setosa* (Rjabinin, 1974)	0	0	66
Cymbaeremaeidae	*Ametroproctus canningsi* Behan-Pelletier, 1987	1	1	0
	Scapheremaeus palustris (Sellnick, 1924)	0	9	0

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Table 1, continued

Family	Species	Canopy Litter	Total Lichens	Forest Floor
Scheloribatidae	*Parapirnodus coniferinus* Behan-Pelletier et al., 2002	0	6	0
	Scheloribates (Scheloribates) sp.	0	1	0
	Scheloribates (Hemileius) sp.	0	6	0
Oribatulidae	*Diphauloppia* sp.	0	1	0
	Oribatula sp.	0	0	13
	Phauloppia sp.	1	178	0
	Zygoribatula sp.	4	43	0
Chamobatidae	*Chamobates* sp.	0	0	1
Ceratozetidae	*Ceratozetes thienemanni* Willmann, 1943	0	0	141
	Ceratozetes cuspidatus Jacot, 1939	0	0	2
	Jugatala sp.	0	6	0
	Neogymnobates marilynae Behan-Pelletier, 2000	0	137	0
Mycobatidae	*Cyrtozetes lindoae* nov. sp. Behan-Pelletier	0	0	1
	Mycobates corticeus Behan-Pelletier, 2001	5	0	0
Species Richness		10	14	45

TABLE 2. Observed and theoretical oribatid mite species richness for canopy and forest floor habitats associated with western redcedar trees in the Isaiah Creek watershed in the Interior Cedar-Hemlock forest zone of British Columbia, Canada.

	Observed	Jackknife 1st order	Jackknife 2nd order	Chao 1	Chao 2
Canopy litter	10	12.92 (1.6)	13.92	12.00 (3.7)	12.25 (3.4)
Arboreal lichens	14	16.92 (2.2)	19.75	18.50 (0.0)	18.50 (0.0)
All canopy	19	21.96 (1.7)	22.96	20.00 (1.9)	21.25 (3.4)
Forest floor	45	56.67 (3.7)	61.58	50.79 (5.0)	55.29 (7.8)
Total	61	72.89 (4.1)	74.94	66.56 (4.6)	68.20 (5.5)

Values are mean estimates (± SD) based on 50 randomized permutation tests without sample replacement.

TABLE 3. Results of Principal Components Analysis (PCA) and Discriminant Function Analysis (DFA) of the correspondence between oribatid mite species abundances and habitats associated with western redcedar trees in the Interior Cedar-Hemlock forest zone of British Columbia, Canada.

Principal Components			
	PC 1	PC 2	PC 3
Eigenvalue	4.258	1.834	1.370
Cumulative (%) of variance	42.58	60.93	74.63
Factor coordinate of top species driver	O.nova (-0.874)	Phaul. (-0.707)	Banks. (-0.774)
Discriminant Functions			
	DF 1	DF 2	DF 3
Eigenvalue	69.467	19.344	3.426
Cumulative (%) of variance	75.27	96.23	99.94
Contributing species based on standardized coefficients	Lioc.1(-4.013)	Lioc.1 (-1.182)	C.seg (-0.933)
Contributing species based on factor structure matrix correlations	Q.quad (0.297)	N.mari (0.838)	C.seg (-0.841)

Species abbreviations are for *Oppiella nova*, *Phauloppia* sp., *Banksinoma* sp. nr. *setosa*, *Liochthonius* sp. 1, *Quadroppia quadricarinata*, *Neogymnobates marilynae*, and *Camisia segnis*.

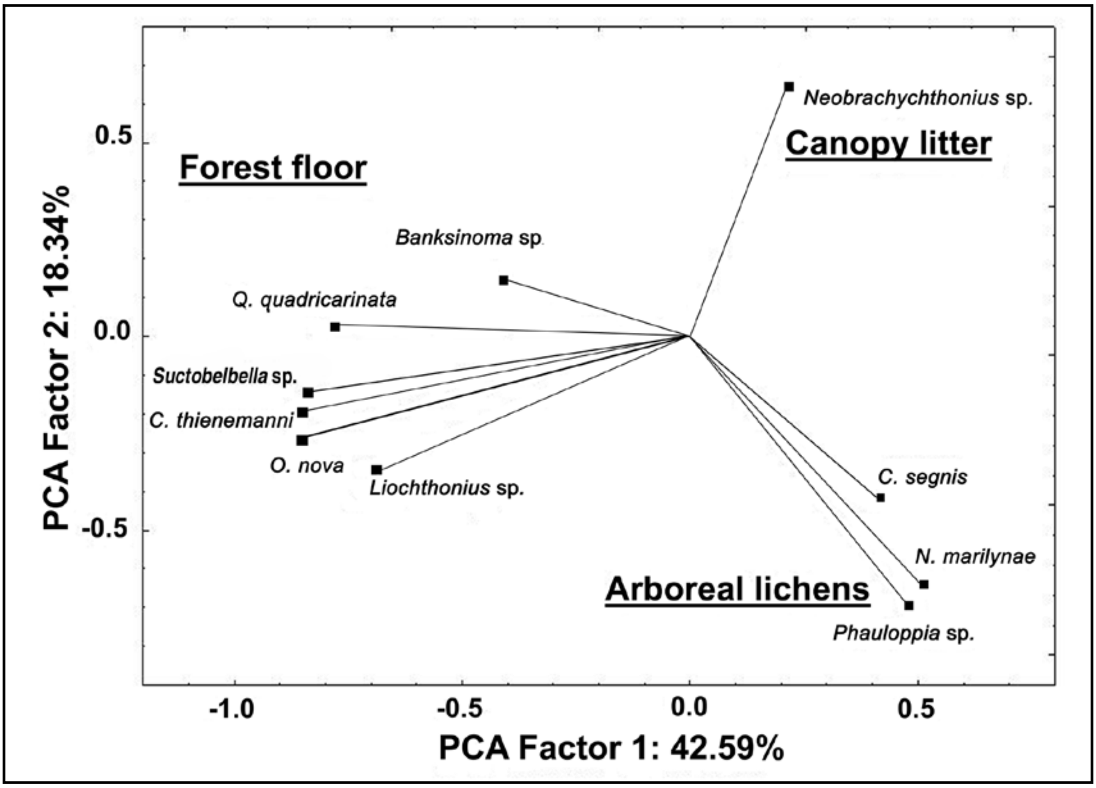

Figure 2. Plot of 1st and 2nd principal components with % explained variation for adult oribatid mite assemblages (top 10 species based on standardized abundances) collected from canopy litter, canopy lichens and forest floor habitats associated with western redcedar trees in the Interior Cedar-Hemlock biogeoclimatic zone of British Columbia, Canada.

by the physical structure of the lichen (Seyd and Seaward 1984).

Among the different lichen functional groups, abundance and richness of oribatid mites was significantly greater in foliose lichens compared with alectorioid or cyanolichen functional groups. Differences in oribatid mite abundance and richness among lichen functional groups could be related to a suite of differences among the lichen functional groups such as physical structure, moisture holding capacity, or palatability. The compact nature of many common foliose lichens compared to alectorioid and cyanolichen groups, and their close association with the branch, may allow greater moisture holding capacity and resistance against desiccation for the lichen inhabitants, or trap organic matter for detritivorous oribatid mites. The palatability of different lichen species may differ with different parts of the lichen (thallus, asci, spores, algae) and with the amount of secondary products produced. For example, in a herbivory study of lichen species using a generalist herbivorous snail, 15 of the 16 foliose species studied were consumed at higher rates than *Lobaria pulmonaria*, the single cyanolichen species in the study (Gauslaa 2005), suggesting foliose lichens may be more appetizing to lichenivorous fauna than cyanolichens.

The relative abundances of the top three lichen-dwelling oribatid mites (*Camisia segnis*, *Phauloppia* sp., and *Neogymnobates marilynae*) changed with lichen functional group, but these changes were not substantial, nor distinguishable in PCA or DFA. Different lichen types (foliose, cyanolichen, alectorioid groups) were similar in oribatid mite species composition, but oribatid mite assemblages associated with these lichens differ from assemblages found in canopy litter accumulations and forest floors in the ICH zone. All three of the dominant lichen-dwelling oribatids in the ICH zone are previously recorded from lichen habitats. For example, *Neogymnobates marilynae* is described from arboreal lichens in a dry coastal forest (Behan-Pelletier 2000), *Phauloppia* spp. are common oribatid mites on lichen (Seyd and Seaward 1984, Smrž and Kocourková 1999) that are known to feed on lichen thalli (Seyd and Seaward 1984), and nymphal stages of *Camisia segnis* have been observed feeding on lichen (Seyd and Seaward 1984).

Both PCA and DFA primary ordination axes differentiate the species and community groups based on a canopy versus ground distinction. The species along the positive of PCA ordination axes 1 are canopy specialists, while species along the negative of PCA ordination axes 1 are found on the ground (e.g. *Oppiella nova*, *Ceratozetes thienemanni*, *Suctobelbella* sp. 5). Similarly, the species contributing to the separation of community groups as corresponding with DFA factor 1 were also ground species (*Liochthonius* sp. 1, *Quadroppia quadricarinata*). Species and assemblages in this study appear to also differentiate based on microhabitat within the canopy system; PCA and DFA secondary ordination axes relate to canopy litter versus lichens as habitat. The species drivers of PCA factor 2 are the canopy litter specialists *Neobrachythonius* sp. 1 and the lichen-dwelling *Phauloppia* sp. and *Neogymnobates marilynae*. Similar patterns were observed in the contributing species of DFA factor 2.

Seyd and Seaward (1984) suggest many oribatid mite species found in association with lichens are lichen restricted, or prefer lichens as habitat or food; this would explain the different oribatid mite assemblages observed in canopy litter accumulations. Erdmann et al. (2007) found, based on the stable isotopic signatures of the mites and their potential food resources, that different oribatid mites inhabiting corticolous (bark-dwelling) habitats occupy distinct trophic niches, and could be classified as lichen feeders, algal/bryophyte feeders, or bark/fungal feeders. Most species in Erdmann's study were bryophyte feeders, but members of the genus *Phauloppia*, *Camisia* and *Cymbaeremaeus* (family Cymbaeremaeidae includes *Ametroproctus* spp. and *Scapheremaeus* spp. both found in lichen samples of this study) were predominantly lichen feeders. The results of Erdmann et al. (2007) support the presence of some genera found in arboreal lichen (e.g. *Phauloppia*, *Camisia*) associated with western redcedar of the ICH zone.

Vertical moisture gradients observed in canopy microclimate have been shown to influence the diversity and distribution of lichen species in a number of ecosystems (McCune 1993, Sillett 1995, Coxson and Coyle 2003); these gradients may additionally contribute to differences in abundance and number of oribatid mite species associated with arboreal lichens. The upper canopy receives more light; as such, lichens and litter accumulations are susceptible to moisture loss, whereas lower canopy habitats are more shaded and have higher and more constant levels of relative humidity (McCune 1993). Moisture regimes and humidity of microhabitats are fundamental factors influencing the diversity, abundance and distribution of oribatid mites (Seyd and Seaward 1984, Siepel 1996, Smrž and Kocourková 1999, Materna 2000), and drought extremes in canopy litter and arboreal lichen habitats most likely limit the abundance and richness of these oribatid mite assemblages (Siepel 1996). Canopy habitats, and in particular canopy litter accumulations, were extremely dry during the collection period, compared with forest floor organic soils.

Species richness on the forest floor was four times higher than all canopy habitats combined, and estimates of species richness increased forest floor diversity by another 20 species. However, the difference in richness between arboreal and terrestrial habitats could also result, in part, from sampling bias, as almost ten times more individuals were identified from the forest floor versus in the canopy (Buddle et al. 2005). The oribatid mite species associated with the canopy litter accumulations (10 species) had five species in common with lichen assemblages (14 species). The canopy litter accumulation assemblage likely represents a combination of epicorticolous species living in crevices in the bark (André 1984, Nicolai 1989, Prinzing 2005), and lichen-dwelling species moving among lichen patches. Erdmann et al. (2007) suggest that corticolous oribatid mites are a recent adaptation having radiated from lichen and bryophyte habitats to colonise the bark of living trees, which may partially explain the low species richness in canopy litter. A single oribatid mite species, *Neobrachychthonius* sp. 1, found in high abundance in canopy litter accumulations was specific to this habitat, and also represents a new record of this genus inhabiting a canopy system.

The number of unique canopy species (species not found on the forest floor: 16/19 species) suggests that the canopy oribatid mite community (canopy litter plus arboreal lichens) associated with old-growth western redcedar in the Interior Cedar-Hemlock zone is distinctly different from the forest floor and not a random subset of the forest floor assemblage. This observation is consistent with other studies of canopy and forest floor oribatid mite communities in temperate forest systems (Aoki 1973, Voegtlin 1982, Winchester et al. 1999, Lindo and Winchester 2006). Further sampling of lichens and other microhabitats in the Interior Cedar-Hemlock forest zone of British Columbia, along with species level identification of other invertebrate groups, is expected to reveal high invertebrate biodiversity similar to lichen dominated canopy systems in coastal cedar-hemlock forests. However, the canopy litter accumulations and forest floor oribatid mite assemblages found at Isaiah Creek differed from those observed in an ancient coastal forest, where tree crown architecture allows for the formation of suspended organic soils (Lindo and Winchester 2007a), and forest floors have high decomposition rates (Lindo and Winchester 2007b). The western redcedar trees sampled at the Isaiah Creek site lacked complex tree crowns, and litter accumulations at branch/trunk interfaces were small, highly desiccated, and relatively undecomposed; thus canopy litter accumulations are most likely ephemeral or supplemental habitat for epicorticolous assemblages of oribatid mites, and arboreal lichens are the primary habitat for canopy oribatid mite assemblages. It is unclear to what extent the differences between the two study areas relate to climatic differences between the coastal and interior rainforests, and to what extent they relate to differences in stand age between the Isaiah Creek site (325-425 years) and the site of Lindo and Winchester (2007a) (>800 years). This question could be resolved by extending sampling across a range of age classes, including the antique forests of the ICH that are known as hotspots for epiphytic lichen biodiversity (Goward 1994, Arsenault and Goward 2000).

Quantitative studies of forest biodiversity in the ICH have focussed largely on canopy lichens (Goward 1994, Campbell and Fredeen 2004, Radies and Coxson 2004, Goward and Spribille 2005), and to a lesser extent on soil organisms (Durall et al. 1999, Forge and Simard 2001), but we know little about the microarthropod fauna of this area of British Columbia. Additionally, few canopy habitats in forest systems across Canada have been sampled for invertebrates (but see Dwyer et al. 1997, Winchester et al. 1999, Vance et al. 2003, Fagan et al. 2006, Lindo and Winchester 2006). Here, we contribute to faunistic inventories requiring detailed knowledge at the species level, by describing the oribatid mite communities associated with canopy litter accumulations, arboreal lichen functional groups and forest floor organic soils in the ICH zone. Since tree age has been shown to increase lichen diversity and abundance (Esseen et al. 1996) and influence vertical moisture gradients (McCune 1993), and older forests are more structurally complex and heterogeneous than young, even-aged stands (Franklin and Van Pelt 2004), arboreal oribatid mite communities may show successional changes with forest stand development in relation to availability of arboreal habitats such as lichens and canopy litter accumulations. Thus, further studies on the effects of forest harvest on arboreal and terrestrial diversity of microarthropods are warranted in efforts to preserve forest biodiversity.

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