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PRE- AND POST- FIRE MICROARTHROPOD ASSEMBLAGES ON RIDGE,
CLIFF FACE AND CLIFF BASE HABITATS WITHIN THE LINVILLE GORGE
WILDERNESS AREA, NORTH CAROLINA

479

A Thesis

by

ROBERT JOHN PLESZEWSKI

Submitted to the Graduate School

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Pre- and Post Fire Microarthropod Assemblages On Ridge, Cliff Face and
Cliff Base Habitats Within The Linville Gorge Wilderness Area, North Carolina

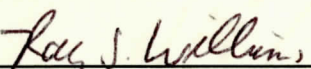
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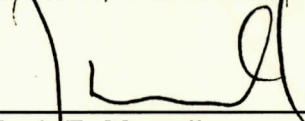
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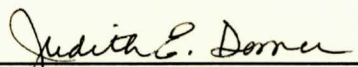
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ABSTRACT

**PRE- AND POST- FIRE MICROARTHROPOD ASSEMBLAGES ON RIDGE,
CLIFF FACE AND CLIFF BASE HABITATS WITHIN THE LINVILLE GORGE
WILDERNESS AREA, NORTH CAROLINA.**

(DECEMBER 2003)

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This study represents the first quantitative approach investigating microarthropod communities on vertical cliff faces. The study site was located on the Gold Coast Wall in the Linville Gorge Wilderness Area, Burke County North Carolina. Comparisons were made on microarthropod assemblages between the cliff face and adjacent ridge and cliff base over two years one pre- (2000) and one post-fire (2001). Dependent variables, including microarthropod taxonomic groups, litter/organic depth, percent litter water, and soil core bulk density were analyzed using a General Linear Model procedure to compare habitats within and between years. Regression analysis was used to relate animal density to litter/organic depth, percent water, and bulk density. Total microarthropod density between the three habitats changed between pre- and post-fire years.

Total microarthropod densities in the pre-fire year (i.e. 2000) were significantly lower on the cliff face compared to the adjacent ridge and base habitats. After fire (i.e. 2001), the three habitats were not significantly different from one another in total microarthropod abundance. Pre-fire density of oribatid and mesostigmatid mites was significantly lower on the cliff compared to the ridge (highest abundance), with the base habitat intermediate to both. There was no difference between the three habitats in prostigmatid mites. Post-fire mesostigmata were significantly higher on the base compared to the other two areas. Oribatida and mesostigmata were significantly reduced on the ridge and base after the fire, with no significant change observed on the cliff.

A reduction of microarthropod densities on the ridge and base in the post-fire year (2001) coincides with altered habitat. Both Oribatida density and diversity were significantly reduced on the ridge and base after the fire, with no change on the cliff face. These data suggest that the resulting differences between pre- and post-fire years in microarthropod abundance on the ridge and base were the possible result of different sampling depths within the litter/soil stratum, coupled with changes in the abiotic factors of bulk density and soil moisture content associated with these varying soil strata due to fire.

I conclude that the cliff face represents a distinctly different habitat from the adjacent ridge and base, and can be considered an insular community.

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DEDICATION PAGE

My high school science teacher Mr. Monty Coggins. Thank you for always encouraging me. This is just as much yours as it is mine.

My Father James M. Pleszewski. Here it is, I'm going outside to play now.

My Mother Lucille A. Pleszewski. Thank you for teaching me to use a microscope.

My Sister's Cara and Susan J. Pleszewski. If I can do it you can do it.

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INTRODUCTION

Characteristics of Cliff Habitats

Vertical cliffs and high-angle rock outcrops represent some of the last undisturbed habitats on earth (Larson 1990; Larson et al. 1999; Larson et al. 2000). Their inaccessibility and unique orientation within the landscape have afforded them persistence and protection. As insular communities, cliffs and rock outcrops serve well as model systems in which to study how biotic and abiotic factors interact to create and maintain a specific community type. Although there have been many studies addressing the vegetation associated with cliff-face systems, many have been qualitative and rarely have the botanical and ecological surveys related biotic and abiotic factors together (Shure and Ragsdale 1977; Larson et al. 1989; Wiser 1994; Wiser et al. 1996; Larson et al. 2000).

Within the unglaciated eastern United States (more specifically the Southern Appalachians) vertical cliffs and high-angle rock outcrops are dominated by edaphically controlled herbaceous plant communities surrounded by the deciduous forests that characterize the region (Baskin and Baskin 1988; Oosting and Anderson 1937). Additionally, high-elevation rock outcrop habitats within the Southern Appalachians contain large numbers of endemic and rare plant species that represent northern disjuncts and, what some would consider,

relics of a once wide spread Pleistocene alpine flora (Wiser 1994; Wiser et al. 1996). The overall extent of rock outcrops and cliff-face habitats is minimal when compared to the surrounding habitats. However, their contribution to the biodiversity of an area or region may actually be quite high when one considers the high surface area that may be present as the result of vertical orientation, coupled with topographic heterogeneity and a lack of major physical disturbances (Larson et al. 2000).

Rock outcrops are defined as areas of bedrock exposed above the soil level (Larson et al. 2000). Based on the Larson et al. (2000) definition of a cliff, a rock outcrop can be considered a cliff if it is tall, steep and has on top a level or sloping *plateau* or *ridge*, and a *pediment* or *base* below. By this definition, many rock outcrop communities within the Southern Appalachians can be termed cliffs or cliff-face habitats, often existing widely separated from one another and infrequently (Wiser et al. 1996). However, within the Linville Gorge Wilderness Area (LGWA), rock outcrops are a dominant land feature and are closely associated with the cliffs in the area (Newell and Peet 1998).

Cliff-face ecosystems are set apart from adjacent horizontal habitats in several ways due to their vertical orientation. As described by Larson et al. (2000), vertical orientation in space affects; (1) the total amount of direct radiation a surface receives, (2) the way radiation input varies diurnally, seasonally and latitudinally, (3) wind speeds on the surface, (4) the amount of direct precipitation received (moisture), (5) stability due to gravity thus influencing the drainage, nutrients, and soil development, and (6) the thermal environment. It is precisely

these abiotic factors affected by vertical orientation and modified to varying degrees by the heterogeneity of the cliff's surface that interact to maintain a unique "biotic community" on cliff-face habitats (Larson et al. 2000).

Large free-face cliffs with homogenous composition support little to no vascular vegetation, but instead may be dominated by lichens. Cliffs formed with more diversity in their composition will tend to weather ununiformly and result in a higher degree of heterogeneities on the cliff's surface, resulting in more places for macroscopic organisms to live (Larson et al. 2000). Therefore, heterogeneity is an important component of the cliff-face community.

Bunce (1968) observed that a variety of cliff microhabitats provided suitable habitat for species not found in the surrounding area, while Davis (1951) recognized six distinct habitats of the rock face; (1) pavement, (2) sloping rock, (3) vertical rock, (4) overhanging rock, (5) step-crevice, and (6) ledge. He also noted the distinctiveness of the saxicolous community with each one.

Winterringer and Vestal (1956) actually went as far as to make a key describing 16 types of ledges subdivided into habitats with extensive surface coverage, and microhabitats which are too small to be considered habitats. They additionally considered level ledges to be similar in environment to "gently rounded rock slopes" (Winterringer and Vestal 1956).

With respect to the different microhabitats that can be found on a heterogeneous cliff face, cliff-ledges contain a greater abundance of species compared to fissures, cliff-ridges and -faces (Ursic et al. 1997). When compared to crevices, Ursic et al. (1997) found that almost 95% of the species found on

quarry walls occurred at a higher frequency on ledges than in crevices. Additionally, they (1997) found that areas without ledges contained less herbaceous and more bryophyte species when compared to areas with ledges.

The extent to which rock outcrop communities will support an assemblage of species is not only a function of a stable ledge, but also the edaphic environment of the ledge. In a study of succession on granite outcrop communities, Burbank and Platt (1964) described four plant communities representing successional stages. They concluded that these successional stage communities were correlated to "edaphic conditions." Specifically, it was the soil depth and resulting stability of soil moisture associated with the increase in soil depth that allowed for these "successional communities" to develop, rather than the build up of vegetation through seral stage development. Soil depth increases occur as soil builds up through debris trapped and deposited by vegetation, allowing for the succession of vegetation. Additionally, any build up of soil is a function of the depressions within the outcrop caused by physical weathering and not by vegetational processes themselves. This process was also the contention of Winterringer and Vestal (1956), who concluded that soil accumulation through physical processes on rock is more important in plant succession than the floral sequence itself, (e.g. crustose lichens to foliose lichens to fruticose lichens to mosses to herbs to woody plants, etc.). They provided the example that in some cases, moss-lichen communities remain moss-lichen communities on rock surfaces and are not preceded or succeeded by other vegetational seres (Winterringer and Vestal 1956).

Litter and Soil Fauna

Forest floor litter (O horizons) and soil (A horizon) biota derive much of their energy and nutrient supply from the large amounts of net primary production that falls to the ground from the above-ground vegetation or autotrophic community (Seastedt 1984; Elliott et al. 1993; Coleman and Crossley 1996; Schlesinger 1997; Hansen 2000). Therefore, the litter and soil ecosystem (or community) can be described as a consumer or heterotrophic one (Smith 1990; Norton 2000), playing a critical role in the recycling of nutrients back to the producer (or autotrophic) component of the ecosystem through decomposition of dead organic matter and the mineralization of nutrients (Crossley 1977a; Seastedt 1984; Werner and Dindal 1987; Hansen et al. 2001).

The structure and function of plant communities, including the spatial and numerical aspects, is in part influenced by the soil microbial community through such processes as mineralization, nitrogen fixation, decomposition and the immobilization of nutrients (Bever 1994; Zabinski and Gannon 1997). However, the incorporation of organic matter into the mineral soil is largely thought to be accomplished through the synergistic effects of the soil fauna with the soil microflora within the decomposer food web (McBrayer and Reichle 1971; Schlatte et al. 1998).

Among the multitude of litter and soil biota involved in such ecosystem processes are the microarthropods, comprising the most taxonomically diverse group of all soil fauna (Anderson 1975; Seastedt 1984; Walter 1987; Blair et al. 1990; Hanson 2000). More specifically, Acari (Order Acari [depending on

author], Class Arachnida) numerically dominate the litter and soil community (Wallwork 1983; Seastedt 1984; Norton 1985; Norton 1990). This taxonomic group may have the greatest effect on the soil environment (Norton 1985).

The Acari is currently considered a natural group (O'Connor 1984; Lindquist 1984), with three recognized lineages (Orders by some authorities, Suborders by others). These include the Opilioacariformes, Parasitiformes and Acariformes (Lindquist 1984; Barnes 1987; Evans 1992; Walter and Proctor 1999) which can be separated into two major groups, (1) Anactinotrichida including the Opilioacariformes and Parasitiformes, and (2) Actinotrichida including the Acariformes (Lindquist 1984). Opilioacariformes includes the opilioacarida, the Parasitiformes includes the holothyrida, mesostigmata and ixodidae, and the Acariformes includes the prostigmata, astigmata and oribatida mites. From these three recognized mite lineages, edaphic members include more than 150 families, approximately 1000 genera and 6,500 known species of Oribatida (Norton 1985; Norton 1990), 60 families, 681 genera and approximately 6400 species of Prostigmata (Kethley 1990), and approximately 30 families and at least 120 genera of Mesostigmata (Krantz and Ainscough 1990).

Mite abundance in the litter and soil is often variable yet extensive with soil moisture exerting a strong positive influence on their quantitative aspects (Blair et al. 1990; Hansen et al. 2001). Within the upper 10 cm of the litter and soil, the density of mites can range between 50,000 and 250,000 individuals per m² (Walter and Proctor 1999). For Oribatida, reports of species numbers range from 40 (adults) per 20 cm² (Hansen 2000), to 45 per 500 cm² (Moritz 1965), and 26

per 5 cm² (Karppinen 1958). Oribatid populations of 100,000 per m² have been reported in forest floors (Crossley 1977b). For prostigmata, densities of up to 117,340 per m² are known (Kethly 1990).

Mite feeding ecology can have a profound influence on the soil community (floristic and faunistic) and its physical structure and fertility (McBrayer and Reichle 1971; Norton 1985; Walter and Proctor 1999). Further consideration of the edaphic mites as they relate to soil structure and nutrient cycling finds that predatory Mesostigmata and Prostigmata mites do not directly influence soil processes (Norton 1985). They may, however, have important indirect effects through their trophic interactions with other soil biota (McBrayer and Reichle 1971). Diplopoda, Isopoda, and Collembola (among others) are known to have a regulatory influence on the number of saprotrophic organisms within the soil, thus affecting the microbial standing crop (Panikov and Simonov 1987). The same may be true of edaphic mites.

The Saprophagous and Mycophagous Oribatid mites are considered to exert the greatest effects on soil structure and nutrient cycling through their feeding habits (Crossley 1977b; Norton 1985). Their indirect effects are considered to be more important to the functioning of the soil ecosystem than influences on energy flow as previous studies reveal only a small fraction of energy actually passes through the Oribatids (Crossley 1977a; Crossley 1977b; Norton 1985).

Saprophagous mites feed on and directly break down decomposing organic material through comminution, while Mycophagous mites (e.g.

fungivorous mites) feed on soil microflora. These feeding activities and subsequent movement of soil result in soil mixing, aeration of the soil medium, dispersal of microflora, and creation of inoculation sites on substrates for microflora and the production of fecal pellets (Hole 1981; Norton 1985). Additionally, changes in substrate surface area, along with soil fragment movement, can increase leaching and oxidation rates (Seastedt 1984).

Several counter arguments have also been formed with respect to the importance and impact of saprophagous mites on the soil system (Norton 1985). Greater consensus has been reached concerning the role of mycophagous mites and their importance in interacting with microflora, where they release bound limiting nutrients such as nitrogen via feeding and defecating. This is a key process in the release of nutrients bound in microflora (Wallwork 1983; Norton 1985). Conceptually, the litter and soil biota within the forest floor ecosystem plays a critical role in the recycling of nutrients back to the producer (or autotrophic) component of the ecosystem. The important relationship between microarthropods and the microbial community has implications for the success of the floral community living within the same area. Therefore, one can assume that because the floral communities of rock outcrop and rock-ledge habitats are edaphically controlled, an important factor in the development and maintenance of these communities within these habitats would be the soil biota, which are important in nutrient cycling among other processes.

Cliffs and Ecological disturbance

Depending on the height, topography, and degree of separation from the ridge and cliff-base habitats, most high-angle cliff ledges are isolated environments. Within the LGWA, many ledges are completely separated from the adjacent habitats of the ridge and base. This degree of insulation affords these cliff-face habitats a degree of protection from major abiotic disturbances.

Effects of fire on the soil environment can be immediate and long-term. Immediate effects of fire are a result of heat transfer into the soil environment and combustion of soil organic matter, which can affect soil organisms and other biological components connected to decomposition and mineralization (DeBano et al. 1998). Long-term effects would include ecosystem productivity losses as a result of disrupted nutrient cycling (Knoepp and Swank 1993; DeBano et al. 1998). Although the resulting effects of fire on soil nutrients has been well established, the effects of fire on microarthropod communities has been largely overlooked. Although research is being conducted on macroarthropods, the mites are seldom examined, due to taxonomic difficulties, when one considers soil fauna and fire effects, despite the fact that they are believed to have the most important influence in ecosystem functions as it pertains to soil structure and fertility.

Nutrient loss occurs both during and after a fire. Losses can occur through: (1) direct volatilization of elements into the atmosphere, (2) loss through particulate matter movements of smoke and ash via wind, streamflow, and leaching, and (3) immobilization of nutrients within incompletely burned organic

matter, i.e. vegetation and detritus (Boerner 1982; Schlesinger 1997; DeBano et al. 1998). The degree to which these losses will affect the nutrient cycling within a given system will be based on site specific variables, including climate, degree of burn intensity, pre-burn site characteristics, and topography (Boerner 1982). Whether or not a soil organism will be affected by fire depends on the combined variables of organism depth, depth of heat penetration and depth of organic matter combustion (Smith 2000).

My study provides one of the first qualitative and quantitative studies investigating cliff-face microarthropods. Its aim was to compare the microarthropod community existing on the cliff-face habitat with that of the adjacent horizontal ridge and base habitats to determine if the cliff represents a unique habitat due to specialized physical and abiotic attributes. Additionally, this study investigated the role of a major ecological disturbance (a suppressed ecological process) in the form of fire on the microarthropod community within the ridge, cliff-face and base habitats. From approximately late October to late November of 2000, the LGWA experienced a series of fires, which burned through approximately 2428 ha of the LGWA (Jason Riddle, personal communication). Areas burned included both the ridge and base habitats of this study. In all, approximately 68% of the 2046 ha of thermic oak pine forest and 50% of the 2333 ha of acidic cove and slope forests in the LGWA were burned (Jason Riddle, personal communication). Based on personal observation, the fires that swept through both the thermic oak pine and acidic cove and slope

forests in the LGWA can be described as surface and ground fires, with minimal to no effects to the canopy.

Because cliffs are isolated habitats due to their vertical orientation within the landscape, it is presumed that they are free from ecological disturbances such as fire or a need to be fire maintained. Following a significant ecological disturbance the community composition on the cliff face may not change, while the adjacent ridge and base habitat communities would be altered due to fire. My study allowed me to elucidate this.

The objectives of my study were to: (1) qualitatively describe and quantitatively compare the microarthropod communities on the ridge, cliff-face and base habitats of the Gold Coast Wall Area within the LGWA, (2) investigate the role of litter and soil depth, percent soil moisture, and bulk density on the microarthropod communities of the ridge, cliff-face and base habitats, (3) qualitatively describe and quantitatively compare the Oribatid mite community on the ridge, cliff-face and base habitats over two years, (4) assess the role of a major ecological disturbance in the form of fire on the microarthropod communities (with a concentration on the Oribatid mites) on the habitats pre- and post-fire, and (5) establish the first taxonomic catalogue for the Oribatida within the LGWA.

METHODS AND MATERIALS

Site Description

The Linville Gorge Wilderness Area is on the eastern edge of the Blue Ridge Escarpment within the Southern Appalachian Mountains (Newell and Peet 1998). It is located in Burke County, North Carolina and comprises part of the Pisgah National Forest. Encompassing approximately 4441 ha, LGWA is one of three remaining large tract old-growth forests within the Southern Appalachians (Newell and Peet 1998). Prominent in this landscape is the Linville River, with Jonas Ridge on the east and Linville Mountain on the west. Elevations range from 400 m above sea level at the lowest point to 1250 m at the highest point (Newell and Peet 1998; USDA 1991). The LGWA is defined by a mosaic of complex topography, including steep slopes, rising vertical rock cliffs and exposed rock outcrops. The vast area that the LGWA encompasses, coupled with its unique topography, make it one of the most enticing areas in the southeastern United States for such outdoor recreational activities as hunting, hiking, camping, backpacking, and rock climbing.

Vegetation data provided in Newell and Peet (1998) show the LGWA is composed of 28 community types categorized under eight major vegetation classes. Prominent are the thermic oak-pine forests (40% of total area) and acidic cove and slope forests (47%). Rock outcrops, associated with steep

escarpments, are the dominant land features and contain 8% of the LGWA vegetation (Newell and Peet 1998). However, it should be noted that the vegetation descriptions described by Newell and Peet (1998) did not include areas inaccessible by foot, thereby excluding the vertical and near vertical cliff-face habitats within the gorge. Therefore, the vegetation associated with rock outcrops within the LGWA is undoubtedly greater than 8%.

For my study, litter samples were collected on the west side of LGWA in the area locally known as the Gold Coast Wall. This region of the gorge was chosen as my study site for two reasons: (1) it is an area with a discernable ridge, cliff-face and cliff-base (hereafter habitats), and (2) this area has experienced little to no anthropogenic disturbance with respect to camping and hiking on the ridge and base and no anthropogenic disturbance in the form of recreational rock climbing on the cliff face.

For the purpose of my study, a cliff face is defined as a vertical or near-vertical area surrounded by: (1) a plateau or ridge forming a level or sloping platform above the cliff face, and (2) a pediment or base below the cliff face (Larson et al. 2000). Vegetation associated with these habitats includes a thermic oak-pine forest on the ridge, rock outcrops on the cliff and acidic cove and slope forest at the base (Newell and Peet 1998). The cliff-face area included both a north and south facing aspect, while the base and ridge had an east facing aspect.

From approximately late October to late November 2000, a series of fires burned approximately 2428 ha of the LGWA. Areas impacted included both the

ridge and base habitats adjacent to the Gold Coast Wall. Overall, approximately 68% of thermic oak pine forest and 50% of acidic cove and slope forest in the LGWA were burned (Jason Riddle, personal communication).

Sampling Regime

Samples were collected in August and September of 2000 (pre-fire year), and July and August 2001 (post-fire year). Eight replicate samples were taken from each habitat in 2000 and ten in 2001.

Litter and soil microarthropods were sampled on the ridge at 10 m intervals along a transect parallel and above the cliff face, approximately 100 m from the precipice. The transect was located within a thermic oak-pine forest 1.2 km south of the Conley Cove parking area along the Rock Jock Trail. Universal Transverse Mercator coordinates (UTM) for the ridge transect are Easting 418467 and Northing 3971141 (Zone 17 NAD83). Base samples were collected on a transect located in an acidic cove and slope forest approximately 1.6 km south of the Conley Cove hiking trail and 100 m from the Linville River. Coordinates for the base transect are Easting 418947 and Northing 3971299 (Zone 17 NAD83).

Samples from the cliff face were collected haphazardly based on safety considerations and accessibility from a fixed rope line. Accessible ledges with litter and soil accumulations were sampled when in reach on a rappel. A fixed line was anchored in two separate places in order to access enough ledges to complete collection. Ridge and base samples were collected from the same

location in 2000 and 2001. Cliff samples in 2001 were not from the same location as the 2000 samples.

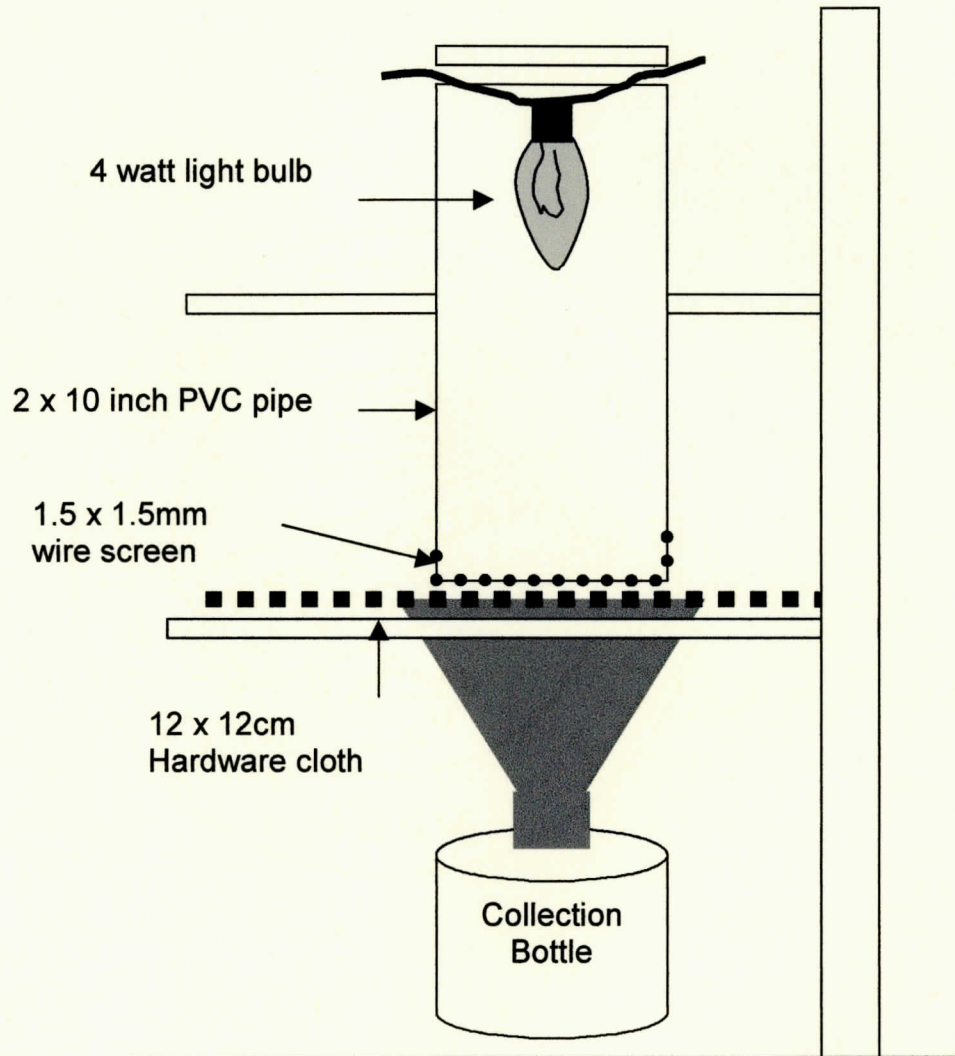
Sample Extraction

Samples (cores) were extracted using a PVC pipe 5 cm in diameter to a depth of 5 cm. Therefore, animals below 5 cm were not collected. Cores were placed into a plastic storage bag and chilled until they could be placed into the microarthropod extractors (see below) in the laboratory, approximately 3 to 5 hours after collection. After samples were extracted, soil/litter measurements were made of the depth of the; (1) leaf litter (O_i horizon or L layer), (2) organic layer (O_i or O_e and O_a horizons depending on the depth, or F and H layers respectively), and soil (i.e. to A horizon) or rock substrate. Litter, organic and soil depth measurements were later added together to obtain the litter/organic depth. Sample bulk density was calculated as the dry core mass per unit volume.

Microarthropod Extractor

The microarthropod extractors were built based on the combined designs of Crossley and Blair (1991) and Merchant and Crossley (1970). The premise of the extractor is that a heat source positioned above the soil core will provide constant heat to desiccate the sample. As the sample core dries from the top down, animals move away from the heat and desiccated soil into collection containers. A diagram of the extractor is found in Figure 1.

Figure 1. Modified Tullgren funnel microarthropod extractor based on the combined designs of Crossley and Blair (1991) and Merchant and Crossley (1970).



Specifically, each extractor consisted of PVC pipe 5.1 cm in diameter and 25.4 cm in height, with a 1.5 x 1.5 mm mesh wire screen attached to the bottom. Cores were positioned such that the sample would dry evenly from the top to the bottom. Desiccation from all sides will force the animals into a potentially wet center of the core, greatly limiting extraction efficiency.

Sample cores consisted of different proportions of litter and organic layer horizons and soil depending on the sample and habitat. Each PVC pipe was set upon a hardware cloth (12 x 12mm) platform directly above a plastic funnel. A four-watt light bulb provided a continuous heat source. Extractors had a wooden cap placed on the top of the pipe when the light was on. Arthropods were extracted for 7 days, or until the sample was dry. Animals were collected in a 90% ethanol solution below the funnels.

To reduce sample loss, placement of the litter/soil cores into extractors was performed with a white piece of paper placed below the funnel. Litter (and thus animal) loss through the funnel during placement was returned to the extractor. This was repeated until no loss via placement was observed.

Water Content Measurements

All samples were initially weighed for fresh mass (wet mass) prior to being placed into the microarthropod extractors. After extraction, samples were transferred to paper bags and dried at 40°C. Dried samples were then reweighed for dry mass. Percent water content was calculated as $((\text{freshmass} - \text{drymass}) / \text{freshmass}) \times 100$.

Animal Sorting

Collected animals and associated debris from the extractors were transferred to a petri dish with a visible numbered grid. With the use of a dissecting microscope, animals were systematically counted within the grids. All animals were initially organized into suborders of Order Acari (mites): Mesostigmata, Prostigmata, Oribatida; Orders of Class Hexapoda (insects): Collembola, Diplura and Protura; other mites (Acari suborders not included above); other arthropods, including Orders of Class Arachnida: Araneae and Pseudoscorpiones; and classes of Phylum Arthropoda: Pauropoda and Symphyla.

Oribatid Mites were removed for further identification. Identification consisted of: (1) sorting animals into gross morphological categories, (2) making permanent glass slides, and (3) identifying animals to the lowest possible taxa.

Oribatida Mounting Techniques and Identification

Prior to mounting, Oribatida mites were separated into groups to facilitate the identification of similar animals. Mites were first categorized as either Lower Oribatida [Macropylina] including Palaeosomata, Enarthronota, Parhyposomata, Mixonomata and Desmonomata, or Higher Oribatida (Brachypylina = Circumdehiscentiae) (see Balogh 1972; Krantz 1978; Marshall et al. 1987; Balogh and Balogh 1992a; Balogh and Balogh 1992b; Norton 1992).

Mounting of mites consisted of removing animals from their respective containers after separation and placing them onto a 7.62 cm x 2.54 cm x 1.22

mm glass microscope slide containing CMC-10 mounting media (CMC-10 Mounting Media, Masters Company, Inc., Bensenville, IL). Mites were arranged within the media and a cover slide was placed over them. Slides were then placed onto a slide warmer for 4 to 7 days in order to clear animals and harden the media. After slide preparation, each animal on the slide was numbered by placing a number on the glass slide to the side of the animal. In this way, each Oribatid mite collected had a specific number based on slide and sample. Oribatida identification was facilitated with the use of published and unpublished keys (Balogh 1972; Krantz 1978; Dindal 1990; Balogh and Balogh 1992a; Balogh and Balogh 1992b; and Norton 1992 *unpublished*). See Appendix A for a complete taxonomic listing of Oribatid mite taxa identified in my study, organized following Balogh and Balogh (1992a) and Balogh and Balogh (1992b).

Statistical Analysis

For statistical comparisons within and between the three habitats, I used individual samples within each habitat as a replicate. Response variables included densities of total animals, total acari, other arthropods, collembola, mesostigmata, prostigmata, oribatida, litter/organic depth, percent water, and core bulk density. Density is the number of animals per g of sample (i.e. litter and soil). This density conversion allowed me to account for varying weight of samples within and between habitats. Abiotic response variables included litter/organic depth, percent water, and core bulk density.

All response variables were tested for normality using Proc Univariate (SAS for PC, SAS institute, Cary, NC). Data not normally distributed were log transformed. In addition, values deemed as significant outliers were removed.

The Proc GLM procedure was used to test for significant differences in dependent variables between habitats and within habitats between years. To assess potential pre- and post-fire effects, I tested for significant effects of habitat, year and the interaction of habitat x year for each dependent variable. Pair-wise comparison of means used Tukey's Studentized Range Test.

The Proc REG procedure was used for regression analysis of the dependent variables against litter/organic depth, percent water, and core bulk density. Values of $P \leq 0.05$ are considered significance for all analyses.

Analysis of Oribatida

For the analysis of the Oribatida, I condensed or made taxonomic groupings based on the number of animals present consisting of general taxonomic groups, families, genera groups, and genera. This was done by allowing numerically abundant genera to remain as genera, while genera with few individuals or genera sufficiently similar in taxonomy were grouped together into genera groups or taxonomic groups. Low abundance of genera or genera groups resulted in a family taxonomic category.

Taxonomic groups included Phthiracaridae, Euphthiracaridae, *Eohypochthonius* sp., *Platynothrus* sp., *Trhypochthoniellus* sp., *Nanhermannia* sp., *Hermanniella* sp., Gymnodamaeoid Genera, *Eueremaeus* sp., Eremuloid

Genera, Damaeoid Genera, *Rhinosuctobelba* sp., Oppiid Genera, Licaroid Genera, Carabodidae, *Kalyptrazetes* sp., Galumnoid Genera, Oribartelloid Taxa, Ceratozetoid Genera, and Oribatuloid Genra. See appendix A for a complete listing of Oribatida by major groups, taxa, family, genera groupings, and genus with habitat distributions.

The Proc Means Procedure (SAS for PC, SAS institute, Cary, NC) was used to generate the mean number of individuals (within taxonomic groups) per mean g of soil, along with the percentage of oribatid groups within habitats for both years. Taxonomic groups were then described.

RESULTS

In total, 5880 animals were collected and sorted from the three habitats over two years. Acari comprised the dominant group of soil fauna, followed by Collembola, in both the pre- and post-fire years (Figures 2 and 3). In the pre-fire year of 2000, total animals, acari and collembola densities were significantly lower in the cliff-face habitat compared to the adjacent ridge and base habitats, which were not significantly different from one another (Figure 2). The density in all animal groups within all three habitats was substantially lower in the post-fire year of 2001. There were no significant differences between the three habitats in density of total animals or acari in 2001 (Figure 3). Collembola density was significantly greater within the base compared to the ridge and cliff-face habitats, which were not significantly different from one another in the post-fire year 2001 (Figure 3).

For total animals, acari, collembola and oribatida, there were significant effects of habitat, year and a habitat x year interaction (Table 1). When only the Acari are considered, the most abundant Acari suborder within each habitat for both years was Oribatida (Figures 4 and 5). Both Oribatida and Mesostigmata in the pre-fire year of 2000 were significantly lower in the cliff-face habitat compared to the adjacent ridge and base habitats, which were not significantly different from one another (Figure 4). In the post-fire year of 2001, only Mesostigmata was different

Figure 2. Mean density of microarthropods collected in Year 2000 (pre-fire). P-values below dependent variables from Proc GLM procedure between habitats. An * indicates means significantly different within each variable using Tukey's Studentized Range Test, $\alpha = 0.05$. Total Animals = all animals in all categories. Acari = the Acari suborders Oribatida, Mesostigmata and Prostigmata. Other Arthropods = Arthropods excluding Collembola and all Acari. Bars represent standard error of the mean.

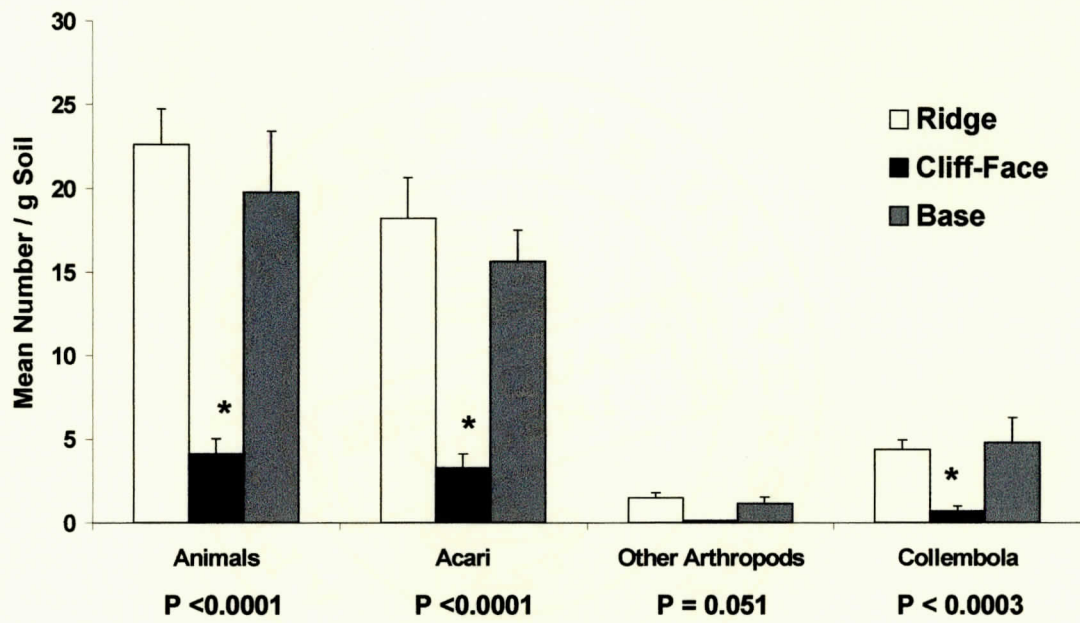
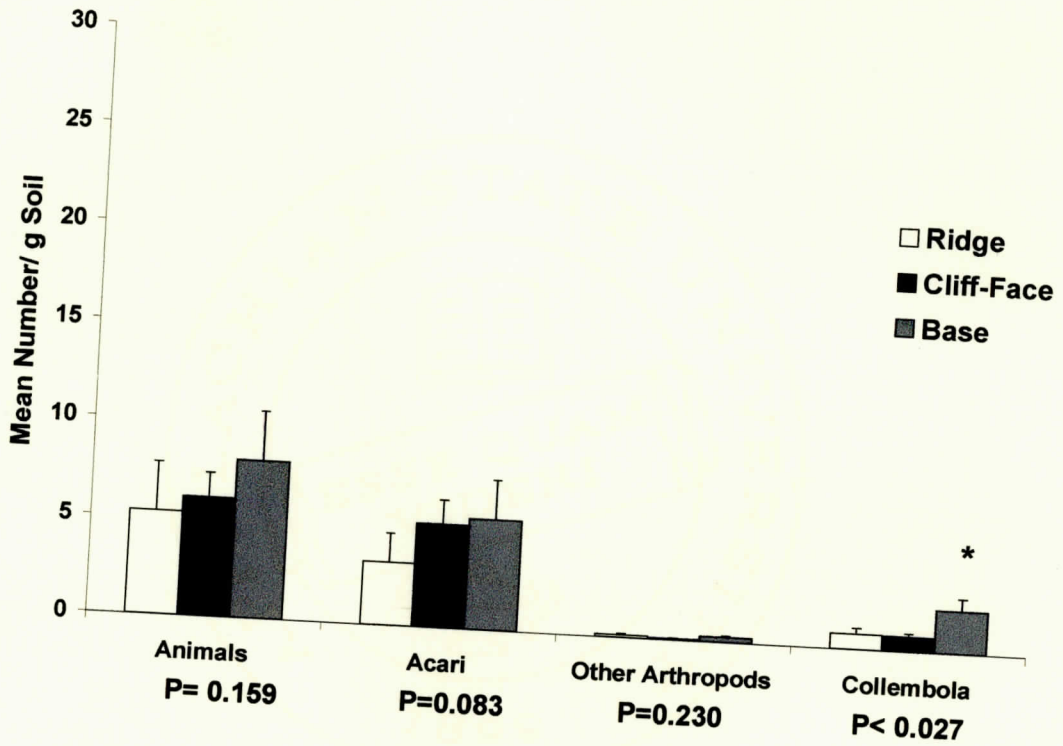


Figure 3. Mean density of microarthropods collected in Year 2001 (post-fire). P-values below dependent variables from Proc GLM procedure between habitats. An * indicates means significantly different within each variable using Tukey's Studentized Range Test, $\alpha = 0.05$. Total Animals = all animals in all categories. Acari = the Acari suborders Oribatida, Mesostigmata and Prostigmata. Other Arthropods = Arthropods excluding Collembola and all Acari. Bars represent standard error of the mean.



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Table 1. Analysis of biotic and abiotic dependent variables by habitat, year, habitat x year (Proc GLM). df = 2 for habitat and habitat x year, df = 1 for year. P values ≤ 0.05 are presented in bold type.

Dependent Variable	P-value
Total Animals	
habitat	0.01
year	< 0.0001
habitat x year	0.0001
Acari	
habitat	0.014
year	< 0.0001
habitat x year	< 0.0001
Other Arthropods	
habitat	0.023
year	0.002
habitat x year	0.94
Collembola	
habitat	< 0.0001
year	0.0003
habitat x year	0.003
Oribatida	
habitat	0.05
year	< 0.0001
habitat x year	< 0.0001
Mesostigmata	
habitat	0.0002
year	< 0.0001
habitat x year	0.002
Prostigmata	
habitat	0.042
year	0.037
habitat x year	0.038
Other Mites	
habitat	0.539
year	0.36
habitat x year	0.681
Percent Water	
habitat	< 0.0001
year	0.2264
habitat x year	< 0.0001
Litter Organic Depth	
habitat	0.0118
year	< 0.0001
habitat x year	< 0.0001
Bulk Density	
habitat	0.2490
year	< 0.0001
habitat x year	0.0010

Figure 4. Mean density of Acari for Year 2000 (pre-fire). P-values below dependent variables from Proc GLM procedure between habitats. An * indicates means significantly different within each variable using Tukey's Studentized Range Test, $\alpha = 0.05$. Dependent variables include the Suborders of Acari including Oribatida, Mesostigmata and Prostigmata. Other = any suborder of Acari excluding Oribatida, Mesostigmata, and Prostigmata. Bars represent standard error of the mean.

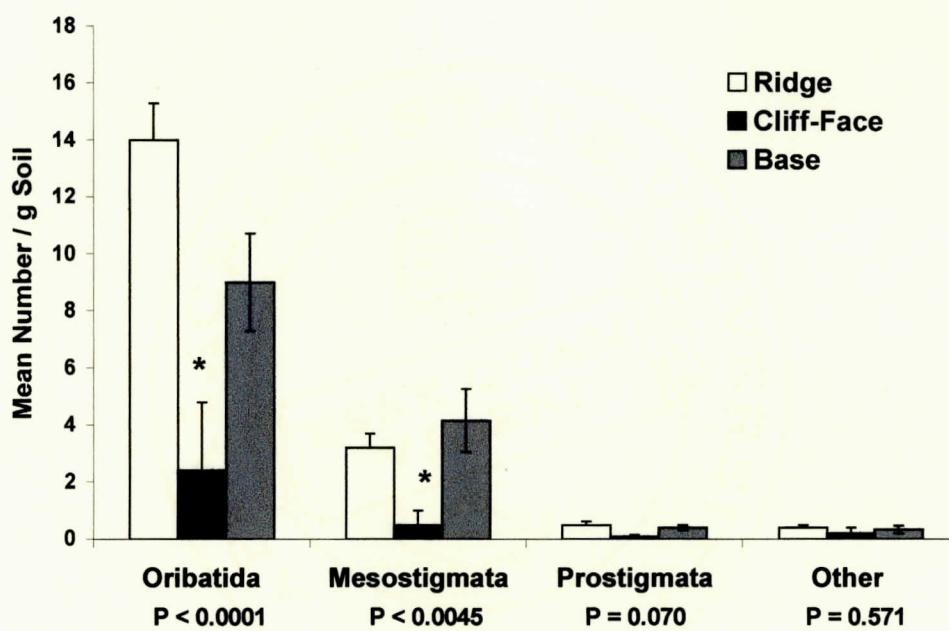
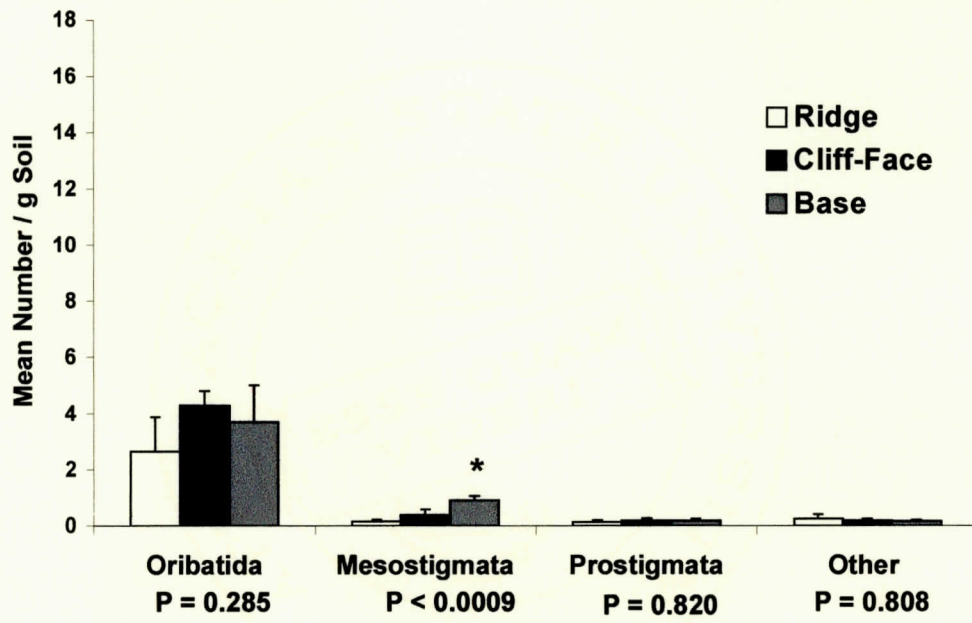


Figure 5. Mean density of Acari for Year 2001(post-fire). P-values below dependent variables from Proc GLM procedure between habitats. An * indicates means significantly different within each variable using Tukey's Studentized Range Test, $\alpha = 0.05$. Dependent variables include the Suborders of Acari including Oribatida, Mesostigmata and Prostigmata. Other = any suborder of Acari excluding Oribatida, Mesostigmata, and Prostigmata. Bars represent standard error of the mean.



among habitats, being significantly greater in density on the base (Figure 5). Between years, each Acari suborder was significantly related to year and its interaction with habitat and Oribatida, Prostigmata and Mesostigmata were related to habitat (Table 1.)

Within the ridge and base habitat Oribatida and Mesostigmata were significantly lower in the post-fire year of 2001 compared to the pre-fire year of 2000 (Figure 6), while each suborder except Prostigmata had a similar response on the base (Figure 7). On the cliff face, only the suborder Prostigmata had any difference between years, increasing on the cliff in year 2001 (Figure 8).

The mean percent water content in the pre-fire year of 2000 was significantly lower in the cliff-face habitat compared to the adjacent ridge and base habitats, which were not significantly different from one another (Figure 9). Although this trend changed in the post-fire year of 2001, the three habitats remained significantly different from one another, presumably because the base and cliff had higher litter water content than the ridge (Figure 9). Within each habitat, mean percent water decreased significantly on the ridge in the post-fire year 2001 and increased significantly on the cliff face in that same year (Figure 10). There was a significant affect of habitat and its interaction with year on the percent water content (Table 1).

In the pre-fire year of 2000, the ridge was significantly higher than the cliff-face habitat in mean litter/organic depth (Figure 11). In the post-fire year of 2001, there was a change in this trend, with both the ridge and base having less litter/organic depth than the cliff face, although only the base was significantly

Figure 6. Mean density of Acari on ridge in 2000 and 2001. P-values below dependent variables from Proc GLM procedure between year 2000 (Pre-Fire), and year 2001 (Post-Fire). An * indicates a mean significantly different between years for that variable using Tukey's Studentized Range Test, $\alpha = 0.05$. Dependent variables include the Suborders of Acari; Oribatida, Mesostigmata and Prostigmata. Other = any suborder of Acari excluding Oribatida, Mesostigmata and Prostigmata. Bars represent standard error of the mean.

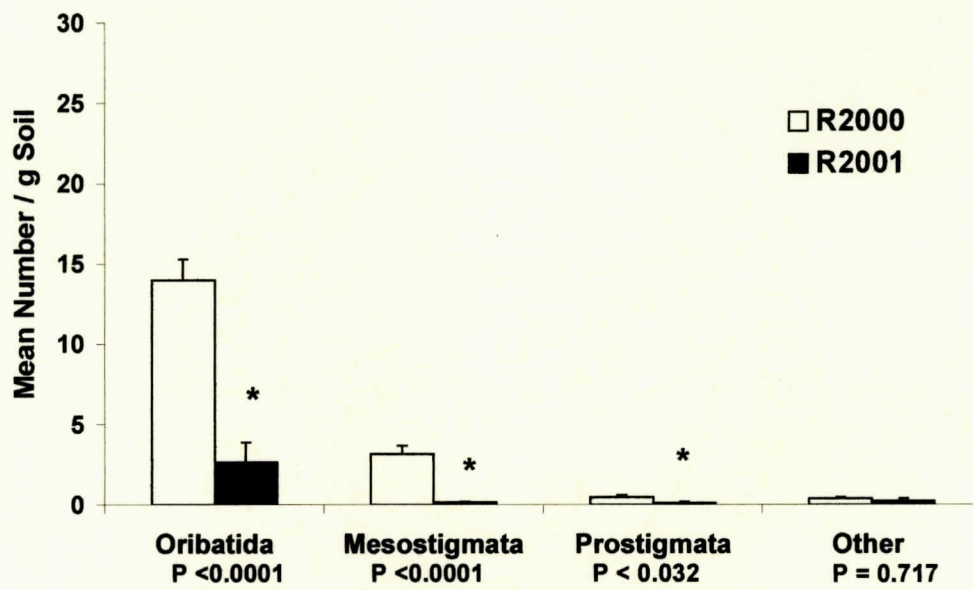


Figure 7. Mean density of Acari on base in 2000 and 2001. P-values below dependent variables from Proc GLM procedure between year 2000 (Pre-Fire), and Year 2001 (Post-Fire). An * indicates a mean significantly different between years for that variable using Tukey's Studentized Range Test, $\alpha = 0.05$. Dependent variables include the Suborders of Acari; Oribatida, Mesostigmata and Prostigmata. Other = any suborder of Acari excluding Oribatida, Mesostigmata and Prostigmata. Bars represent standard error of the mean.

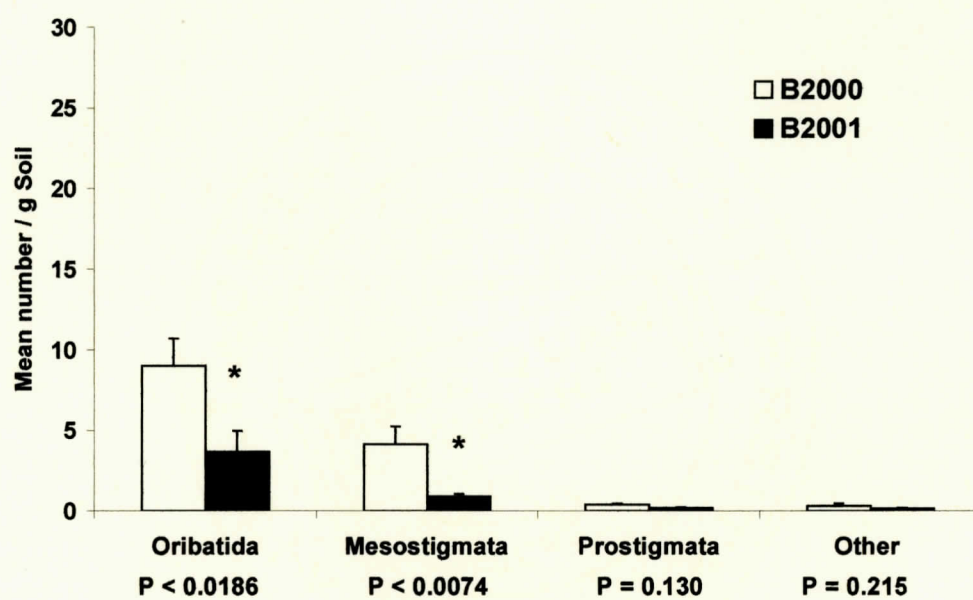


Figure 8. Mean density of Acari on cliff face in year 2000 and 2001. P-values below dependent variables from Proc GLM procedure between year 2000 (Pre-Fire), and year 2001 (Post-Fire). An * indicates a mean significantly different between years for that variable using Tukey's Studentized Range Test, $\alpha = 0.05$. Dependent variables include the Suborders of Acari; Oribatida, Mesostigmata and Prostigmata. Other = any suborder of Acari excluding Oribatida, Mesostigmata and Prostigmata. Bars represent standard error of the mean.

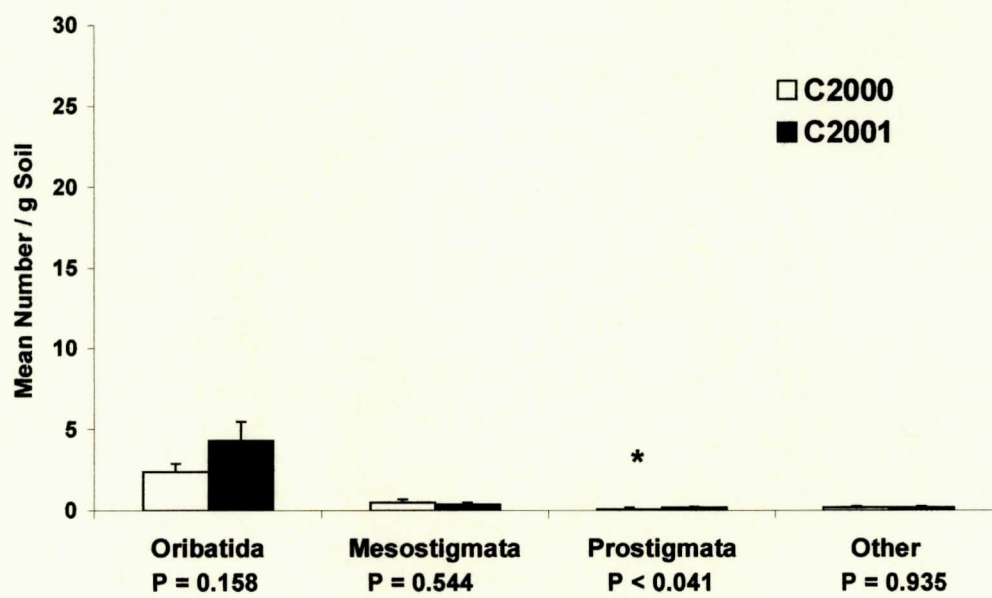


Figure 9. Mean percent water content between habitats in year 2000 and 2001. P-values below year from Proc GLM run between the three habitats in that year. An * indicates means significantly different within that year using Tukey's Studentized Range Test, $\alpha = 0.05$. Bars represent standard error of the mean.

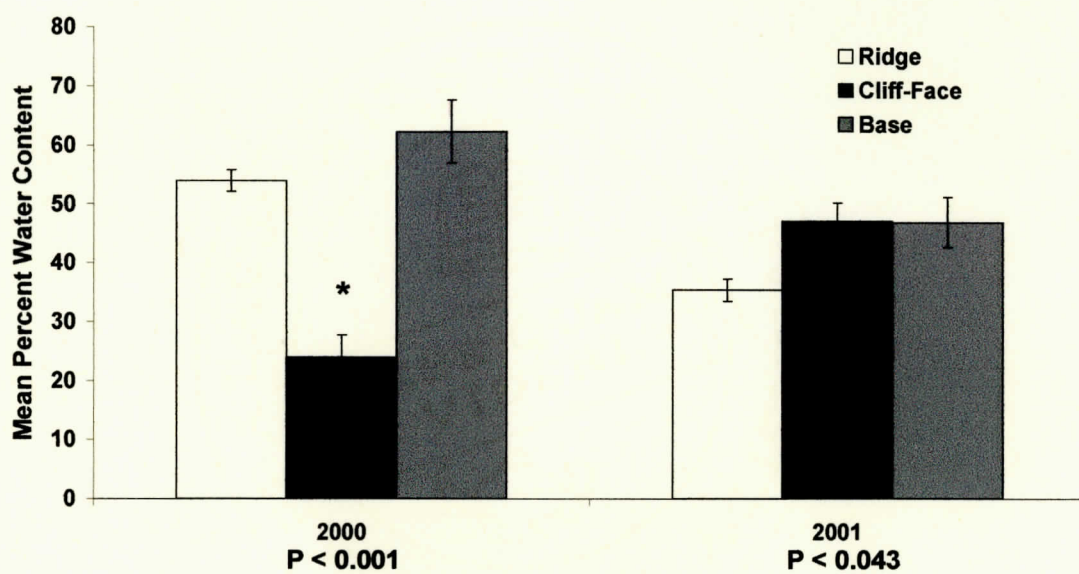


Figure 10. Mean percent water content by habitat in year 2000 and 2001. P-values below habitat from Proc GLM procedure run between the two years for each habitat. An * indicates a mean significantly different between years using Tukey's Studentized Range Test, $\alpha = 0.05$. Bars represent standard error of the mean.

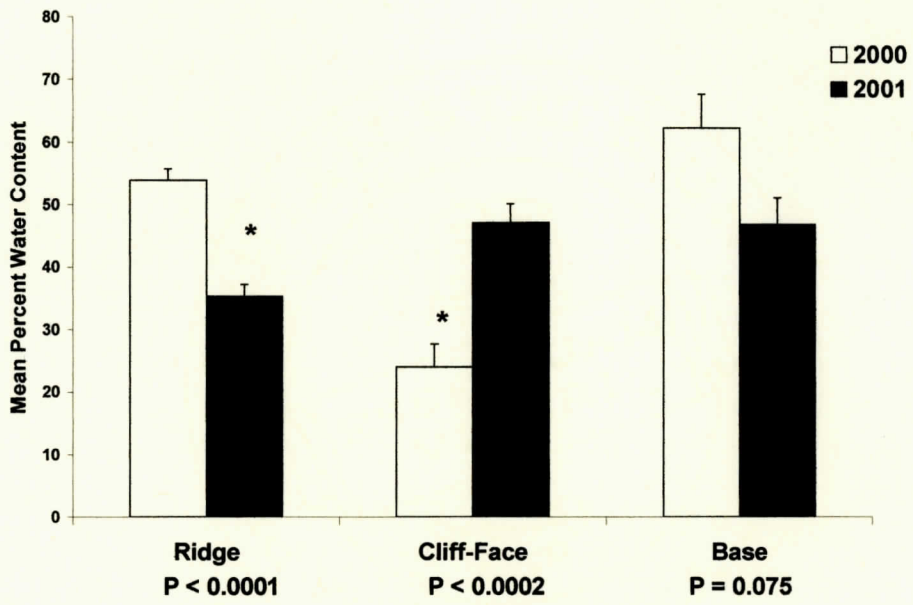
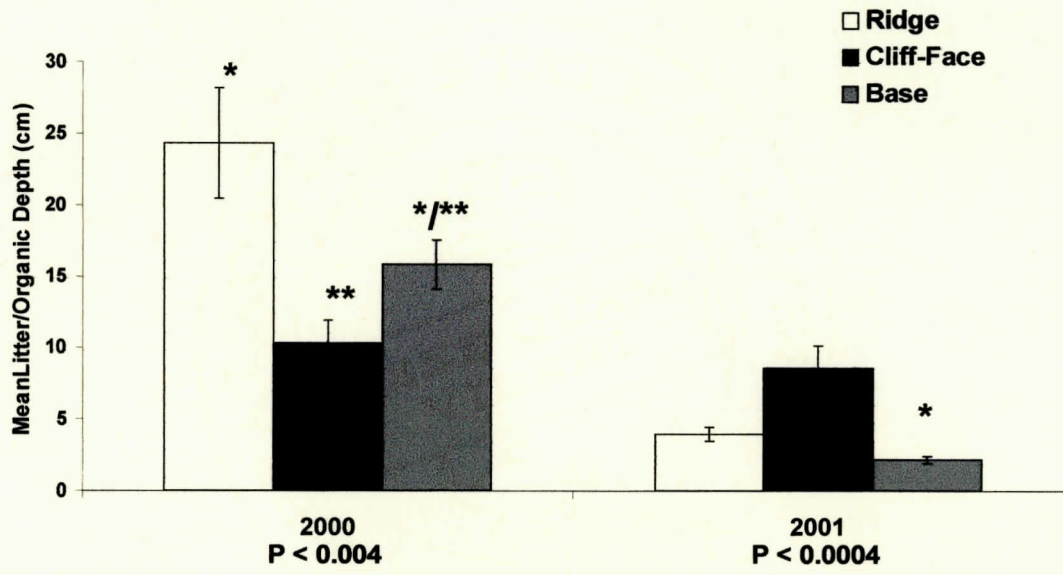


Figure 11. Mean litter/organic depth (LO depth) between habitats in year 2000 and 2001. P-values below year from Proc GLM procedure run between the two habitats in that year. An * indicates means significantly different within that year using Tukey's Studentized Range Test, $\alpha = 0.05$. Bars represent standard error of the mean.



different (Figure 11). Within habitats, the ridge and base both had significantly lower litter/organic depth in the post-fire year of 2001, while the cliff face was unchanged between years (Figure 12). There was a significant affect of habitat, year and habitat x year interaction on litter/organic depth (Table 1).

Mean sample core bulk density in the pre-fire year of 2000 was significantly higher in the cliff-face habitat than the ridge and base, which were similar (Figure 13). After the fire in the year 2001, the mean sample core bulk density of the ridge was significantly greater on the ridge compared to the cliff-face habitat (Figure 13). Within habitats the sample core bulk density was significantly lower in the pre-fire year of 2000 for the ridge and base, while the cliff face was unchanged between years (Figure 14). There was a significant affect of year and habitat x year on sample core bulk density (Table 1).

Regression analysis results for all variables can be found on Table 2. All response variables were significantly correlated with litter organic depth, percent water content of soil and sample core bulk density except the variable "Other mites", which was not significantly correlated with litter/organic depth (Table 2). Total animals, Collembola, Total Acari and Oribatida were all highly correlated (i.e. $P < 0.0001$) with litter/organic depth, percent water and bulk density (Table 2). There was also a significant relationship between percent water and litter/organic depth and percent water and bulk density (Table 2). Litter/Organic depth was related to and bulk density ($P < 0.0001$).

Figure 12. Mean litter/organic depth (LO depth) by habitat in year 2000 and 2001. P-values below habitat from Proc GLM procedure run between the two years. For each habitat, an * indicates a mean significantly different between years using Tukey's Studentized Range Test, $\alpha = 0.05$. Bars represent standard error of the mean.

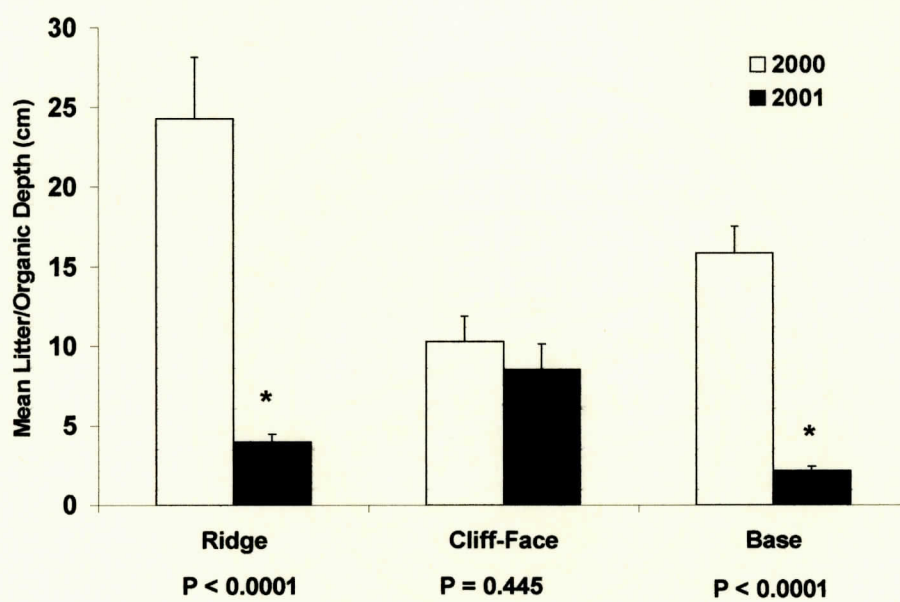


Figure 13. Mean bulk density between habitats in year 2000 and 2001. P-values below year from Proc GLM procedure run between the two habitats in that year. An * indicates means significantly different within that year using Tukey's Studentized Range Test, $\alpha = 0.05$. Bars represent standard error of the mean.

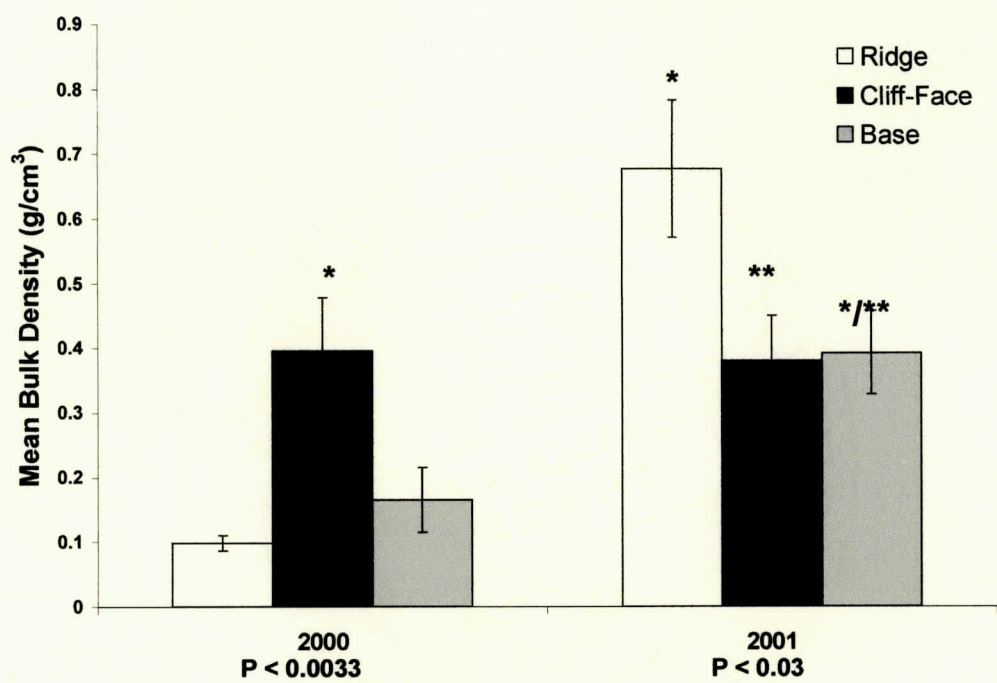


Figure 14. Mean Bulk Density by habitat in year 2000 and 2001. P-values below habitat from Proc GLM procedure run between the two years for each habitat. An * indicates a mean significantly different between years using Tukey's Studentized Range Test, $\alpha = 0.05$. Bars represent standard error of the mean.

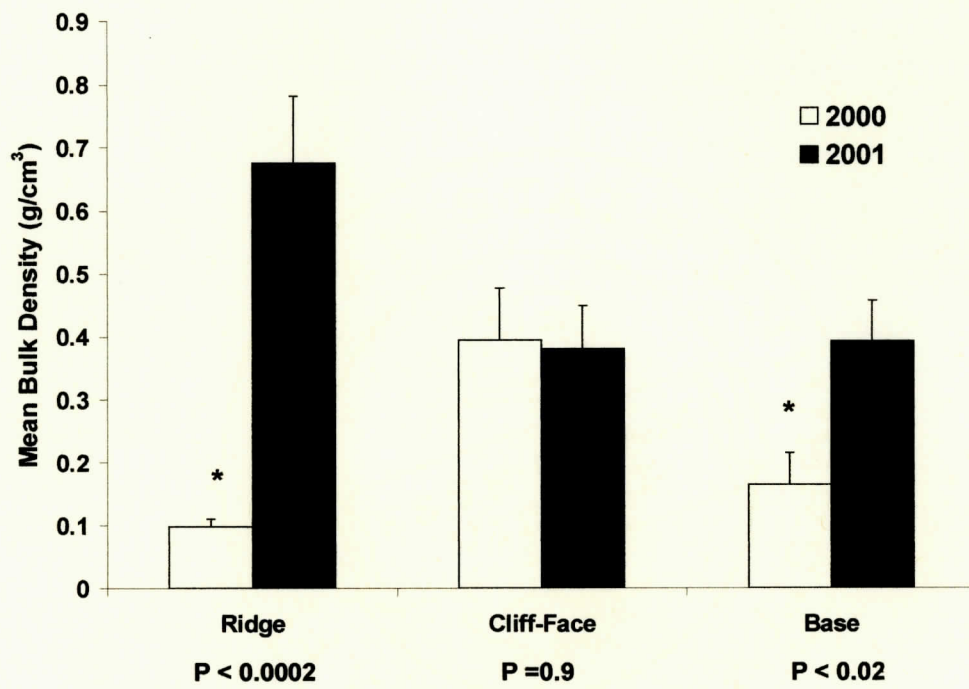


Table 2. Regression analysis of dependent variables on the independent variables of litter/organic depth, percent water content of soil, and sample bulk density. P values ≤ 0.05 are presented in bold type.

	r^2	P
Total Animals		
Litter/Organic depth	0.4	<0.0001
Percent Water	0.6	<0.0001
Bulk Density	0.8	<0.0001
Other Arthropods		
Litter/Organic depth	0.13	0.02
Percent Water	0.2	0.002
Bulk Density	0.3	<0.0001
Collembola		
Litter/Organic Depth	0.4	<0.0001
Percent Water	0.5	<0.0001
Bulk Density	0.5	<0.0001
Total Acari		
Litter/Organic Depth	0.4	<0.0001
Percent Water	0.5	<0.0001
Bulk Density	0.7	<0.0001
Mesostigmata		
Litter/Organic Depth	0.3	<0.0001
Percent Water	0.5	<0.0001
Bulk Density	0.3	<0.0001
Prostigmata		
Litter/Organic Depth	0.2	0.001
Percent Water	0.3	<0.0001
Bulk Density	0.3	<0.0001
Other Mites		
Litter/Organic Depth	0.05	0.1
Percent Water	0.1	0.02
Bulk Density	0.2	0.0007
Oribatida		
Litter/Organic Depth	0.5	<0.001
Percent Water	0.5	<0.0001
Bulk Density	0.7	<0.0001
Percent Water		
Litter/Organic Depth	0.2	0.001
Bulk Density	0.4	<0.0001
Litter Organic Depth		
Bulk Density	0.4	<0.0001

Oribatida Analysis

A total of 58 genera (within 30 families) were identified among the 2265 adult Oribatida collected within the three habitats over both years. A complete taxonomic list is provided in Appendix A. The 58 genera were condensed into 20 groups consisting of families, groups of genera or taxa or genus based on the conventions of Balogh 1972, Balogh and Balogh 1992a, and Balogh and Balogh 1992b. Of these 20 groups, only the Oribatuloid taxa, Ceratozetoid genera group and *Eueremaeus* sp. showed any consistent trends in density between the two years and between habitats (Figures 15 and 16). For both years, these trends included a lower density on the ridge for the Oribatuloid genera group, greater density on the cliff face for the Ceratozetoid genera group, and greater density of *Eueremaeus* sp on the ridge (Figure 15 and 16).

On the ridge in the pre-fire year of 2000, *Trhypochthoniellus* sp. and *Eueremaeus* sp. were the dominant mites, accounting for 17 and 35 percent respectively of the Oribatida collected (Table 3). Conversely, in the post-fire year of 2001, *Eueremaeus* sp. and the Oribatuloid Genera group dominated in the ridge, accounting for 30 and 40 percent of the mites respectively (Table 3).

Within the cliff in the pre-fire year of 2000, the Oribatelloid Genera group was the dominant group, accounting for 23 percent of the mites collected (Table 3). In the post-fire year of 2001, the Carabodidae dominated with 40 percent, followed by the Ceratozetoid genera with 25 percent and the Oribatelloid Genera

Figure 15. Mean density of adult Oribatida taxa between habitats in year 2000 (pre-fire). See Appendix A for a complete listing of Oribatida taxa present within the groupings presented here.

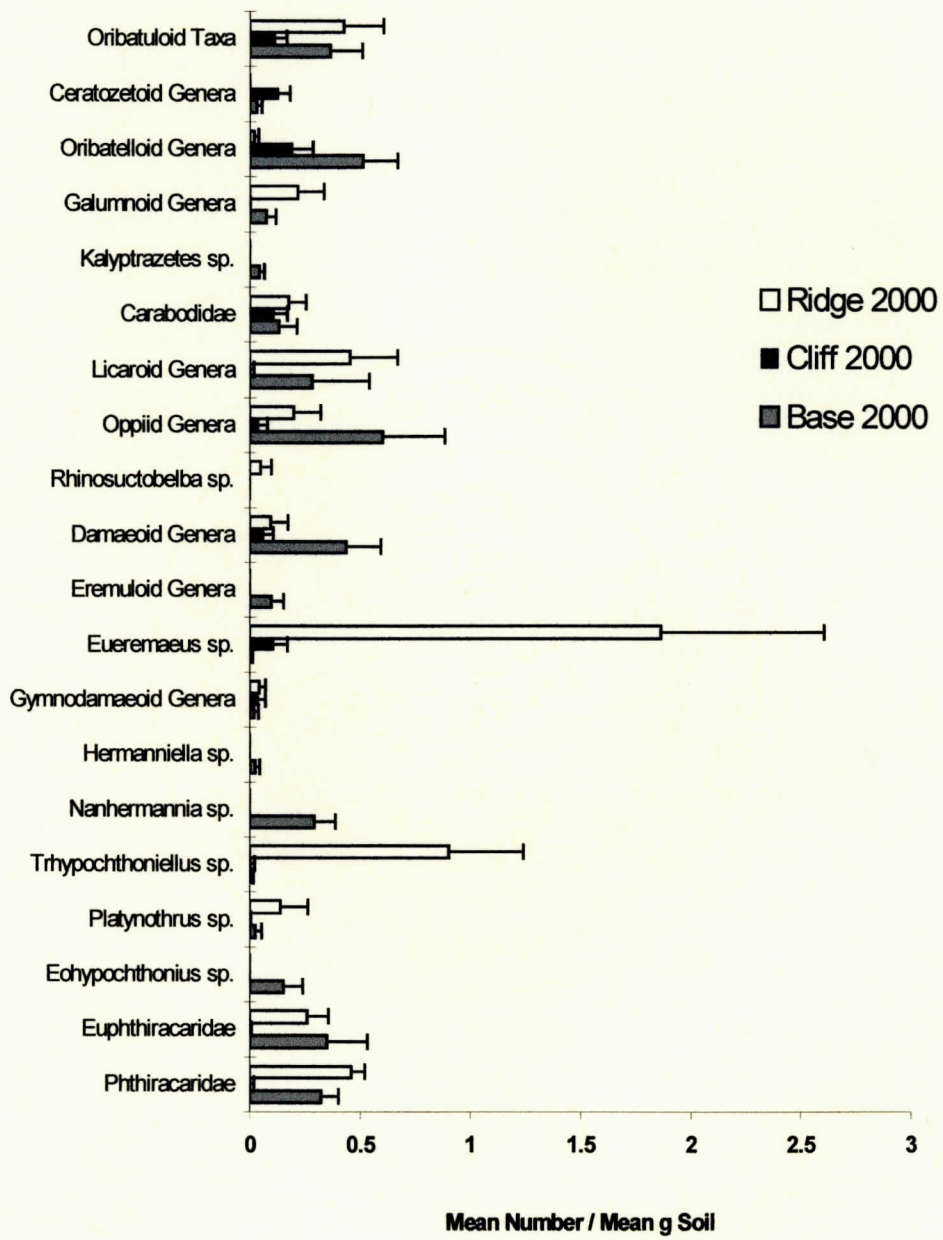
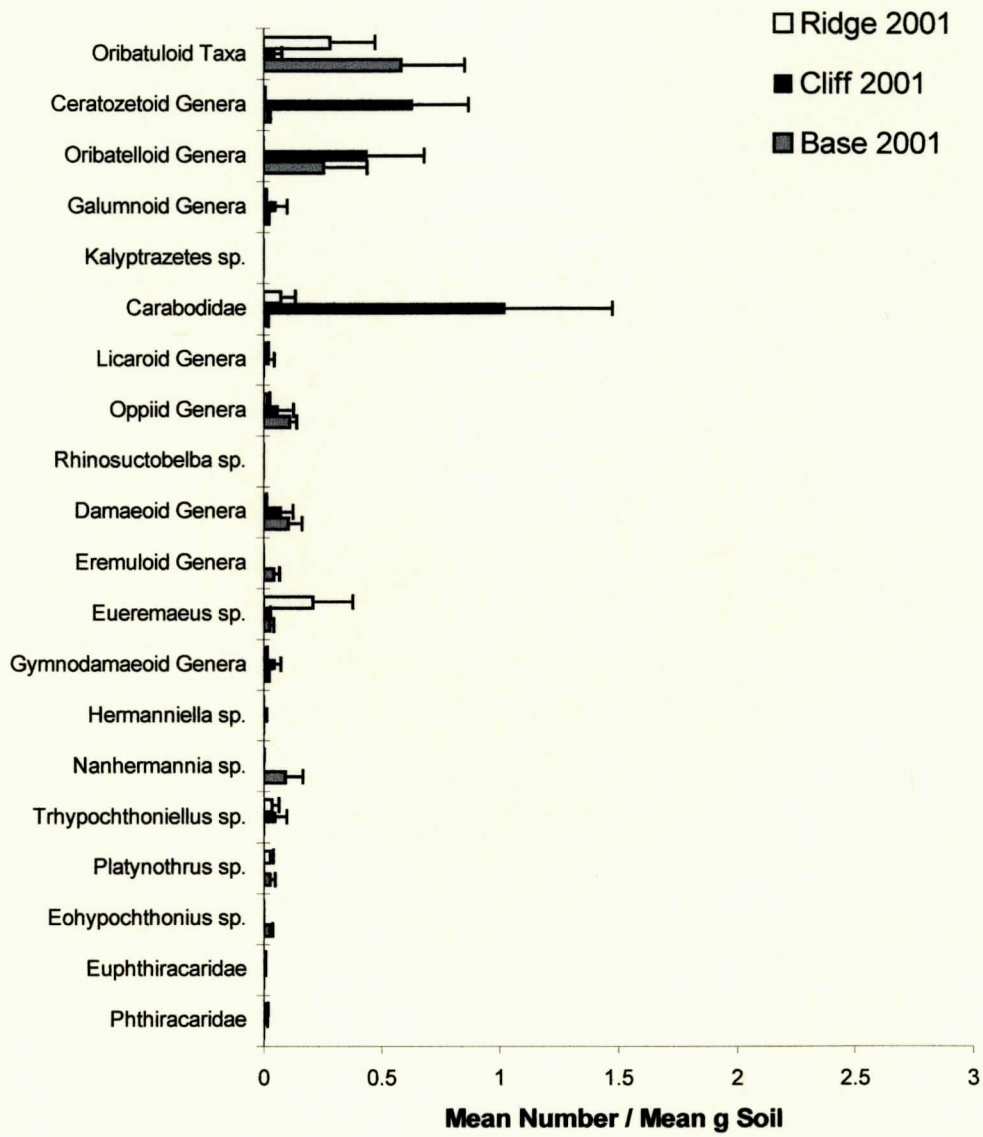


Figure 16. Mean density of adult Oribatida taxa between habitat in year 2001 (Post-Fire). See Appendix A for a complete listing of Oribatida taxa present within the groupings presented here.



with 17 percent.

The Oppiid Genera was most abundant within the base in year 2000, accounting for 16 percent of the oribatida groups collected. In 2001, there was a distinct shift towards the Oribatuloid taxa on the base , being comparable to the ridge in percent occurrence (Table 3).

Oribatid mites associated only with the Ridge habitat include *Rhinosuctobelba* sp., although they were found in very low density only in the year 2000. *Eohypochthonius* sp. and the Eremuloid Genera group were exclusively found in the Base in both years.

Because samples on the ridge and base were collected from the same place in the year 2000 and 2001, I was able to compare changes in total diversity of Oribatida by sample site between years. Overall, diversity on the ridge and base decreased in the post-fire year of 2001 (Figures 17 and 18).

Figure 17. Ridge Oribatida diversity based on the number of taxonomic groups collected in the year 2000 (pre-fire) and year 2001(post-fire). Year 2000 sample number = 8, year 2001 sample number = 10. ND = No data available.

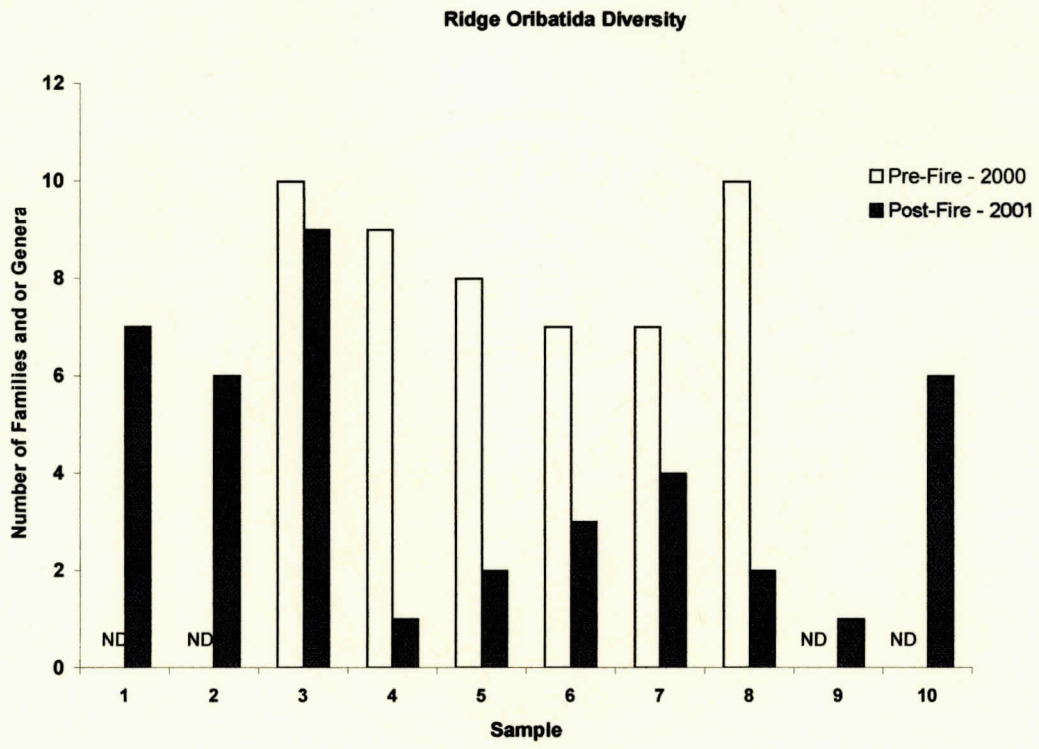
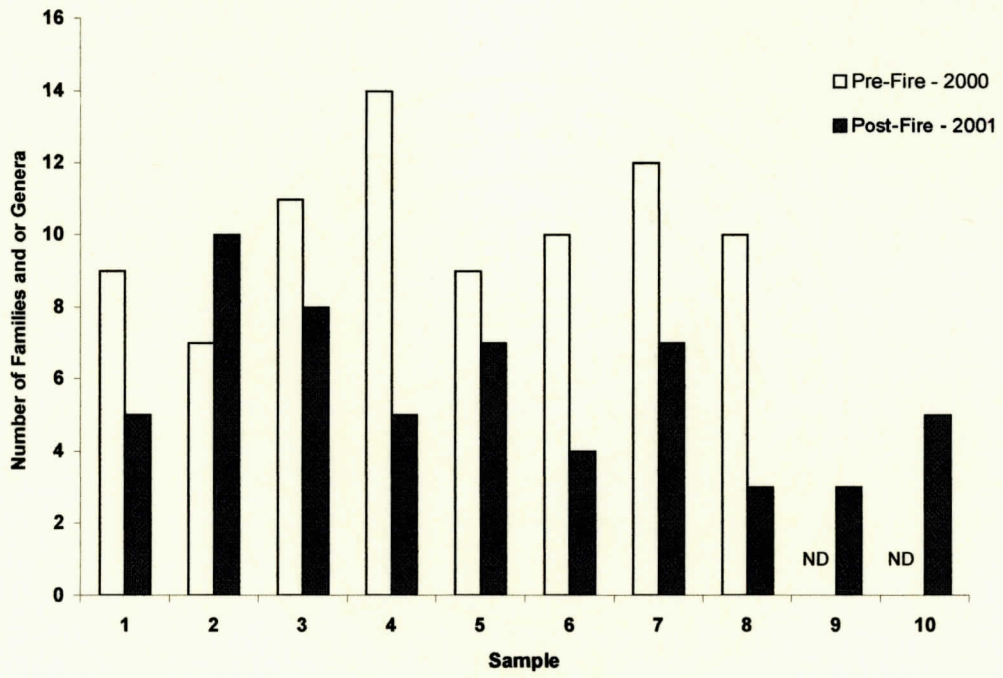


Figure 18. Base Oribatida diversity based on the number of taxonomic groups collected in the year 2000 (pre-fire) and year 2001(post-fire). Year 2000 sample number = 8, year 2001 sample number = 10. ND = No data available.

Base Oribatida Diversity



DISCUSSION

The low intensity ground fire that swept through the study area after the first year of data collecting (i.e.2000) gave me the unique opportunity to quantitatively examine if cliff-face habitats are insulated habitats, by determining the effects of fire on soil microarthropod abundance and community structure. Although previous work has been conducted investigating the effects of fire on forest litter and soil communities, the simultaneous investigation and comparison of microarthropods on cliff-face habitats with the adjacent ridge and base habitats both pre- and post-fire has, to my knowledge, never previously been investigated. Indeed, little is known about the assemblages of microarthropods on cliffs, with or without disturbance.

Because cliffs are potentially insulated habitats, a natural disturbance in the form of fire gives one the opportunity to quantitatively test the hypothesis that cliff-face ecosystems are stable, isolated habitats. I refer to fire as a disturbance in my study because the Linville Gorge Wilderness Area has been fire suppressed for many years. Due to the physical characteristics of a cliff-face habitat, it is fair to assert that fire is not a normal ecological process or disturbance important in maintaining this habitat type, the central focus of this study.

Fire ecology research today is mainly concerned with aspects of habitat maintenance and restoration, thinning of hazardous fuel loads through prescribed burnings, fire behavior and fuel loading. Few studies pertaining to the effects of fire on soil processes ever consider the soil fauna outside of macroinvertebrates, or go beyond describing the large generalized taxonomic groups like class or order. Considering that many believe the soil microarthropod community is indirectly involved with the health and maintenance of the soil ecosystem, closer consideration of these animals needs to be incorporated into the effects of fire on this component of the ecosystem.

Identification of mites (Acari) beyond suborder is rarely carried out when questions about their community composition pertaining to the ecology of the forest floor are being investigated. This is unfortunate (although understandable) due the difficulty in collecting and identifying these small, abundant animals (Wallwork 1983). However, because they are by far the most dominant faunal component of the soil ecosystem, and are speculated to be the single most important factor maintaining the health of soils through their comminution of organic soil particles and interactions with microbes and other soil biota, investigating both the structure of mite communities in unique habitats such as cliffs, combined with the role of ecological disturbance such as fire, provides for a comprehensive approach towards understanding soil/litter processes.

Microarthropods and abiotic soil factors between ridge, cliff and base pre- and post-fire

Both the diversity and abundance of edaphic arthropods is directly related to plant productivity, microhabitat diversity and low inter-specific competition (Hole 1981). Changes in abundance of the Oribatida mites (which numerically dominate the soil microarthropod community), within the LGWA are potentially the result of the effects of fire on the abiotic factors measured. Variability in such factors as porosity, soil structure, humidity, temperature, nutrient concentration, and amounts of organic matter are among those that influence microhabitat structure and, therefore, mite populations (Tousignant and Coderre 1992).

In the pre-fire year of 2000, microarthropod density was lower on the cliff-face habitat compared to the adjacent ridge and base habitats, which were similar in microarthropod abundance (Figure 2). By contrast, in the post fire year of 2001, there was no difference in the abundance of microarthropods between these three habitats (Figure 3). Both the ridge and base habitats had significant reductions in microarthropod abundance between years, in contrast to the cliff-face habitat, which remained unchanged between years. Based on the soil water content, litter/organic depth, and bulk density data, the change in microarthropod abundance within the Gold Coast Wall area was likely related to differences between habitats in these three variables (Figures 9, 11 and 13).

Percent Water Content

Both the microarthropod density and water content were greatest on the ridge and base habitats in the pre-fire year (2000) (Figures 2 and 9) and decreased in the post-fire year (2001) to where there was no significant difference between the cliff and these habitats (Figures 3 and 9). The base habitat showed no significant difference in soil water content between the two years, while there was a significant increase in the percent soil water content on the cliff face and decrease on the ridge in the post-fire year (Figure 10). In general, there appears to be a trend of greater soil microarthropod density with greater soil moisture status, which is in part supported by the results of my regression analysis (Table 1). Blair et al. (1990) reported that out of four forest types studied, the greatest number of forest floor microarthropods recorded was from the type with the highest forest floor moisture content. Anderson (1975) observed a synchronous relationship with rainfall and the abundance of soil animals in chestnut and beech litters. Additionally, Ferguson (2001) reported that Collembola and mite abundance's were positively correlated with weekly soil humidity measurements.

The loss of soil substrate after the fire directly reduced the amount of water capable of being held within the litter/organic layers on the ridge and base. As mites are positively correlated with water content within the soil substrate, there could be some correlation. This association may be due to the interactions associated with the amount of water in the substrate and the amount of

microhabitat diversity and food materials, both abiotic and biotic, available to mites within these habitats. With more water, there will be an increase in mineral leaching and decomposition from which microarthropods can take advantage. Although a clear understanding of the environmental and physical needs of mite communities is not available at this time, several speculations can be offered. With an increase in available water, leaching and decomposition will be enhanced. Some macrophytophages do not consume freshly fallen litter material and therefore require decayed food material (Luxton 1972). Another possibility is that water-soluble polyphenols will be leached and provide for a more attractive food source (Luxton 1972). The combined processes of drying, re-wetting and freezing of the soil increases biotic activity and decomposition of plant materials (Anderson 1973). Therefore, the pre-fire ridge and base would have been more conducive to a higher abundance of microarthropods.

The higher cliff-face water content in the post-fire year of 2001 was possibly the result of the reduced water holding capacity on the ridge. As the fire decreased the amount of litter and organic depth, a resulting reduction in the porosity level and soil moisture retaining properties within the soil lead to increase streamflow and runoff from the ridge onto the cliff face.

Although the cliff face had an increase in water content in 2001, there was no increase in microarthropods from the pre-fire year of 2000 (Figures 2, 3 and 10). The apparently stable cliff-face microarthropod community between the pre- and post-fire years in light of increased water availability is possibly due to the

observation that the vertically oriented cliff-habitat is subject to different environmental inputs compared to the horizontal ridge and base habitats. For example, the principle abiotic variables influencing the moisture status of the cliff face include radiation and wind, both of which radically differ on the horizontally oriented base and ridge. The amount of radiation that a cliff receives is dependent upon four variables; slope, aspect, location (or latitude) of the cliff on the earth's surface with respect to the ecliptic and time (Larson et al. 2000). It is the interaction of these four variables that determines the radiation regime of a cliff face, potentially influencing the microarthropod community composition through its affects on other variables such as soil moisture. Additionally, radiation is an abiotic factor that controls other factors on the cliff-face such as temperature, a direct result of radiation inputs. This will, therefore, influence the moisture regime to varying degrees based on the spatial heterogeneities present on any one particular cliff.

Wind could have both an indirect and direct influence on the microarthropod community composition of cliffs. Indirectly wind can influence the composition through its affects on the boundary layer of both leaves and rock surfaces, which in turn results in an affect on the overall water availability on the cliff. Increased wind force and activity will function to destabilize the boundary layer of air associated with plant leaves and the rock surface. With this destabilization of the boundary layer there will be increased evaporation of water from plant leaves and rock surface under conditions where the moisture level of

the atmosphere is lower than that of the vegetation or rock substrate (Larson et al. 2000). Therefore, biota living on cliffs experiencing high levels of wind activity coupled with dry air masses need to be adapted to such conditions. As the boundary layer is lost from the rock surface, there will be an increase in heat transfer to the atmosphere and evaporation of water resulting in cooling and drying of the substrate (Larson et al. 2000).

Litter/Organic Depth

I observed a significant reduction in the soil litter/organic depth after the fire in both the ridge and base habitat, while the cliff face did not differ between the two years (Figure 12). Because there was no significant decrease in the mean soil moisture on the base habitat in the post-fire year (Figure 10), coinciding with the reduced litter/organic depth (Figure 12) and lower microarthropod density on the base after the fire (Figures 2 and 3), the depth of the litter/organic layer may be a more important variable in sustaining a mean microarthropod density from year to year than soil water content. Blair et al. (1990) concluded that microarthropod densities in four forest types within the Northeastern U.S. were positively related to both the amount of organic matter and soil moisture content. Since soil moisture status is a function of the accumulations of organic matter, Blair et al. (1990) states that organic matter might in fact be the more important factor of the two. This conclusion is further supported by the observation that the percent water content was significantly

greater in the cliff-face habitat in the post-fire year compared to the pre-fire year (Figure 10), with no subsequent increase in microarthropods following this change in water content on the cliff face (Figures 3 and 12). Although there appears to be a significant trend towards lower microarthropod density and lower litter/organic depth in the post-fire year, this may only be the result of sampling depth. Considering that the edaphic community is distributed throughout the soil horizons, sampling in the pre-fire year would only result in observing the microarthropod community within the first five centimeters of the upper most soil horizon (pre-fire community structure). As the fire burned through the forest floor, the upper most horizon layer would have burned away, thus exposing a lower horizon and associated microarthropod community. The result is a post-fire community layer now exposed at the upper layer, with the pre-fire community structure at a lower depth. Therefore, the post-fire year microarthropod density may be representative of a lower depth community. Additionally, the loss of litter/organic depth to fire on the ridge and base resulted directly in a reduction of microarthropods due to microarthropod fatalities, habitat, and habitat resource loss. Although the spatial distribution of microarthropods within the three habitats was not considered here, the litter/organic soil complex itself may contribute to suitable habitat availability capable of influencing microarthropod density. Tousignant and Coderre (1992), recognizing the difficulty in considering all of the variables and their contribution to the distribution and abundance of microarthropods within the soil complex, found that relative humidity,

temperature, and potassium and sodium content were abiotic factors most important in influencing edaphic mite distributions. Whether or not the microarthropod community rebounded between the first and second sampling times is unknown, and therefore conclusions based on habitat structure from post-fire litter/organic inputs is unavailable. However, what is certain is that the loss of microarthropods due to fatalities, habitat, and habitat resource loss did not occur on the cliff-face habitat, which was insulated from the fire.

Bulk Density

Microarthropod abundance has been found to be inversely related to bulk density (Blair et al. 1990). Ridge and Base habitat microarthropod abundance in both the pre- and post-fire years was inversely related to bulk density. In the pre-fire year of 2000, ridge and base habitat microarthropod abundance was high when sample bulk density was low compared to the post-fire year of 2001, when mean bulk density increased and microarthropod abundance decreased (Figures 2, 3, 13 and 14). Conversely, there was no significant difference in the microarthropod abundance or bulk density on the cliff-face habitat in either year (Figures 2, 3 and 14).

The physical characteristic of bulk density may be the abiotic variable that best explains the observed trends of microarthropod abundance from year to year among the three habitats when considering the effects of fire on microarthropod abundance. Of the three abiotic variables used to correlate

microarthropod abundance, only water content and bulk density can be directly comparable to microarthropod density (qualitatively and quantitatively), as these variables represent the environment of the sample cores. Litter/organic depth measurements represent a depth greater than that of the sample core's 5cm depth. Therefore, this measurement is arguably not directly representative of the sample core, and therefore not directly comparable to the number or types of animals in a sample. I assumed that the abundance of microarthropods should be correlated with the sample area depth. Even though there was a significant trend in microarthropod abundance and litter/organic depth, some caution must be taken in interpreting correlations between arthropod abundance and sample depth.

Surface fire spread across a forest floor is related to the availability of fine fuels (which carry the spread of the fire) and the availability of oxygen to these fuel loads. Drier fuels burn faster than wet fuels and the less compact a fuel load is the faster the rate of fire spread. Considering that the sample bulk density of the pre-fire year (2000) was low on the ridge and base, the potential for the loss of the upper layers to fire was high. Low O_e and O_a horizon bulk density leads to an increase in the combustion rate of these organic layers (Frandsen 1987). Because the post-fire year (2001) bulk density measurements were high in the ridge and base, it appears that the fire only burned through the less dense component of the litter/organic layer fuels, there-by leaving the lower and higher density litter/organic layer with minimal alterations. A litter/organic layer with

higher density would be the result of compaction over time. Considering that high bulk density litter/organic layers are more compact (and thus have reduced habitat space) makes it probable that this type of soil would have less microarthropods compared to a soil layers with less bulk density and greater habitat space.

My data suggests that the observed differences between pre- and post-fire years in microarthropod abundance on the ridge and base are the result of different sampling locations within the litter/organic soil stratum, coupled with the abiotic factors of bulk density and soil moisture content associated with these varying soil strata. As the fire burned through the ridge and base habitats, the upper litter/organic layers were lost. This exposed a deeper litter/organic layer in the post-fire year (2001), making post-fire samples indicative of a soil layer classifiable as a lower soil layer in the pre-fire year.

Oribatida abundance by Habitat and Taxonomy Category among the three habitats pre- and post-fire

Of the microarthropods collected in the three habitats in both the pre- and post-fire years, members of the order Acari were the dominant group, followed by the insect order Collembola (Figures 1 and 2). Typically, 90-95% of the total microarthropods in forested soils are mites (Acari) and springtails (Collembola) (Seastedt 1984; Blair et al. 1990). In my study the dominant Acari group in both years was the Oribatida, followed by the Mesostigmata. My findings in the LGWA agree with previous contentions that within most organic forest soils

Oribatid mites are the most abundant group (Wallwork 1983; Migge et al. 1998).

Oribatid mites collected in this study included members the Lower Oribatida [Macropylina] including Mixonomata, Enarthronota, Desmonomata, and Higher Oribatida [Brachypyulina = (Circumdehiscentiae)] (Appendix A). In all, eight groups were identified at the level of genus; three groups were identified at the level of family; eight groups were identified at the level of superfamily, and one group was identified as a taxa group composed of several families.

Based on my results, the cliff face does not contain a unique community of microarthropods when compared to the ridge or base (Appendix A). This does not imply that the cliff habitat is unimportant. As previously stated, soil microarthropods are important in their indirect affects on nutrient cycling. In general, most cliff faces are nutrient limited and characterized by having low plant productivity (Larson et al. 2000). Therefore, it may be that an indirect contribution to the maintenance of the cliff-face's nutrient cycle is the defining role of the microarthropods in the system.

As I am unaware of any previous attempts to characterize the Oribatida mite community composition within the LGWA, there is no way to know if these are base line populations or not. This study, presumably the first of its kind in the LGWA, can be used as a basis for comparisons in the future and used to build upon to obtain a complete picture of the Oribatida within the LGWA.

As previously stated, the microarthropod abundance in my study was closely related to soil water, litter/organic depth and bulk density (Table 2).

Because the Oribatid mites made up the great majority of the arthropods I collected, it appears that soil water content, litter/organic depth and bulk density are important factors contributing to the distribution of Oribatid mite species in LGWA. These factors are especially apparent in the pre-fire year of 2000. However, whether or not the alteration of these factors by the fire was important in changing the overall Oribatid diversity and density or in affecting the reduction of Oribatida due to habitat structure and fatalities as a consequence of the fire is not known, although fire did affect Oribatida diversity on the ridge and base (Figures 17 and 18).

Considering that the Oribatida have remained tied to their ancestral litter habitat (Norton 1990), there must be quantifiable relationships between the Oribatida and litter and soil environment that would elucidate their community composition and abundance in the three habitats within the LGWA. Further consideration of the abiotic aspects of the forest floor ecosystem may provide some insight. Others have hypothesized that with increased resource heterogeneity as a result of increased litter heterogeneity (i.e. litter composed of more than one species), there will be an increase in the rate and efficiency of litter utilization by invertebrates and microflora (Blair et al. 1990). It therefore stands to reason that an increase in resource use and efficiency would be mediated by an increase in species composition. In my study, both the ridge and base are habitats characterized as having greater vegetation and litter-fall compared to the cliff-face habitat. This would equate to greater soil microhabitat

heterogeneity and therefore greater resource availability on the ridge and base. One would expect, therefore, that both the ridge and base would have greater arthropod species composition compared to the cliff face. The cliff-face habitat is, however, a more stable habitat with respect to the litter environment, as there are little to no direct litter inputs from the cliff face due to limited vegetation, wind and gravity. This stability, which results in a longer development time of the soil substrate and presumably slower decomposition rates may contribute to a stable microarthropod community composition. Consequently, there was no significantly observable difference among the three habitats in arthropod species composition. Observed differences between the habitats included only a significant difference in mite abundance among the three habitats in the pre-fire year of 2000. Anderson (1975) attributed the increase in microarthropod diversity within the seral stages of beech and chestnut litter within litter bags to be a function of both food resource partitioning and increases in microhabitat complexity. Hansen and Coleman (1998), in a study of litter complexity and composition as determinants of Oribatid mite diversity and composition, found mixed litters to decompose faster and contain a higher degree of microhabitats and Oribatid species than simple or monotypic litters. Additionally, they observed the trend of similar species composition between similar litter-types, suggesting that species do differentiate between litter types. Overall studies such as these and others (see Hansen 2000) suggest that Oribatid mite composition is related to habitat composition. As it was not demonstrated that there was a difference in

Oribatid composition among the three habitats, the mite composition within the LGWA may be limited to those species listed in Appendix A.

Previous work suggests that the depth of the litter layer is important in determining microarthropod assemblages. Hansen and Coleman (1998) found that the number of different habitats within the *Betula allegheniensis*, *Quercus rubra*, and *Acer saccharinum* litter (both singularly and mixed) increased with depth. Both the ridge and base habitats in the pre-fire year were significantly deeper with respect to litter and organic layer depth when compared to the cliff habitat. Microhabitat variety was not a variable measured in this study.

However, the idea that litter and organic heterogeneity, along with habitat complexity, increases with depth and contribute to higher Oribatida numbers could explain why the ridge and base habitats in the pre-fire year contained a greater abundance of Oribatid mites. Both the ridge and base habitats obtain litter inputs from the vegetation associated with each, while on the cliff-face habitat the vegetation is patchy, mostly herbaceous, and predominately lacking a loamy component. Further research is needed to understand this relationship.

Summary

While the cliff-face Oribatid community composition was not different from the adjacent ridge and base habitats, there are differences in the quantity of microarthropods among the three habitats in the pre-fire year of 2000 compared to the post-fire year of 2001. My data supports the notion that the cliff-face

habitat is an insulated habitat from fire. Due to its orientation within the landscape, the Gold Coast Wall area of the LGWA was insulated from the fire that burned through the area in late October to late November of 2000. Cliff-face communities are not fire maintained habitats due to the lack of fuels and low vegetation cover which allows fires to burn through habitats (Larson et al. 2000). In fact, the absence of fire may be a controlling factor in the development and persistence of cliff habitats and the plant and animal species living there (Larson et al. 2000). Within the LGWA, the cliff-face habitat was found to be a stable habitat between the two years, while the ridge and base habitats were subject to the effects of the fire. Although, I maintain that the cliff-face habitat is unique within the LGWA when compared to the ridge and base habitats, it is not significantly different with respect to the Oribatid mite community. Cliff-face microarthropods may be under a continued state of disturbance as a result of stochastic abiotic variables such as moisture and temperature. Therefore, although insulated from fire, the cliff is subject to perturbations similar enough to those on the ridge and base to result in similar levels of microarthropods within the litter layers.

REFERENCES CITED

- Anderson, J.M. (1975) Succession, diversity and trophic relationships of some soil animals in decomposing leaf litter. *Journal of Animal Ecology* 44:475-495.
- Balogh, J. (1972) The oribatid genera of the world. Akadémiai Kiadó. Budapest. 188pp.
- Balogh, J. and Balogh, P. (1992a) The oribatid mites genera of the world. Volume I. The Hungarian Natural History Museum. Budapest. 263pp.
- Balogh, J. and Balogh, P. (1992b) The oribatid mites genera of the world. Volume II. The Hungarian Natural History Museum. Budapest. 375pp.
- Barnes, R.D. (1987) *Invertebrate Zoology*. 5th ed. Philadelphia: Saunders College Publishing, 893 pp.
- Baskin, J.M., and Baskin, C.C. (1988) Endemism in rock outcrop plant communities of unglaciated eastern United States: an evaluation of the roles of the edaphic, genetic and light factors. *Journal of Biogeography* 15: 829-840.
- Bever, J.D. (1994) Feedback between plants and their soil communities in an old field community. *Ecology* 75:1965-1977.
- Blair, J.M., Parmelee, R.W., and Beare, M.H. (1990) Decay rates, nitrogen fluxes, and decomposer communities of single- and mixed-species foliar litter. *Ecology* 71: 1976-1985.
- Boerner, R.E.J. (1982) Fire and nutrient cycling in temperate ecosystems. *BioScience* 32:187-192.
- Bunce, R.G.H. (1968) An ecological study of Ysgolion Duon, a mountain cliff in Snowdonia. *Journal of Ecology* 56:59-75.
- Burbanck, M.P., and Platt, R.B. (1964) Granite outcrop communities of the piedmont plateau in Georgia. *Ecology* 45:292-306.
- Coleman, D.C., and Crossley Jr., D.A. (1996) *Fundamentals of soil ecology*. Academic Press, San Diego. 205p
- Crossley, D.A., Jr. (1977a) The roles of saprophagous arthropods in forest soils: current status and concepts, pp 49-56. *in* Mattson, W.J. Ed. *The role of arthropods in forest ecosystems*. Springer, New York, USA. 104 pp.

- Crossley, D.A., Jr. (1977b) Oribatid Mites and Nutrient Cycling. pp 71-85.
in: Biology of Oribatid mites. D.L. Dindal, Ed. SUNY-CESF,
Syracuse, NY.
- Crossley, D.A.Jr., and Blair, J.M. (1991) A high-efficiency, "low-
technology" Tullgren-type extractor for soil microarthropods.
Agriculture, Ecosystems and Environment. 34:187-192.
- Davis, P.H. (1951) Cliff vegetation in the Eastern Mediterranean. *Journal
of Ecology* 39:63-93.
- DeBano, L.F., Neary, D.G., and Ffolliott, P.F. (1998) Fire's effects on
ecosystems. John Wiley & Sons, Inc. New York. USA. 333p.
- Dindal, D.L. (Ed) (1990) *Soil Biology Guide.* John Wiley & Sons, Inc. New
York. USA. 1349pp
- Elliott, W.M., Elliott, N.B., and Wyman, R.L. (1993) Relative effect of litter
and forest type on rate of decomposition. *Am. Midl. Nat.* 129:87-95.
- Evans, G.O. (1992) *Principles of Acarology.* Wallingford, UK. CAB
International. 563 pp.
- Ferguson, S.H. (2001) Changes in trophic abundance of soil arthropods
along a grass-shrub-forest gradient. *Canadian Journal of Zoology*
79:457-464.
- Frandsen, W.H. (1987) The influence of moisture and mineral soil on the
combustion limits of smoldering forest duff. *Canadian Journal of
Forest Research* 17:1540-1544.
- Hansen, R.A. (2000) Effects of habitat complexity and composition on a
diverse litter microarthropod assemblage. *Ecology* 81:1120-1132.
- Hansen, R.A., and Coleman, D.C. (1998) Litter complexity and composition
are determinants of the diversity and species composition of oribatid
mites (Acari: Oribatida) in litterbags. *Applied Soil Ecology* 9:17-23.
- Hansen, R.A., Williams, R.S., Degenhardt, D.C., and Lincoln, D.E. (2001)
Non-litter effects of elevated CO₂ on forest floor microarthropod
abundances. *Plant and Soil* 236:139-144.
- Hole, F.D. (1981) Effects of animals on soil. *Geoderma* 25:75-112.

- Karppinen, E. (1958) Über die Oribatiden (Acar.) der finneschen Waldböden. *Ann. Zool. Soc. Vanamo*. 19: 1-43. *in* Siepel, H. (1996) Biodiversity of soil microarthropods: the filtering of species. *Biodiversity and Conservation* 5:251-260.
- Kethley, J. (1990) Acarina: Prostigmata (Actinedida). p 667- 756. *in* Dindal, D.L. (Ed). *Soil Biology Guide*. John Wiley & Sons, Inc. New York. USA. 1349 pp.
- Knoepp, J.D., and Swank, W.T. (1993) Site preparation burning to improve southern Appalachian pine-hardwood stands: nitrogen responses in soil, soil water, and streams. *Canadian Journal of Forest Research* 23:2263-2270.
- Krantz, G.W. (1978) A manual of acarology. 2nd ed. Oregon State University Book Stores, Inc. Corvallis. 488 pp.
- Krantz, G.W., and Ainscough, B.D. (1990) Acarina: Mesostigmata (Gamasida). p 583-665. *in* Dindal, D.L. (Ed). *Soil Biology Guide*. John Wiley & Sons, Inc. New York. USA. 1349 pp.
- Larson, D.W. (1990) Cliff hangers: Neglected treasures on the escarpment cliffs. *Clintonia* 5:1-4.
- Larson, D.W., Spring, S.H., Matthes-Sear, U., and Bartlett, R.M. (1989) Organization of the Niagra Escarpment cliff community. *Canadian Journal of Botany* 67: 2731-2742.
- Larson, D.W., Matthes, U., and Kelly, P.E. (1999) Cliffs as natural refuges. *American Scientist* 87: 411-417.
- Larson, D.W., Matthes, U., and Kelly, P.E. (2000) *Cliff ecology: pattern and process in cliff ecosystems*. Cambridge university Press. Cambridge UK. 340pp.
- Lindquist, E. E. (1984) Current theories on the evolution of major groups of Acari and on their relationship with other groups of Arachnida, with consequent implications for their classification. *In*: Griffiths, D.A. & Bowman, C.E. (Eds). *Acarology VI, Vol 1*. Chichester: Ellis Horwood Limited, pp. 28-62.
- Luxton, M. (1972) Studies on the oribatid mites of a Danish beech wood soil. *Pedobiologia* 12:434-463.

- Marshall, V.G., Reeves, R.M., and Norton, R.A. (1987) Catalogue of the oribatida (acari) of continental United States and Canada. *Memoirs of the Entomological Society of Canada*. 139: 1-418.
- McBrayer, J.F., and Reichle, D.E. (1971) Trophic structure and feeding rates of forest soil invertebrate populations. *Oikos*. 22:281-388.
- Merchant, V.A., Crossley, D.A. Jr. (1970) An inexpensive, high-efficiency Tullgren extractor for soil microarthropods. *Journal Ga. Entomol. Soc.* 5:83-87.
- Migge, S., Maraum, M., Stefan, S., and Schaefer, M. (1998) The oribatid mite community (Acarina) of pure and mixed stands of beech (*Fagus sylvatica*) and spruce (*Picea abies*) of different age. *Applied Soil Ecology* 9:115-121.
- Moritz, M. (1965) Untersuchung über den Einfluß von Kahlschlagmaßnahmen auf die Zusammensetzung von Hornmilbengemeinschaften (Acari: Oribatei) norddeutscher Laubund Kiefern-mischwälder. *Pedobiologia*. 5:56-101. *in* Siepel, H. (1996) Biodiversity of soil microarthropods: the filtering of species. *Biodiversity and Conservation* 5:251-260.
- Newell, C.L., and Peet, K.R. (1998) Vegetation of Linville Gorge Wilderness, North Carolina. *Castanea* 63: 275-322.
- Norton, R.A. (1985) Aspects of the biology and systematics of soil arachnids, particularly saprophagous and mycophagous mites. *Quaestiones Entomologicae* 21:523-541.
- Norton, R.A. (1990). Acarina: Oribatida. p 779- 803. *in* Dindal, D.L. (Ed). *Soil Biology Guide*. John Wiley & Sons, Inc. New York. USA. 1349pp.
- Norton, R.A. (1992) The keys to the oribatids of North America. Unpublished.
- Norton, R.A. (2000). Soil Acarology: Oribatida. 52nd Annual Acarology Summer Program Folder Handout. Unpublished. The Ohio State University.
- O'Connor, B.M. (1984) Phylogenetic relationships among higher taxa in the acariformes, with particular reference to the astigmata. pp19-25. *in* Griffiths, D.A. & Bowman, C.E. (Eds). *Acarology VI, Vol 1*. Chichester: Ellis Horwood Limited, pp. 28-62.

- Oosting, H.J., and Anderson, L.E. (1937) The vegetation of a barefaced cliff in Western North Carolina. *Ecology* 18:280-292.
- Panikov, N.S., and Simonov, Y.V. (1987) Influence of microarthropods on rate of decomposition of plant litter. *The Soviet Journal of Ecology* 17:194-200.
- Schlatte, G., Kampichler, C., and Kandeler, E. (1998) Do soil microarthropods influence microbial biomass and activity in spruce forest litter? *Pedobiologia* 42:205-214.
- Schlesinger, W.H. (1997). *Biogeochemistry: An analysis of Global Change*. 2nd ed. Academic Press. San Diego. California. USA. 588p.
- Seastedt, T.R. (1984) The role of microarthropods in decomposition and mineralization processes. *Annual Review of Entomology* 29: 25-46.
- Shure, D.J., and Ragsdale, H.L. (1977) Patterns of primary succession on granite outcrop surfaces. *Ecology* 58:993-1006.
- Smith, J.K. (Ed). (2000) *Wildland fire in ecosystems: effects of fire on fauna*. Gen. Tech. Rep. RMRS-GTR-42-vol. 1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 83p.
- Smith, R.L. (1990) *Ecology and Field Biology*. 4th Ed. Harper and Row, New York USA. 922pp.
- Tousignant, S., and Coderre, D. (1992) Niche partitioning by soil mites in a recent hardwood plantation in Southern Québec, Canada. *Pedobiologia* 36:287-294.
- United States Department of Agriculture. (1991) *Linville Gorge Wilderness: Pisgah National Forest*. Map.
- Ursic, K.A., Kenkel, N.C., and Larson, D.W. (1997) Revegetation dynamics of cliff faces in abandoned limestone quarries. *Journal of Applied Ecology* 34:289-303.
- Wallwork, J.A. (1983) Oribatids in forest ecosystems. *Ann. Rev. Entomol.* 28:109-130.
- Walter, D.E. (1987) Trophic behavior of "mycophagous" microarthropods. *Ecology* 68:226-229.

- Walter, D.E., and Proctor, H.C. (1999) *Mites: ecology, evolution and behavior*. CABI Publishing, New York, 352pp.
- Werner, M. R., and Dindal, D.L. (1987) Nutritional ecology of soil arthropods. *in* Slansky, F. Jr., and Rodriguez, J.G. eds (1987) *Nutritional ecology of insects, mites, spiders, and related invertebrates*. John Wiley & Sons, New York.
- Winterringer, G.S., and Vestal, A.G. (1956) Rock-ledge vegetation in Southern Illinois. *Ecological Monographs* 26:105-130.
- Wiser, S.K. (1994) High-elevation cliffs and outcrops on the Southern Appalachians: vascular plants and biogeography. *Castanea* 59:85-116.
- Wiser, S.K., Peet, R.K., and White, P.S. (1996) High-elevation rock outcrop vegetation of the Southern Appalachian Mountains. *Journal of Vegetation Science* 7:703-722.
- Zabinski, C.A., and Gannon, J.E. (1997) Effects of recreational impacts on soil microbial communities. *Environmental Management* 21:233-238.

APPENDIX A

**Taxonomic Catalogue of the Oribatida within the Linville Gorge Wilderness
Area, North Carolina
Organized based on Marshall et al. 1987.**

MIXONOMATA (Grandjean, 1969)

	Pre-Fire 2000			Post-Fire 2001		
	Ridge	Cliff	Base	Ridge	Cliff	Base
PHTHIRACAROIDEA (Perty, 1841)				X		
Phthiracariidae (Perty, 1841)				X		
<i>Atropacarus</i> Ewing, 1841					X	
<i>Hoplophorella</i> Ewing, 1909				X		
<i>Hoplophthiracarus</i> Jacot, 1933				X		
<i>Phthiracarus</i> Perty, 1841				X		
EUPHTHIRACAROIDEA (Jacot, 1930)				X		
Euphthiracariidae (Jacot, 1930)				X		
<i>Euphthiracarus</i> Ewing, 1917					X	
<i>Microtritia</i> Markel, 1964				X		
<i>Rhysotritia</i> Markel and Meyer, 1959				X		

ENARTHRONOTA (Grandjean, 1947)

	Ridge	Cliff	Base
HYPOCHTHONOIDEA (Berlese, 1910)			
HYPOCHTHONIDAE (Berlese, 1910)			
<i>Echypochothonus</i> Fernandez, 1984			X

DESMONOMATA (Woolley, 1973)

	Ridge	Cliff	Base
CROTONOIDEA (Thorell, 1876)			
Camisiidae (Oudemans, 1900)			
<i>Piatyothrus</i> Berlese, 1913	X	X	X
Trhyochothoniidae (Willmann, 1931)			
<i>Trhyochothoniellus</i> Willmann, 1928	X	X	X
NANHERMANNOIDEA			
NANHERMANNIDAE (Sellnick, 1928)			
<i>Nanhermannia</i> Berlese, 1913	X		X

BRACHYPYLINA (Hull, 1918) [= Circumdehiscenciae]

Apteroqasterine oribatid mites

	Ridge	Cliff	Base
HERMANNIELLOID GENERA			
HERMANNIELLOIDEA (Grandjean, 1934)			
4.1 Hermannielloidea Genera			
Hermanniellidae (Grandjean 1934)			
<i>Hermanniella</i> Berlese, 1908		X	
GYMNODAMAEOID GENERA			
GYMNODAMAEOIDEA (Grandjean, 1954)			
4.2 GYMNOAMAEOIDEA GENERA			
Liodidae (Grandjean 1954)			
<i>Liodia</i> (Grandjean 1954)		XX	XX
<i>Piatyfolides</i> Berlese, 1908	X		
GYMNODAMAEIDAE (Grandjean 1954)	X		
<i>Gymnodamaeus</i> Kulczynski, 1902		X	
<i>Nortonella</i> Paschoal, 1982		X	
PLATEREMAEOIDEA (Traaegardh, 1931)			
PLATEREMAEIDAE (Traaegardh, 1931)			
<i>Allocladamaeus</i> Banks, 1947		X	
EREMAEOID GENERA			
EREMAEOIDEA (Woolley, 1965)			
4.3. Eremaeoid Genera			
EREMAEIDAE (Sellnick, 1928)	X	X	X
<i>Euremaeus</i> Mielnicz, 1963 (= <i>Kartoeramaeus</i> Higgins, 1967)	X	X	X

		Pre-Fire 2000		Post-Fire 2001		
		Ridge	Cliff	Ridge	Cliff	
EREMULOID GENERA	AMEROBELBOIDEA (Grandjean, 1954)					
	4.4. Eremuloid Genera					
	EREMULIDAE (Grandjean, 1965)					
	EREMOBELBIDAE (Balogh, 1961)					
DAMAEOID GENERA	DAMAEOIDEA (Berlese, 1896)					
	4.5. DAMAEOID GENERA					
	DAMAEIDAE (Berlese, 1896)					
	Belba Norton, 1978 (<i>Protobelba</i> Norton, 1978)					
Suctobeloid Genera	OPPIOIDEA (Grandjean, 1954)					
	4.7. Suctobeloid Genera					
	SUCTOBELBIDAE (Jacot, 1938)					
	Rhinusuctobelba Woolley and Higgins, 1969					
	Oppioid Genera	4.10. Oppioid Genera				
		4.10.2. Oppiid Genera (<i>Oppiidae grandjean</i> , 1951)				
	LIACAROID GENERA	GUSTAVIOIDEA (Oudemans, 1900)				
		[= LIACAROIDEA (Sellnick, 1928)]				
		4.13. Liacaroid Genera				
		LIACARIDAE (Sellnick, 1928)				
<i>Liacarus</i> Michael, 1898						
<i>Procoronyetes</i> Woolley, 1969						
ASTEGISTIDAE (Balogh, 1961)						
<i>Cultroribula</i> Berlese, 1908						
<i>Furcorribula</i> Balogh, 1943						
PELOPPIIDAE (Balogh, 1943)						
<i>Ceratoppia</i> Berlese, 1908						
<i>Metapyropia</i> Woolley, 1969						
CARABODOID GENERA	CARABODOIDEA (C.L. Koch, 1837)					
	4.14. Carabodoid Genera					
	CARABODIDAE (C.L. Koch, 1837)					
MICROZETOID GENERA	MICROZETOIDEA (Grandjean, 1936)					
	5.4. Microzetoid Genera					
	MICROZETIDAE (Grandjean, 1936)					
GALUMNOID	5.5. Galumnoid Genera					
Pterogasterine oribatid mites						
MICROZETOID GENERA	5.4. Microzetoid Genera					
GALUMNOID	5.5. Galumnoid Genera					

		Pre-Fire, 2000			Post-Fire, 2001		
		Ridge	Cliff	Base	Ridge	Cliff	Base
ORIBATELLOID GENERA	5.3. Oribateilloid Genera			XX			
	CERATOZETOIDEA (Jacot, 1925)						
	ORIBATELLOIDEA (Jacot, 1925)		x				
	ACHIPTERIOIDEA (Thor, 1929)						
	AUSTRACHIPTERIIDAE (Luxton, 1985)						
	<i>Paralammellobates</i> Bhaduni et Raychaudhuri, 1968						
	<i>Lammellobates</i> Hammer, 1958						
	ORIBATELLIIDAE (Jacot, 1925)						
	<i>Adoribatella</i> Woolley, 1967						
	<i>Ferocella</i> Grabowski, 1971						
	<i>Ophidiotrichus</i> Grandjean, 1953						
	<i>Oribatella</i> Banks, 1895						x
	TEGORIBATIDAE (Grandjean, 1954)						
<i>Lepidozetes</i> Berlese, 1910			x				
<i>Tegoribatetes</i> Ewing, 1917							
ACHIPTERIIDAE (Thor, 1929)							
<i>Achiptera</i> Berlese, 1885			x				
<i>Anschiptera</i> Grandjean, 1932			x			x	
<i>Paraschiptera</i> Van der Hammen, 1952			x			x	
CERATOZETOID GENERA	5.2 Ceratozetoid Genera			XX			
	CERATOZETOIDEA (Jacot, 1925)						
	ZETOMMIDAE (Shaldybina, 1966)						
	<i>Hererozetes</i> Wilmann, 1917						x
<i>Zetomimus</i> Hull, 1916						x	
MYCOBATIDAE (Grandjean, 1954)							
<i>Pelopsia</i> Hall, 1911							
ORIBATULOID TAXA	5.1. Oribatuloid Taxa		XX	XX			
	ORIPODOIDEA (Jacot, 1925)						
	PROTORIBATIDAE (J. Balogh et P. Balogh, 1964)						
	<i>Liebstackia</i> Oudemans, 1906						
	ORIBATULIDAE (Thor, 1929)						
	<i>Oribatula</i> Berlese, 1867						x
	<i>Paraphaulopoda</i> Hammer, 1967						x
	SCHLERORIBATIDAE (Grandjean, 1953)						
<i>Scheloribatetes</i> Berlese, 1908						x	
<i>Hemiteilus</i> Berlese, 1916						x	
<i>Floribatetes</i> Norton & Kethley, 1989						x	

VITA

Robert Pleszewski attended East Carolina University in Greenville, North Carolina where he concentrated in Ecological and Environmental studies and graduated with a Bachelor of Science Degree in Biology in 1994. After graduation Robert pursued his interests in traveling, mountain biking and climbing throughout the Appalachian Mountains of North Carolina and Virginia.

In 1995 Robert enrolled in postgraduate studies in Russian language at the University of North Carolina, and in 1997 did a Study Abroad Program at the Moscow State Linguistics University, Russia.

On his return from Russia, Robert taught Biology and Chemistry courses at the community college level for two years, and in 1999 he entered the Appalachian State Universities graduate biology program. From September of 2002 to October of 2003, Robert worked for the United States Geological Survey and National Park Service in the area of Fire Ecology.