# THE LONG TERM EFFECTS OF CLEARCUTTING ON THE DIVERSITY AND ABUNDANCE OF ORIBATID (Cryptostigmata) MITES OF WESTERN NEWFOUNDLAND BALSAM FIR (Abies balsamea) FORESTS



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# The Long Term Effects of Clearcutting on the Diversity and Abundance of Oribatid (Cryptostigmata) Mites of Western Newfoundland Balsam Fir (*Abies balsamea*) Forests.

by

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## ABSTRACT

In an attempt to assess long-term effects of clearcutting on oribatid mite populations, oribatid species diversity and distribution were examined in three different aged forest stands (old - uncut, 60 years and 40 years old regrowth) within balsam fir (*Abies balsamea*) - fern (*Dryopteris*) (FD) and a balsam fir - horsetail (*Equisetum*) (FE) forest types. A total of 360 and 120 soil samples (10 cm x 10 cm x 10 cm) were taken from the two forest types, respectively. Each sample was subsequently divided into upper and lower 5 cm halves to assess vertical distribution of mites. Both species diversity and abundance decreased with increasing soil depth. In addition, relative abundances of smaller oribatid species such as *Oppiella washburni* and *Suctobelbella* spp. increased in the lower layers whereas larger species such as *Parachipteria travei* decreased.

A series of microhabitat samples were also collected in the balsam fir - fern forest to include as many oribatid species as possible. One species, *Euremaeus marshalli*, occured only in microhabitat samples. Average abundances of oribatid mites per sample ranged from 344 to 1894 in FD and from 501 to 886 in FE forest types.

In total, 91 species representing 41 families were collected including 17 new generic and 35 new species records for Newfoundland. *Haplozetes* sp. was also collected representing a new genus record for Canada. The ecology of all species collected is described. The number of species occurring in any one site ranged from 55 to 65 in the FD sites and from 51 to 59 in the FE sites. Populations in both forest types were

dominated by the same common species: *Eniochthonius minutissimus*, *Synchthonius crenulatus*, *Steganacarus thoreaui*, *Nanhermannia bryophila*, *Tectocepheus velatus*, *Oppiella washburni*, *Suctobelbella* spp. and *Parachipteria travei*. Several species were collected from only one forest type and may be useful indicators of differing environmental conditions. In particular, *Epidamaeus longitarsalis*, *Eupterotegaeus* sp., *Fuscozetes setosus* and *Dentachipteria* sp. were characteristic of FD sites whereas *Gozmanyina majestus*, *Ceratozetes gracilis*, *Sphaerozetes arcticus*, *Eupelops* sp. and *Propelops canadensis* were characteristic of FE sites.

Separation of the sample sites through cluster and TWINSPAN analysis indicated differences in species diversity and relative abundances between age classes of both FD and FE forests. However, this separation was most pronounced between the sites of FD forest. Species richness and diversity tended to be highest in the forty year old sites of the FD forest and in the old sites of the FE forest.

Oribatid population data from the FD forest was further assessed in relation to soil and vegetation data from the sites using principle components and discriminant function analysis. This indicated that different forest ages were associated with different soil and vegetation characters as well as different mite species.

Long-term effects of clearcutting vary between forest types and are more obvious in species diversity and relative abundances than in total oribatid abundances. These variations in oribatid community structure between the forest age classes are apparently related to successional changes in the maturing forests.

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## 1.0 INTRODUCTION

Soil microarthropods are closely associated with the processes of decomposition and nutrient cycling, which are important regulators of forest productivity (Dindal 1990, Wallwork 1976, Harding and Stuttard 1974). In forest soils, mites are the most ubiquitous and diverse group of microarthropods, colonizing a variety of terrestrial habitats ranging from aerial portions of vegetation to animal nests. The soil acari belong to four suborders, Mesostigmata, Prostigmata, Astigmata and Oribatida (Cryptostigmata) (Wallwork 1970). Oribatid mites are one of the numerically dominant soil microarthropod groups with densities reaching several hundred thousand per square metre (Norton 1990). They are slow moving mites of which many require specific temperature and moisture conditions. Many are considered mesophilous, depending on saturated relative humidity, whereas, some are xerophilic inhabiting lichen and tree bark (Wallwork 1970).

Oribatid development time from egg to adult varies with environmental factors such as temperature and humidity and with body size. Most medium sized oribatids in the temperate zone probably complete their life cycle in one year but larger species may require two years. There is evidence that repeated reproduction by female oribatid mites and the over-wintering of larval instars as well as adults, result in overlapping generations and a fairly stable population (Norton 1990).

Oribatid mites are particulate feeders generally using chelicerae to tear food into pieces small enough to swallow (Norton 1990). The classification of oribatid feeding types is important in understanding their role in a particular habitat (Siepel and Ruiter-

Dijkman 1993). Based on feeding preference and the assumption that the primary role of oribatids in decomposition is one of litter fragmentation, Luxton (1972) distinguished several feeding guilds of oribatid mites: macrophytophages feed on higher plant material such as decaying wood and leaves, microphytophages prefer soil microflora including fungi, yeasts, algae and bacteria and panphytophages, encompassing a majority of oribatids, feed on both plant material and microflora. Siepel and Ruiter-Dijkman (1993) proposed an alternate system which defined various oribatid feeding guilds based on carbohydrase activity including herbivorous grazers, herbivorous browsers, fungivorous grazers, fungivorous browsers, herbo-fungivorous grazers, opportunistic herbo-fungivores and omnivores.

It has been suggested that the oribatid mites play a major role in the regulation of organic decomposition in forest soil by affecting decomposition rates in various ways. The feeding of microphytophagous mites on a variety of microflora limits the immobilization of nutrients by fungi and bacteria, increases microbial activity and influences both microbial and fungal community structure through selective feeding and spore distribution (Norton 1990, Mitchell and Parkinson 1976, Crossley 1977). Through fragmentation of organic debris, macrophytophagous mites facilitate leaching of soluble materials (Bird and Chatarpaul 1986) and decomposition by bacteria which take advantage of the increased surface area, moisture retention and pH (Crossley 1977). Oribatid mites have also been shown to play a role in the channelling and mixing of forest soils (Crossley 1977). Thus, forest harvesting techniques that affect mite community structure may

indirectly affect the rate of nutrient cycling and decomposition by both bacteria and fungi, resulting in a decline in site productivity (Blair and Crossley 1988).

Despite the importance of the Oribatida, there have been few studies of the effects of forest harvesting on population structure and no studies have examined the long term recovery of oribatid communities following clearcutting. Both Seastedt and Crossley (1981) and Abbott et al. (1980) have reported an immediate drop in oribatid densities following clearcutting in the southern Appalachians citing increased temperatures as the possible cause. Of the major microarthropod groups examined the oribatid population, which showed the most extreme immediate response to the clear-cut and remained the most reduced (Blair and Crossley 1988). This slow recovery may indicate a higher susceptibility to microclimatic changes and may be a reflection of the low fecundity and long generation times of oribatid mites (Norton 1985).

Bird and Chatarpaul (1986) also noted a decrease in oribatid densities following whole tree and conventional forest harvesting in a mixed conifer-hardwood forest on the Canadian Shield. However, analysis at the generic level indicated that no taxa were lost after harvesting. A similar study by Vlug and Borden (1973) on the effects of logging and slash burning on Acari and Collembola in a British Columbia coniferous forest reported that the decrease in oribatid densities following logging was accentuated by subsequent burning.

Other researchers have reported an initial increase in oribatid abundance after clearcutting followed by a long-term decline. The increase was attributed to a temporary

increase in organic debris following clearcutting which provided some species with the necessary resources to reproduce rapidly (Huhta 1976; Huhta et al. 1967, 1969). Unfortunately, most of these studies group oribatid species as a single unit so effects on individual species are not known. Some species unable to tolerate the drastic microhabitat change brought on by clearcutting may be eliminated while others may flourish (Huhta et al. 1967).

Since the oribatid fauna of Newfoundland is relatively unstudied, this study has three main goals:

1. To provide baseline data on oribatid populations of mature balsam fir forests of western Newfoundland for use in long term ecological monitoring.
2. To determine the community composition of the oribatid fauna in two different forest types of western Newfoundland.
3. To assess the long term effects of clearcutting on oribatid diversity and abundance through comparison of uncut (mature) and regrowth (60 and 40 years) sites within each forest type.

# 2.0 MATERIALS AND METHODS

## 2.1 STUDY SITES

An adequate understanding of oribatid fauna recovery in a given site after forest harvesting would involve a long term study requiring large commitments of finances and time. A practical alternative was to select for comparison three different aged forest stands from the same geographical area, having similar soil, moisture and vegetation characters. Undoubtably, the main problem was to maintain homogeneity between the sites.

The study sites were located on the western coast of Newfoundland (Figure 1), a heavily forested area with the predominant species being *Abies balsamea* (balsam fir). Topography of this area is rugged with elevations ranging from sea level to over 800m (Roberts 1983).

This study examined the oribatid fauna of two different forest types which lay in close proximity to one another: balsam fir-*Dryopteris* (FD); and balsam fir-*Equisetum* (FE) forests (Figures 2, 3, 4 and 5). According to Meades and Moores (1989), FD sites are characterized as being nutrient rich and moderately moist whereas FE sites are wetter with a wider variety of plant species composing the understory (Table 1).

Three different aged stands, 40 year, 60 year and old (no history of cutting), were chosen within each forest type, with selection criteria for stands including geographical proximity, similar edaphic and moisture conditions and similar vegetation.

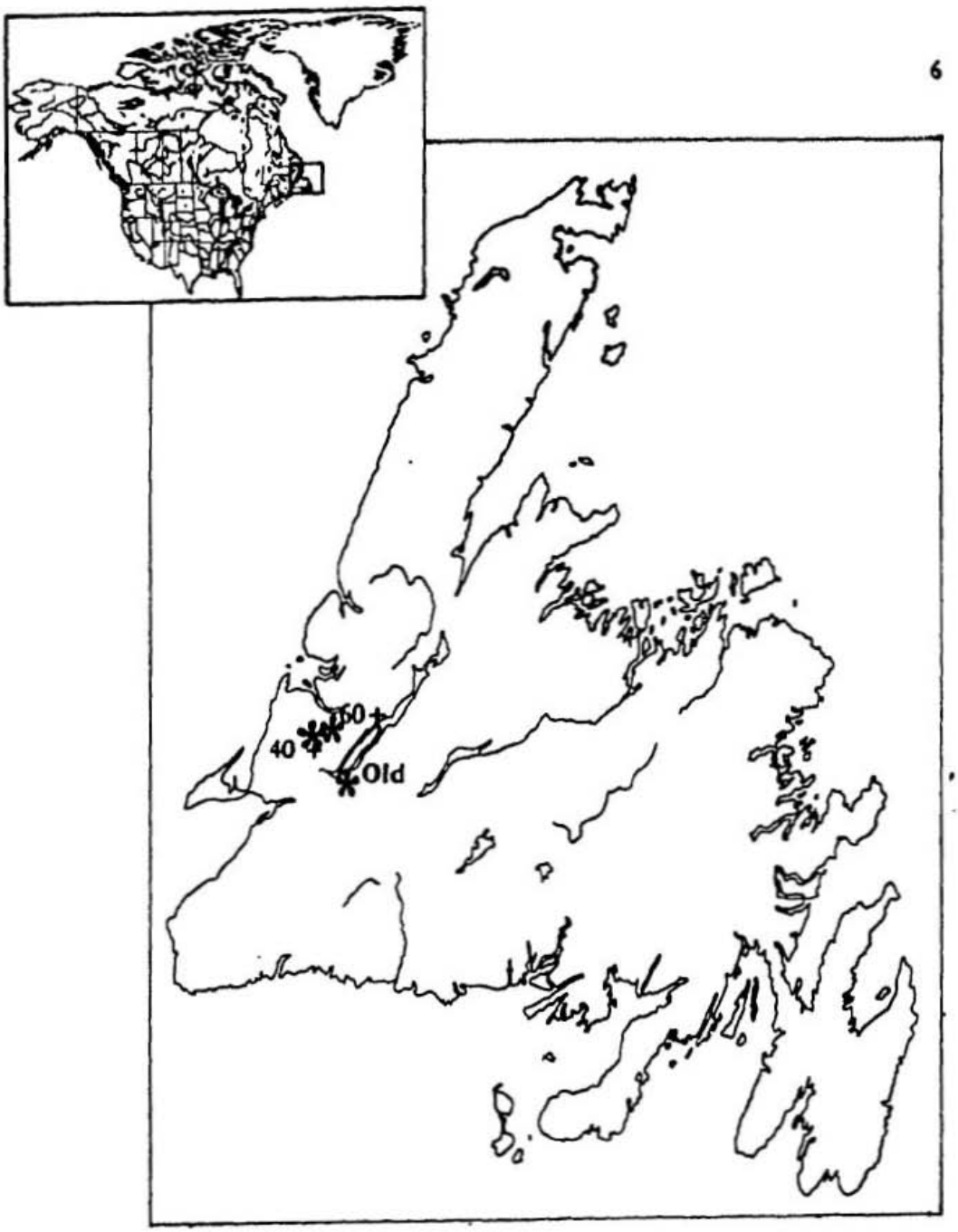



Figure 1: Map of Newfoundand indicating locations of the three sampling areas, old uncut (Old), 60 year old regrowth and 40 year old regrowth, within each of the Balsam fir (*Abies balsamea*) - fern (*Dryopteris*) and Balsam fir - horsetail (*Equisetum*) forest types.

**Figure 2: Representative study site from the old fir (*Abies balsamea*) - fern (*Dryopteris*) forest located in western Newfoundland.**


**Figure 3: Ground vegetation of the old (uncut) fir (*Abies balsamea*) - fern (*Dryopteris)* study sites from western Newfoundland.**

**Figure 4: Representative study site from the old fir (*Abies balsamea*) - horsetail (*Equisetum*) forest located in western Newfoundland.**


**Figure 5: Ground vegetation of the old (uncut) fir (*Abies balsamea*) - horsetail (*Equisetum)* study sites from western Newfoundland.**

**Table 1: Forest type characteristics based on Meades and Moore (1989) for balsam fir (*Abies balsamea*) - fern *(Dryopteris)*(FD) and balsam fir - horsetail (*Equisetum)* (FE) habitats.**

| | **Balsam Fir-*Dryopteris* (FD)** | **Balsam Fir-*Equisetum* (FE)** |
|---|---|---|
| Soil Type | Fragic Humic Podzol | Fragic Humic Gleysol, Gleyed Regisol, Terric mesisol |
| Fertility | Rich - Very Rich | Medium - Rich |
| Moisture | Well drained - moist; stratified soil profile with clear horizons | Moist - wet; Normal soil profile development hampered by incomplete drainage; possibly anaerobic |
| Trees | Balsam fir (dominant species), birch, white/black spruce | Balsam fir (dominant species), birch, eastern larch, white/black spruce |
| Ground Cover | Low herbaceous plants, ferns, feathermoss, maples | Grasses, tall/low herbaceous plants, maples, feathermoss, ferns, fern allies |
| Indicator Plant Species | *Dryopteris spinulosa* | *Equisetum sylvaticum, Rubus pubescens, Dryopteris disjuncta* |

Two replicate sites (Tables 2 and 3) approximately 200m to 2km apart, of each of the three different aged forest stands were chosen in an effort to disperse sampling effort over a wider portion of the forest area.

## 2.2 CLIMATE

Newfoundland is greatly influenced by its proximity to the ocean which produces a maritime climate with short, cool summers and mild winters. Spring is delayed due to the presence of pack ice transported to the north and east coasts, in particular, via the southward flowing Labrador current (Banfield 1983, Roberts 1983).

Newfoundland's west coast, in comparison with the rest of the island, has a relatively long vegetative season and warm summer temperatures, thus possessing the most favorable growing conditions on the island. This area is generally protected from cold northeasterly winds by the presence of the Long Range Mountains and is usually not subject to night frost in July and August (Roberts 1983).

Precipitation is abundant throughout the year occuring on average 200 to 250 days of the year. This pattern is shown in Figure 6 which shows monthly precipitation means,mean daily temperatures and snowfal., from Corner Brook for 1992, 1993 and 1994.

Winters in the central uplands and western hills are cold with the heaviest snowfall (over 400 cm per year) occuring in the southwest (Banfield 1983). Snow patches may persist in lowlands until late May or early June (Roberts 1983).

Climatic variation may exist among the study sites due to geographical features.

**Table 2: Locality descriptions and code designations for study sites on the West coast of Newfoundland.**

| Forest Type | Age | Site # | Code | Locality |
|---|---|---|---|---|
| FD | Old uncut | 1 | FDO-1 | 2km East Martin Pond near Little Grand Lake |
| | | 2 | FDO-2 | Bakeapple Brook near little Grand Lake |
| | 60+ years regrowth | 5 | FD60-5 | Near Logger's School Road on TCH 10 km South of Corner Brook (uphill from TCH) |
| | | 6 | FD60-6 | Near Logger's School Road on TCH 10 km South of Corner Brook (downhill from TCH) |
| | 40+years regrowth | 3 | FD40-3 | Cook's Pond near Stag Lake (uphill from access) |
| | | 4 | FD40-4 | Cook's Pond near Stag Lake (downhill from access) |
| FE | Old uncut | 7 | FEO-7 | 2km East Martin Pond near Little Grand Lake |
| | | 8 | FEO-8 | Bakeapple Brook near little Grand Lake |
| | 60+ years regrowth | 11 | FE60-11 | Near Logger's School Road on TCH 10 km South of Corner Brook (downhill from TCH) |
| | | 12 | FE60-12 | Near Logger's School Road on TCH 10 km South of Corner Brook (downhill from TCH) |
| | 40+years regrowth | 9 | FE40-9 | Cook's Pond near Stag Lake (downhill from access) |
| | | 10 | FE40-10 | Cook's Pond near Stag Lake (downhill from access) |

Table 3: Approximate locations and elevations for the FD (FDO-1, 2; FD60-5, 6; FD40-3, 4) and FE (FEO-7, 8; FE60-11, 12; FE40-9, 10) study sites.

| Site | Latitude (N) | Longitude (W) | Elevation (m) |
|---|---|---|---|
| FDO-1 | 48° 38.00' | 57° 47.50' | 300 - 350 |
| FDO-2 | 48° 39.00' | 57° 47.00' | 300 - 350 |
| FD60-5 | 48° 52.50' | 57° 56.00' | 300 |
| FD60-6 | 48° 52.25' | 57° 55.50' | 300 |
| FD40-3 | 48° 52.25' | 58° 05.50' | 300 |
| FD40-4 | 48° 52.00' | 58° 05.00' | 225 |
| FEO-7 | 48° 38.25' | 57° 47.25' | 350 |
| FEO-8 | 48° 39.00' | 57° 48.25' | 200 |
| FE60-11 | 48° 51.25' | 57° 56.50' | 300-330 |
| FE60-12 | 48° 51.75' | 57° 56.00' | 300 |
| FE40-9 | 48° 52.00' | 58° 05.00' | 250 |
| FE40-10 | 48° 52.25' | 58° 04.75' | 250 |

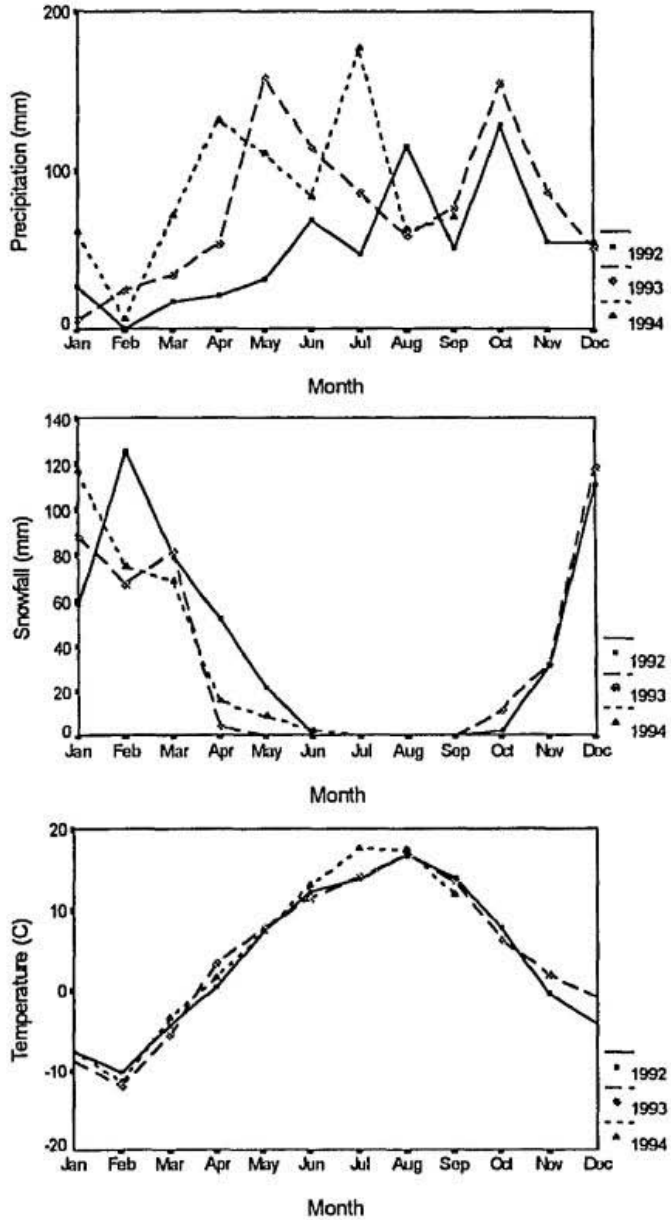



**Figure 6: Mean monthly weather conditions at the Corner Brook weather station (~ 48° 56.00' N 57°54.50' W ) for 1992-1994 provided by the Atmospheric Environment Service.**

This is particularly true of uncut stands of both the *Dryopteris* and *Equisetum* habitats as these sites are of higher elevation and in an area of higher relief than the other sites.

## 2.3 SOIL ANALYSIS

Bill Curran, Forestry Canada, took two soil samples from each FD site in the spring of 1993. For this study only the data for the organic (LFH) horizon is included in subsequent analysis.

This horizon, constituted most of the 10 cm depth of soil samples from which oribatid mite were extracted. The LFH is a composite horizon composed of leaves, woody debris and moss. The original structure of this material in the upper L layer is still discernable, in the lower F layer the material may be partly comminuted rendering some original structures difficult to recognize, in the H layer the material is decomposed and original structure is indiscernable. The organic matter of the LFH horizon increases water and nutrient retention in soils and provides a source of nitrogen and phosphorous increasing soil productivity (Timmer and Armstrong 1985). Carbon percentage for the LFH layer was determined by dividing the percent organic matter by Van Bemmelens Factor (1.724) (Timmer and Armstrong 1985).

One soil sample for each of the FE sites was collected by John Marshall, Forestry Canada, in August, 1994. Though mineral and nutrient analysis data were not completed for these samples, descriptions of their soil horizons and respective depths were provided by Bruce Roberts, Forestry Canada.

Layers within the mineral soil profiles of FD and FE sites were identified following

the criteria for soil horizons presented in ACECSS (1987). The uppermost mineral horizon, Ae, near the zone of leaching and eluviation lies below the organic horizon and, as its light color indicates, is subject to the removal of oraganic matter. Below this, horizon B is characterized in various ways: Bhf and Bf are enriched with aluminum and iron combined with organic matter, Bhf has greater than 5% whereas Bf has 0.5 to 5 % organic carbon; Bc is a cemented pedogenic horizon; Bmg and Bg are subject to poor drainage and periodic reduction. Bmg is also slightly altered by hydrolysis or oxidation resulting in color and structural changes. Mineral horizon C is relatively unaffected by the pedogenic processes in A and B.

## 2.4 VEGETATION ANALYSIS

Vegetation data for each FD site were collected in 1992 by Forestry Canada and the mean value for each character was provided by Dr. I. Thompson. Vegetation characters included: percent cover of feather moss, *Sphagnum* sp., ground lichens, *Lycopodium*, grasses, low and tall fern, low (<0.5m)shrubs, medium (>0.5m) shrubs, woody debris <5cm diameter; trees (>10cm diameter at breast height), logs (woody debris >5cm diameter), mean diameter (cm) of logs on plot, conifer litter, deciduous litter, and fern litter. Shrub diversity (Brillouin's index of diversity for shrub species), foliage diversity at 5m (low), 6 to10m (medium) and 11 to 25+ m (top) heights, stand density (numbers/$m^2$) and standing dead tree density (number/$m^2$) were also recorded.

## 2.5 SAMPLING PROCEDURES

### 2.5.1 Soil

Samples were taken from the FD sites in July and August 1992, June, July, and August 1993 and June 1994. FE sites were sampled in July and August 1994. A total of ten samples were taken from each site per sampling date.

Samples were standardized by collecting from areas of feathermoss cover free from dead wood and deciduous litter. They were collected at 2 to 3 m intervals along a transect starting well inside the plot to avoid edge effects. To allow comparison between sampling dates, subsequent samples were taken in close proximity to the location of previously collected samples.

Samples were taken by cutting around a 10 cm X 10 cm wooden template with a knife. Upon removal, the sample was divided approximately into upper and lower 5 cm subsamples which were stored separately in paper bags and transported in a cooler to the field station for immediate extraction (usually within 2 to 4 hours).

### 2.5.2 SOIL EXTRACTION

Soil samples were extracted in an approximately 15°C room using a modified Berlese funnel (Figures 7 and 8). Each funnel consisted of a 5 cm high sieve with a 2 mm nylon screen mesh base constructed from 15 cm inside diameter PVC piping. The sieve was also lined with a double layer of cheesecloth to reduce debris falling into the collection vial. Three screws placed around the outer margin of the sieve held it approximately 1 cm above a 17 cm inside diameter funnel (20 cm long) allowing for

**Figure 7: Modified Berlese funnel apparatus used for extracting soil samples from fir *(Abies balsamea)* - fern (*Dryopteris*) and fir - horsetail (*Equisetum*) forest sites.**

**Figure 8: Arrangement of Berlese funnel systems used in extraction of soil samples from fir *(Abies balsamea)* - fern (*Dryopteris*) and fir - horsetail (*Equisetum*) forest sites.**

ventilation. Each funnel tip passed through a hole in a piece of cork affixed to the cap of a collection vial. Thus, each vial containing 70% ethanol was directly attached to the funnel reducing alcohol evaporation and the possibility of vial upset. In addition, each cap contained several ventilation holes to prevent condensation in the funnel.

The Berlese funnels were arranged in groups of 9 with each funnel being suspended through a 15 cm diameter hole in a 56 x 71 cm cardboard tray. The tray was strengthened by a wooden frame and supported with four 50 cm high poles.

A 7.5 watt incandescent light bulb was suspended above each funnel. The bulb could be adjusted to various distances from the sample (maximum distance approximately 10.5 cm decreasing at increments of approximately 2.5 cm). For extraction, the bulb was usually between 3-4 cm above the soil sample. Samples were extracted over a period of 7 days.

In 1993, collection vials were filled alternately with water or 70% ethanol to test for possible deterrent effects of the collection medium on mite extraction. Collection fluid for 1994 was alternatively 70% ethanol or an equal mixture of 70% ethanol and Kahle's fluid (Martin 1978).

Extracted organisms were stored in 70% ethanol in the capped bottom vial of each funnel for later separation and identification. Mites were separated from other microarthropods and debris using a dissecting microscope, pipette and needles. They were identified to the lowest possible category and their numbers recorded.

### 2.5.3 Microhabitat

The forest system is composed of a variety of microhabitats each of which may play host to a unique population of mites. To assess species diversity in various microhabitats within FD forest and to determine the possible source of rarer species in the soil samples, two samples were taken from each of eight different microhabitats at each of the six sampling sites in the summer of 1993. A total of 36 samples per microhabitat were collected. Each sample consisted of enough material to fill a small paper lunch bag ( ~20 cm x 12 cm). Microhabitats sampled were: tree hole debris (hole at base of tree under roots); lichen covered branches from the ground and off live trees; bark from dead and live trees; moss from dead and live trees; and deciduous leaf litter (upper ~0-3 cm of loose litter and lower ~4-6 cm compressed layers).

All samples except the lichen covered branches were extracted in the same manner as the soil samples. Lichen covered branches were immersed in 95% alcohol where the lichen was stripped from the branches and agitated for several minutes. The alcohol was then filtered for examination under the dissecting scope. Species abundances for each sample were recorded as rare (1-5 specimens), common (6-10 specimens) and abundant (>10 specimens).

## 2.6 SOIL MOISTURE

Wet weight was recorded for each soil sample in 1993 and 1994 before extraction. After the 7 day extraction period, each sample was transferred to a preweighed paper bag then dried in a 60°C oven for 24 hours before its dry weight was obtained. The difference

between these weights was used to calculate the percent moisture for each sample.

## 2.7 IDENTIFICATION PROCEDURES

Oribatids were cleared in lactic acid for a period of several days to 3 weeks depending on size and sclerotization. Specimens were then examined under a compound light microscope using the 'half-open slide' technique (Balogh 1972). A cover slip is placed on a depression slide to lie over half of the depression. Lactic acid is then dropped into the open portion and is drawn under the cover slip by capillary action. Using a fine brush, the mite is placed as far under the slip as possible. This technique allows manipulation of the specimen during examination through slight movements of the cover slip (Balogh 1972).

All oribatids were identified to genus and many to species using the keys of Norton (1992a, b), Balogh and Mahunka (1983), Balogh (1963, 1972) and various species keys. A species list was compiled following the classification scheme of Marshall et al. (1987). Selected specimens were permanently mounted in Hoyer's medium for a reference collection while others were sorted to genus and stored in ethanol and glycerin in separate vials. Identification of specimens from each taxon was verified by Dr. V. Behan-Pelletier, Agriculture Canada, Ottawa.

## 2.8 STATISTICAL ANALYSIS

A list of oribatid taxa and numbers of each taxon per sample divided into upper and lower subsamples were obtained and analyzed. The data were used to compare oribatid abundance, diversity and vertical distribution among the study sites. For a

majority of the analyses, oribatid numbers from the upper and lower 5cm soil subsamples were combined to give a total number per sample. Along with ANOVA, a range of multivariate analysis techniques, briefly described below, were used to depict oribatid community structure from the study areas.

### 2.8.1 Diversity

Diversity indices were used to describe species abundance relationships in the forest community. However, because these indices combine both total species numbers and their relative abundance (evenness) there has been debate on their effectiveness and value (Krebs 1989). Therefore, they were used in conjunction with a variety of other multivariate techniques. The Shannon-Wiener index, a heterogeneity measure, was calculated using the DIVERS program of Krebs (1991). The Shannon-Wiener Function combines species richness and evenness into one descriptive value for a community. This method places the most weight on the rarer species in the community and attempts to measure the amount of order in a system (Krebs 1989).

A species richness measure, rarefaction, was also used. Rarefaction is a statistical method of determining the number of species expected in a random sample from a community. Rarefaction values were obtained using the RAREFACT program (Krebs 1991) modified by Mrs. R. Thompson for sample sizes up to 10,000 specimens.

### 2.8.2 Classification

Cluster analysis, an hierarchical, agglomerative classification method was employed to identify similarities in the oribatid fauna among sampling sites for the various

sampling dates. Analysis of both numerical and presence/absence data used squared euclidean distance measures for group average linkage clustering (SPSS 1994).

Two-way indicator species analysis (TWINSPAN) (Hill 1979), a polythetic, divisive classification method determined similarities among sampling areas based on both species diversity and abundance data. In this method, samples are initially combined in one group which is successively divided into smaller clusters. Each division is determined by one or more 'indicator species' (Gauch 1982). For this analysis, the TWINSPAN program of ECOSURV (Carleton 1985) was used.

Discriminant function analysis (SPSS 1994) was used to identify variables in the soil, vegetation and oribatid population data that were associated with the forest age classes.

### 2.8.3 Ordination

Ordination summarizes species and sample data in a one to three dimensional space. It arranges the data such that similar species/samples are close together and is used to indicate patterns in a community (Krebs 1989).

Principle component analysis (PCA), using varimax rotation to simplify the interpretation of factors, was employed to indicate patterns in the soil, vegetation and oribatid population data. The resulting factor 1 values for each of the three data sets were used in a three dimensional composite graph. This was accomplished in SPSS (1994).

# 3.0 RESULTS

## 3.1 SOIL DESCRIPTION

### 3.1.1 FD Soil

#### 3.1.1.1 Classification

Soils from the FD sites (Figure 9) have characteristics of a Podzolic soil, that is, a B horizon greater than 10 cm thick and abundant accumulations of humified organic matter combined with varying levels of aluminum and iron. (Agriculture Canada Expert Committee on Soil Survey (ACECSS 1987). Within the Podzolic order, the FD sites belong to one of two groups - Orthic Ferro-Humic (FDO-1, 2; FD40-3) or Orthic Humo-Ferric (FD60-5, 6; FD40-3, 4). The soil of both groups is strongly acidic and is usually found under forest vegetation in humid areas. Ferro-Humic soils have more organic matter and subsequently higher carbon values in the B horizon than the Humo-Ferric soils (ACECSS 1987).

#### 3.1.1.2 Soil Parameters

Mean values for the various soil parameters varied between the three forest ages, though not significantly (Table 4). Aluminum, iron, coarse material (> 2mm diameter) and pH varied with site ages decreasing from the FD40 to FDO sites. Conversely, carbon, potassium, phosphorous, organic matter and layer depth increased from FD40 to FDO sites.

#### 3.1.1.3 Ordination

Factor analysis of the LFH data from the FD sites (Figure 10) grouped FDO-1,

**Figure 9: Soil profiles for the balsam fir (*Abies balsamea*) - fern (*Dryopteris*) forest sites using standard horizon labels from *The Canadian System of Soil Classification* (1987). Refer to Materials and Methods section for descriptions of individual horizons. The numbers 1 and 2 represent subdivisions of a horizon and g = gleyed. Lower limits of samples vary due to blockage of the sampling tube.**

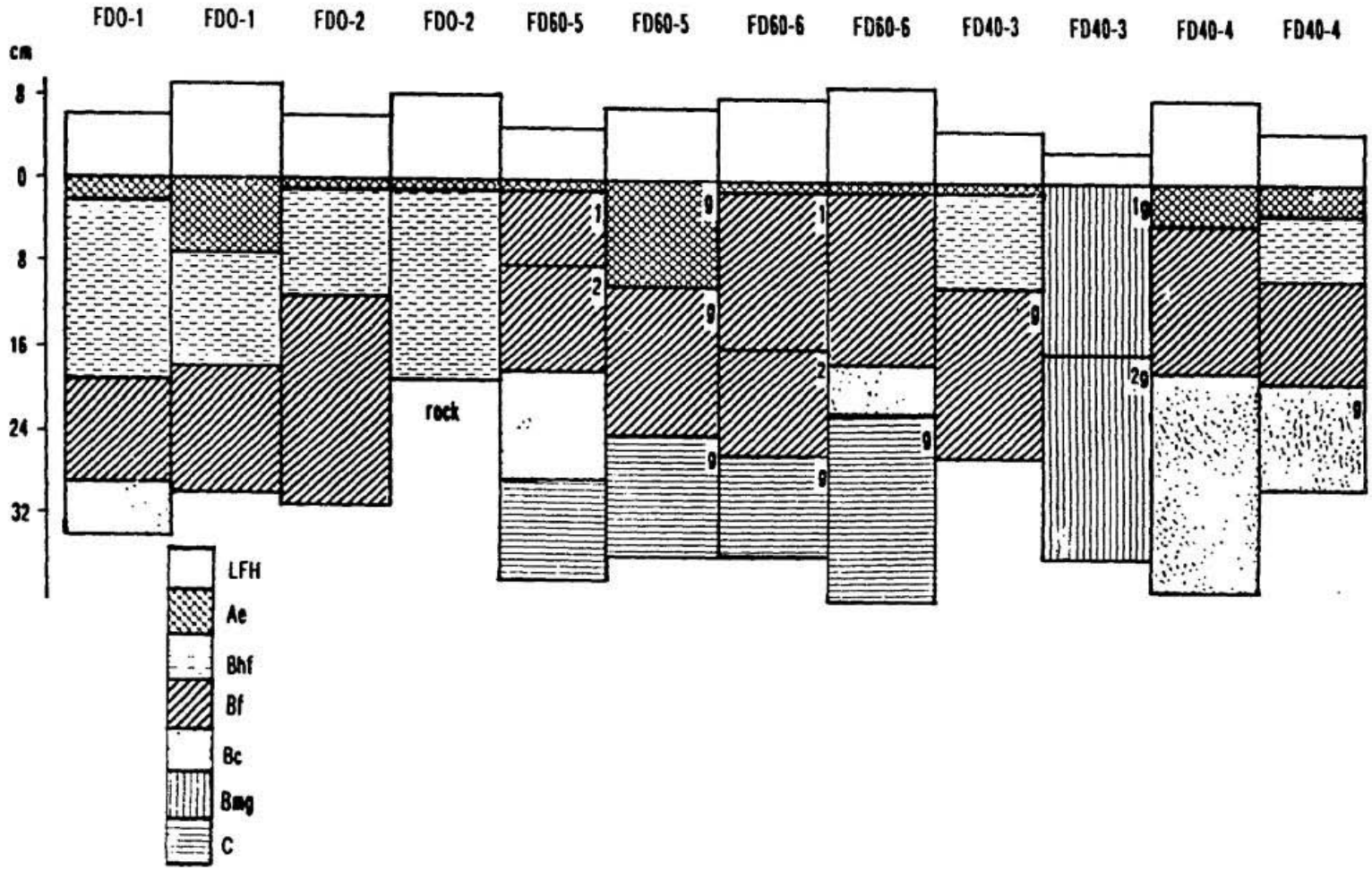

FDO-1
FDO-1
FDO-2
FDO-2
FD60-5
FD60-5
FD60-6
FD60-6
FD40-3
FD40-3
FD40-4
FD40-4
cm
8
0
8
16
24
32
rock
LFH
Ae
Bhf
Bf
Bc
Bmg
C

**Table 4: Mean soil parameter data for the LFH soil horizon of FDO, FD60 and FD40 based on four soil samples per area.**

| CHARACTER | FDO | | FD60 | | FD40 | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. dev. |
| Aluminum (ppm) | 587.65 | 186.04 | 1377.94 | 204.08 | 1657.54 | 1069.65 |
| Calcium (ppm) | 1370.79 | 235.15 | 1774.12 | 308.78 | 678.42 | 540.55 |
| Iron (ppm) | 938.72 | 415.60 | 2256.43 | 2508.03 | 4018.84 | 5104.25 |
| Potassium (ppm) | 781.03 | 20.45 | 642.14 | 201.23 | 578.27 | 373.73 |
| Magnesium (ppm) | 553.05 | 96.41 | 461.67 | 68.19 | 526.40 | 295.63 |
| Nitrogen (ppm) | 111.91 | 3.71 | 54.44 | 22.92 | 102.41 | 111.38 |
| Sodium (ppm) | 97.22 | 1.75 | 288.31 | 283.80 | 50.93 | 24.82 |
| Phosphorous (ppm) | 78.06 | 30.32 | 68.07 | 50.24 | 44.14 | 41.53 |
| Carbon (%) | 45.50 | 2.90 | 40.18 | 1.59 | 30.00 | 12.73 |
| Organic Matter (%) | 80.74 | 1.83 | 69.28 | 2.75 | 51.77 | 21.89 |
| Coarse Matter (%) * | 9.48 | 8.17 | 10.03 | 5.34 | 15.85 | 12.80 |
| Depth (mm) ** | 7.25 | 0.35 | 7.25 | 1.77 | 5.75 | 1.06 |
| pH | 3.75 | 0.25 | 3.82 | 0.28 | 4.07 | 0.31 |

* material larger than 2mm diameter (i.e. rocks, sticks)
** depth of LFH soil layer

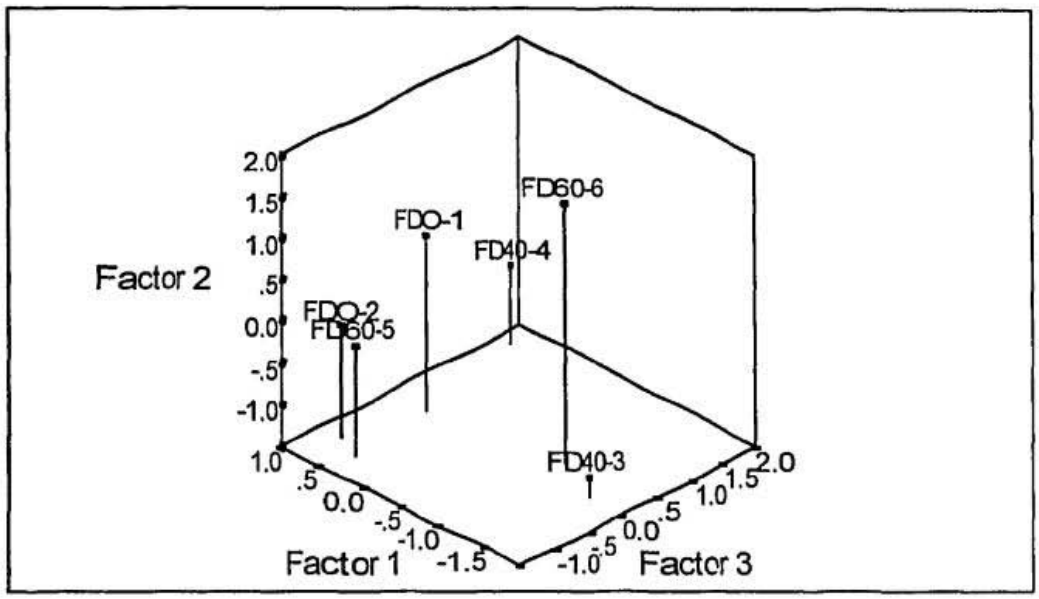



**Figure 10: Ordination of FDO-1, 2; FD60-5, 6 and FD40-3, 4 sample sites based on mean (n=2) LFH soil data.**

FDO-2, FD60-5 and FD40-4 on factor 1. FDO-1 and 2 were closely associated on factor 2 also, indicating that samples collected within the FDO area were similar. The FD60 sites were widely separated on factor 1 but grouped closer on factor 2. The greatest dissimilarity was shown between the two FD40 sites which were separated on all three factors indicating a higher heterogeneity between the FD40 sites than between sites of other areas.

Principle components analysis factors 1 and 2 eigenvalues for individual soil parameters (Table 5) were used to identify associations between the parameters and the FD sites. Based on these values, FDO-1 and 2, FD60-5 and FD40-4 were associated with high amounts of nitrogen, carbon, potassium, magnesium, phosphorous, calcium, organic matter and layer depth. Both FD60-6 and FD40-3 had high amounts of aluminum and iron, but they differed from each other in various other measures. FD60-6 had the highest calcium and sodium levels, thickest LFH layer and the lowest percentage of coarse material. Conversely, FD40-3 was characterized by the lowest amount of sodium, the shallowest LFH layer and a high percentage of coarse material.

#### 3.1.1.4 Discriminant Function Analysis (DFA)

Discriminant analysis was performed on both individual sample data and on mean sample data for FDO, FD60 and FD40. Analysis of the raw sample data did not produce clear separation of the three age areas and the results were difficult to interpret. However, discriminant function analysis of the mean LFH data from the FD sites showed 100% separation of the three age areas (Figure 11). The two samples within each of FDO and

**Table 5: Principle components analysis factors 1 and 2 eigenvalues and discriminant function analysis functions 1 and 2 correlation values for individual LFH soil characters from FD0, FD60 and FD40.**

| Character | PCA | | DFA | |
|---|---|---|---|---|
| | Factor 1 | Factor 2 | Function 1 | Function 2 |
| Aluminum (Al) | -.935 | -.511 | -.028 | .756 |
| Carbon (C) | .996 | .088 | .089 | -.716 |
| Calcium (Ca) | .695 | -.588 | .623 | -.402 |
| Iron (Fe) | -.999 | -.183 | .235 | .794 |
| Potassium (K) | .954 | .460 | -.271 | -.801 |
| Magnesium (Mg) | .193 | .999 | -.000 | -.972 |
| Nitrogen (N) | .061 | .994 | .018 | -.872 |
| Sodium (Na) | .275 | -.899 | .991 | .127 |
| Phosphorous (P) | .990 | .034 | -.547 | -.837 |
| Organic matter | .999 | .147 | .094 | -.805 |
| Coarse matter | -.939 | .178 | -.488 | .334 |
| Depth | .909 | -.254 | .932 | -.168 |
| pH | -.975 | .050 | .687 | -.159 |

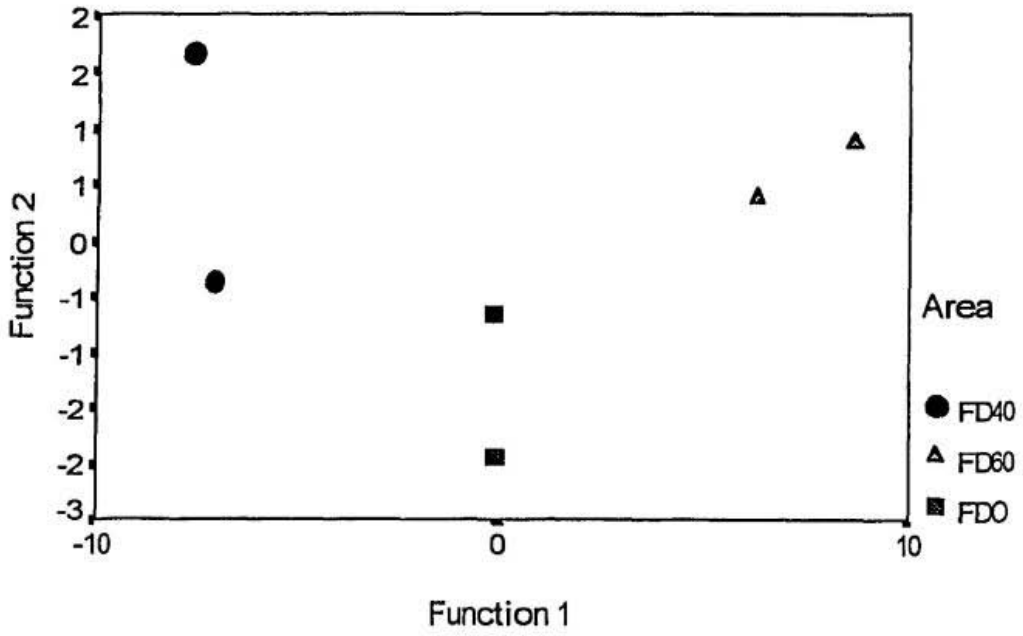



**Figure 11: Discriminant function analysis of mean (n=4) LFH soil data from FDO, FD60 and FD40.**

FD40 grouped closely with one another on function 1 and showed some separation on function 2. FD60 samples were slightly separated from each other on both function 1 and 2.

FDO samples were again associated with high values for nitrogen, carbon, calcium, magnesium, potassium, phosphorous and percent organic matter (Table 5). The FD60 and FD40 areas were associated with high values for iron, aluminum and layer depth.

### 3.1.2. FE Soil

#### 3.1.2.1 Classification

Soil from the FE sites (Figure 12) was classified as Orthic Gleysol soil which has properties indicative of prolonged periods of continuous or intermittent saturation with water. This soil type lacks a well-developed, mineral-organic surface layer and has a gleyed B horizon of at least 10 cm thick (ACECSS 1987).

## 3.2 VEGETATION DESCRIPTION

### 3.2.1. FD Sites

Mean values for the various vegetation characters measured in the FDO, FD60 and FD40 areas are presented in Table 6. FDO had significantly higher values for feather moss, sphagnum, logs and log diameter whereas FD60 had significantly more deciduous litter. Percent cover by low fern and fern litter were significantly lower in FD40. Those variables that increased from FD40 to FDO include feather moss, sphagnum, foliage height diversity (top) and fern litter whereas tall fern, medium shrub, dead standing tree density and coniferous litter decreased.

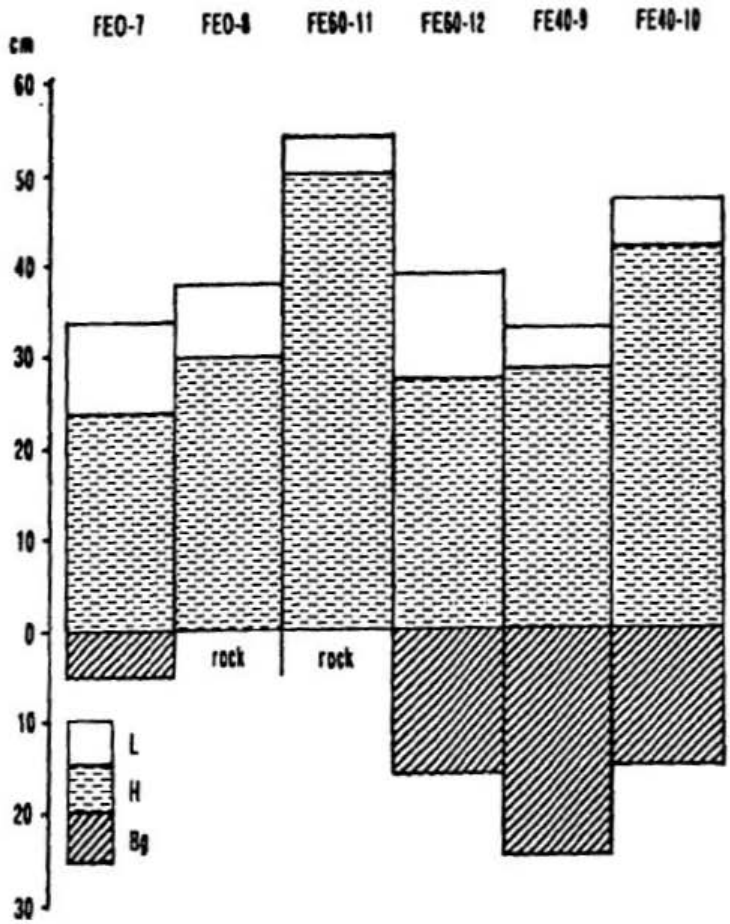



**Figure 12: Soil profiles for the fir (*Abies balsamea*) - horsetail (*Equisetum*) forest sites using standard horizon labels from *The Canadian System of Soil Classification* (1987).**

**Table 6: Mean (n=50) percent cover , density and diversity values for vegetation characters from FDO, FD60 and FD40 where * indicates mean is significantly different from those of other two areas.**

| CHARACTER | FDO | | FD60 | | FD40 | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev | Mean | Std. Dev | Mean | Std. Dev |
| Feather moss (%) | 49.69* | 1.63 | 29.00 | 14.09 | 28.53 | 2.67 |
| Spaghnum (%) | 5.44* | 0.40 | 0.57 | 0.52 | 0.32 | 0.17 |
| Ground lichen (%) | 0.01 | 0.01 | 0.06 | 0.06 | 0.08 | 0.06 |
| Lycopodium (%) | 0.03 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 |
| Grasses (%) | 0.05 | 0.07 | 0.00 | 0.00 | 0.04 | 0.3 |
| Herbaceous plants (%) | 20.12 | 5.80 | 18.39 | 6.15 | 23.54 | 5.37 |
| Low Fern (%) | 21.52 | 6.79 | 28.09 | 5.13 | 18.61* | 6.35 |
| Tall Fern (%) | 6.39 | 2.73 | 10.89 | 7.99 | 11.34 | 2.23 |
| Low Shrub (<0.5 m) (%) | 5.05 | 1.54 | 7.06 | 3.00 | 4.01 | 3.15 |
| Medium Shrub (>0 5 m) (%) | 0.62 | 0.40 | 3.12 | 2.34 | 1.86 | 2.15 |
| Tree (%) | 0.11 | 0.02 | 0.15 | 0.04 | 0.27 | 0.06 |
| Fallen Logs (%) | 7.39* | 3.24 | 2.46 | 0.31 | 4.74 | 0.11 |
| Log Diameter (cm) | 10.35* | 4.00 | 4.73 | 1.80 | 6.02 | 1.84 |
| Slash (woody debris) (%) | 8.62 | 2.94 | 5.59 | 2.02 | 6.90 | 0.17 |
| Coniferous Litter (%) | 10.97 | 2.93 | 16.59 | 14.61 | 17.13 | 0.07 |
| Deciduous Litter (%) | 12.68 | 5.49 | 37.95* | 35.00 | 17.47 | 2.53 |
| Fern Litter (%) | 4.76 | 5.18 | 3.71 | 5.20 | 0.15* | 0.21 |
| Shrub Diversity (H') | 2.63 | 1.13 | 3.32 | 0.69 | 2.30 | 1.13 |
| FHD Low (5 m) | 0.78 | 0.06 | 1.34 | 0.34 | 1.17 | 0.01 |
| FHD Medium (6-10 m) | 1.13 | 0.33 | 1.17 | 0.49 | 0.75 | 0.18 |
| FHD Top (11-25+ m) | 1.14 | 0.62 | 1.01 | 0.94 | 0.95 | 0.04 |
| Stand Density (#/m$^2$) | 0.04 | 0.00 | 0.18 | 0.05 | 0.12 | 0.04 |
| Dead Standing Tree Density (#/m$^2$) | 0.12 | 0.05 | 0.13 | 0.02 | 0.17 | 0.05 |

### 3.2.1.1 Ordination

PCA of the mean vegetation data for the FD sites placed the FDO sites in close proximity and grouped the FD40 sites and FD60-5 on factor 1 (Figure 13). FD60-5 and FD60-6 were grouped slightly closer on factor 2 whereas the FDO and FD40 sites were separated.

The factor 1 and 2 eigenvalues for each variable (Table 7) identify a positive association between the FDO sites and feather moss, sphagnum, logs and log diameter. The FD40 sites and FD60-5 were associated with herbaceous plants, low fern, medium shrubs and shrub diversity whereas FD60-6 was characterized by deciduous litter and tall fern.

### 3.2.1.2 Discriminant Function Analysis

Discriminant function analysis of the mean vegetation data per site resulted in 83% accuracy in the classification of sites due to the inclusion of one of the FD40 sites in the FD60 grouping (Figure 14). Vegetation characters that had higher values in different age classes included logs and log diameter in FDO, foliage height diversity (medium) in FD60 and herbaceous plants in FD40 (Table 7).

Discriminant Function Analysis of a larger data set (38 forest stands belonging to one of FDO, FD60 or FD40) as performed by Dr. I. Thompson, Forestry Canada, (personal communication) showed 100% correct classification of cases. Dr. Thompson's analysis indicated several variables for discriminating among the forest age classes, namely shrub diversity, deciduous litter and number of standing dead stems all of which declined

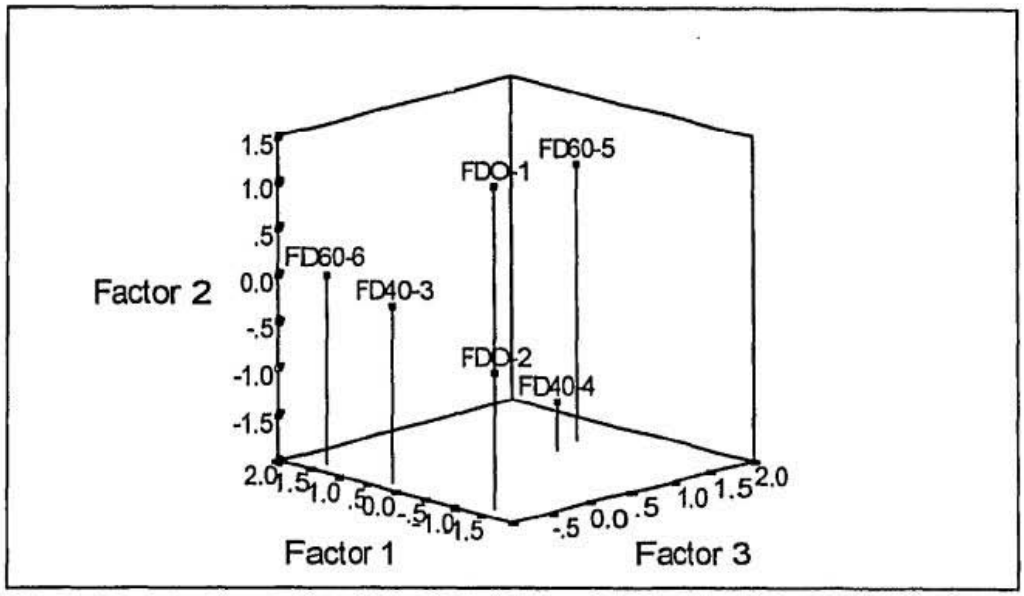



**Figure 13: Ordination of FDO-1, 2; FD60-5, 6 and FD40-3, 4 sample sites based on mean vegetation values.**

**Table 7 : Principle components analysis factors 1 and 2 and discriminat function analysis functions 1 and 2 eigenvalues for vegetation characters from FDO, FD60 and FD40.**

| Character | Factor 1 | Factor 2 | Function 1 | Function 2 |
|---|---|---|---|---|
| Feather Moss | -.981 | .196 | -.274 | .114 |
| Sphagnum | -.975 | .220 | -.533 | .123 |
| Ground lichen | .898 | -.440 | -.348 | -.712 |
| Lycopodium | -.984 | .177 | .679 | -.716 |
| Grasses | -.778 | -.628 | .359 | -.917 |
| Herbaceous plants | .009 | -.999 | .824 | -.150 |
| Low Fern | .387 | .922 | -.034 | -.785 |
| Tall Fern | .966 | -.257 | -.342 | -.099 |
| Low Shrub (<0.5 m) | .352 | .936 | .685 | .331 |
| Medium Shrub (>0.5 m) | .940 | .342 | .528 | .468 |
| Tree | .566 | -.825 | -.426 | -.703 |
| Fallen Logs | -.955 | -.298 | -.707 | .704 |
| Log Diameter | -.999 | -.043 | -.878 | .401 |
| Slash (woody debris) | .019 | .999 | .488 | -.529 |
| Coniferous Litter | .967 | -.255 | .075 | .022 |
| Deciduous Litter | .771 | .636 | -.095 | -.098 |
| Fern Litter | -.534 | .845 | .455 | -.370 |
| Shrub Diversity (H') | .369 | .930 | .354 | .729 |
| FHD Low (5 m) | .992 | .123 | .144 | -.307 |
| FHD Medium (6-10 m) | -.266 | .964 | .090 | -.453 |
| FHD Top (11-25+ m) | -.872 | .490 | -.349 | .233 |
| Stand Density (#/m$^2$) | .960 | .280 | -.405 | -.537 |
| Dead Standing Tree Density (#/m$^2$) | .574 | -.819 | .084 | .884 |

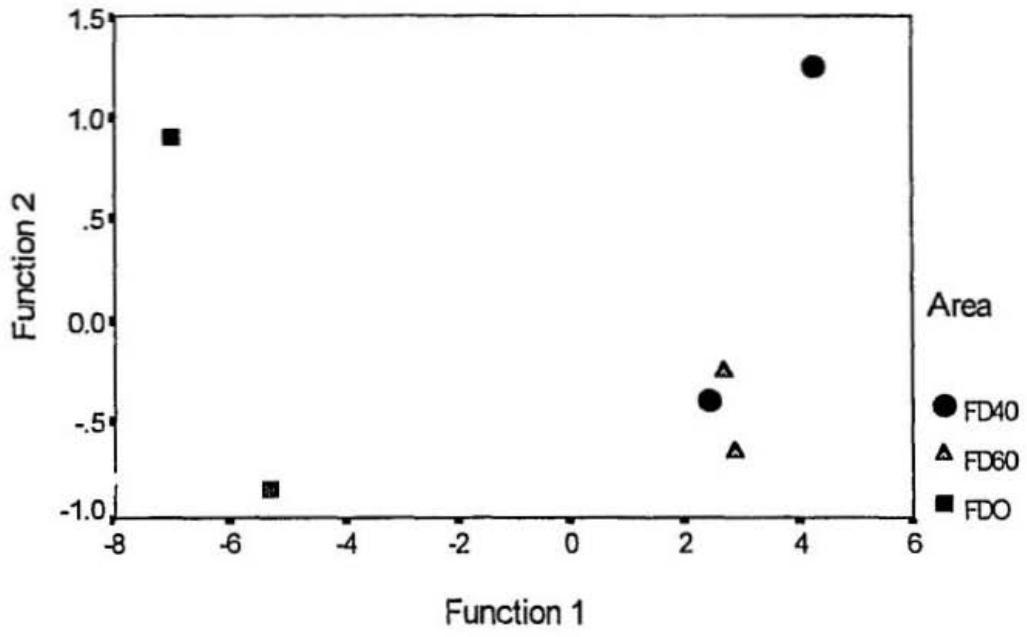



**Figure 14: Discriminant function analysis based on mean vegetation data from FDO, FD60 and FD40.**

with forest age and feather mosses and low shrubs which increased with age.

### 3.2.2. FE Sites

Vegetation analysis was not undertaken for the FE sites. Though the sites were classified as balsam fir, black spruce was abundant in some sites. A list of the more common plant species that occured, based on identifications using Meades and Moore (1989), included *Abies balsamea, Picea mariana, Cornus stolonifera, Geum rivale, Rubus pubescens, Sanguisorba canadensis, Viola cucullata, Dryopteris disjuncta, Dryopteris spinulosa, Dryopteris phegopteris, Athyrium filix* and *Equisetum sylvaticum.*

## 3.3 SOIL MOISTURE

### 3.3.1 FD Sites

The dry weights of the FD soil samples ranged from 28.5 to 48.1grams in the upper subsample and between 45.7 and 88.3 grams in the lower subsample whereas percent moisture ranged from 55 to 79% and from 57 to 83%, respectively (Table 8). All soil weights and a majority of the percent moisture values were highest in the lower 5 cm soil subsamples. Soil sample dry weights differed significantly between the upper and lower 5cm subsamples for all sampling dates whereas percent moisture showed significant difference on only six dates. Dry weight of the soil subsamples differed significantly among the three areas for June, July and August 1993, whereas percent moisture showed significant difference in the upper 5 cm subsamples for all sampling dates and only in August 1993 for the lower subsample.

**Table 8: Mean dry weight (g) and percent moisture content of upper and lower 5 cm soil subsamples (n=10) from FDO-1, 2; FD60-5, 6 and FD40-3, 4 sites where * represents significant difference between the subsamples at p=0.05.**

| Site | Date | Dry Weight (g) | | Percent Moisture (%) | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| FDO-1 | June 1993 | 35.4* | 56.5 | 78.2* | 73.0 |
| | July 1993 | 36.1* | 55.6 | 70.0 | 70.8 |
| | August 1993 | 32.2* | 44.9 | 72.3 | 74.6 |
| | June 1994 | 26.1 | 31.9 | 80.1 | 80.8 |
| FDO-2 | June 1993 | 34.9* | 59.0 | 73.8* | 62.8 |
| | July 1993 | 42.0 | 48.8 | 67.0 | 67.7 |
| | August 1993 | 40.9* | 59.1 | 64.6* | 90.5 |
| | June 1994 | 30.9 | 59.4 | 77.3 | 70.8 |
| FD60-5 | June 1993 | 37.6* | 51.9 | 72.6 | 73.3 |
| | July 1993 | 42.3* | 63.8 | 74.9 | 71.2 |
| | August 1993 | 44.0* | 66.3 | 53.7* | 60.5 |
| | June 1994 | 33.4 | 42.7 | 77.6 | 76.0 |
| FD60-6 | June 1993 | 58.5* | 121.3 | 68.8* | 57.4 |
| | July 1993 | 47.2* | 100.7 | 72.9 | 59.3 |
| | August 1993 | 47.5* | 71.1 | 56.9 | 54.6 |
| | June 1994 | 36.3* | 53.1 | 74.3 | 72.1 |
| FD40-3 | June 1993 | 35.6* | 81 3 | 77.3* | 66.8 |
| | July 1993 | 40.6* | 62.4 | 75.5 | 69.0 |
| | August 1993 | 39.9* | 56.6 | 57.3 | 59.5 |
| | June 1994 | 34.0* | 55.6 | 77.5 | 72.5 |
| FD40-4 | June 1993 | 41.1* | 95.4 | 78.2* | 57.2 |
| | July 1993 | 33.2* | 55.1 | 76.2* | 68.1 |
| | August 1993 | 46.6* | 82.5 | 58.5 | 54.9 |
| | June 1994 | 31.8 | 53.3 | 79.6* | 73.4 |

### 3.3.2. FE Sites

Dry weights for the soil subsamples from the FE sites varied from 38.5 to 50.3 grams in the upper 5 cm and from 43.6 to 60.2 grams in the lower (Table 9). Values differed significantly between the upper and lower subsamples for all but the July 1994 soil samples from FE60. Soil dry weights for FEO, FE60 and FE40 differed significantly in the lower 5 cm subsample from August 1994.

Soil percent moisture ranged from 68.2 to 81.5% and from 72.2 to 81.5% in the upper and lower subsamples, respectively, and did not differ significantly between sites. Percent moisture consistently increased with decreasing forest age in both upper and lower subsamples. FEO had significantly lower percent moisture values in both the upper and lower subsamples for all sampling dates than FE60 and FE40.

## 3.4 ORIBATID FAUNA

Oribatid mites collected from both FD and FE forest types included a total of 41 families and 91 species (Table 10), 14 of which were represented by both adult and immature stages. Among these, 17 genera and 35 species were new records for Newfoundland and one genus was a new record for Canada. Differences in species composition between the FD and FE forest types are evident as each type has 14 and 11 unique species, respectively.

### 3.4.1 MICROHABITAT SAMPLES

Of the 91 species, 64 occured in the microhabitat samples (Tables 11, 12 and 13). Species common in the soil samples were also abundant in the proximal microhabitat

**Table 9: Mean dry weight (g) and percent moisture content of upper and lower 5 cm soil subsamples (n=10) from FEO, FE60 and FE40 where * represents significant difference between the subsamples at p=0.05**

| Site | Date | Dry Weight (g) | | Percent Moisture (%) | |
|---|---|---|---|---|---|
| | | Upper 5 cm | Lower 5 cm | Upper 5 cm | Lower 5 cm |
| FEO | July 1994 | 39.6* | 53.0 | 74.2 | 75.9 |
| | August 1994 | 43.2* | 58.6 | 68.2 | 72.2 |
| FE60 | July 1994 | 38.5 | 43.6 | 79.8 | 80.0 |
| | August 1994 | 50.3* | 60.2 | 75.4 | 77.3 |
| FE40 | July 1994 | 40.7* | 51.7 | 81.5 | 81.5 |
| | August 1994 | 46.2* | 54.6 | 77.2 | 78.9 |

**Table 10: Oribatid mite species collected from balsam fir - *Dryopteris* and balsam fir - *Equisetum* forest stands on the West coast of Newfoundland. * - both adults and immatures collected.**

**Macropylina (lower oribatids)**

**Palaeosomata**
Palaeacaridae
*Palaeacarus hystricinus* Trägärdh, 1932

**Enarthronota**
Hypochthoniidae
*Hypochthonius rufulus* Koch, 1835 *

Eniochthoniidae
*Eniochthonius minutissimus* (Berlese, 1903) *

Brachychthoniidae
*Liochthonius lapponicus* (Trägärdh, 1910) new Newfoundland record
*Synchthonius crenulatus* (Jacot, 1938) new Newfoundland record

**Unplaced Enarthronota**
*Gozmanyina majestus* (Marshall and Reeves, 1971) new Newfoundland record

**Mixonomata**
Phthiracaridae
*Steganacarus (=Hoplophorella) thoreaui* (Jacot, 1930)
*Phthiracarus boresetosus* Jacot, 1930 new Newfoundland record
*Phthiracarus compressus* Jacot, 1930 new Newfoundland record
*Phthiracarus* sp.

Oribotritiidae
*Mesotritia* sp. cf. *testacea* Forsslund, 1963
*Protoribotritia canadaris* Jacot, 1938 new Newfoundland record

Euphthiracaridae
*Euphthiracarus* sp. new Newfoundland record
*Rhysotritia ardua* (Koch, 1841)

**Desmonomata**
Nothridae
*Nothrus anauniensis* Canestrini and Fanzago, 1876 * new Newfoundland record
*Nothrus palustris* Koch, 1841 * new Nev foundland record

Camisiidae
*Camisia biuris* (Koch, 1839) new Newfoundland record

*Camisia lapponica* (Trägärdh, 1910) * new Newfoundland record
*Heminothrus longisetosus* Willmann, 1925 * new Newfoundland record
*Platynothrus peltifer* (Koch, 1839) *
*Platynothrus* sp. * new Newfoundland record

Malaconothridae
*Malaconothrus* sp. cf. *pygmaeus* Aoki, 1969 * new Newfoundland record

Nanhermanniidae
*Nanhermannia bryophila* (sp. to be described by Norton et. al.) * new Newfoundland record

**Brachypylina (higher oribatids)**

**Apterogasterina (Gymnonota)**

Hermanniellidae
*Hermanniella* sp. cf. *subnigra* (Ewing, 1909) new Newfoundland record

Gymnodamaeidae
*Gymnodamaeus* sp. new Newfoundland record

Damaeidae
*Epidamaeus longitarsalis* (Hammer, 1952) new Newfoundland record

Cepheidae
*Cepheus corae* Jacot, 1928 *
*Eupterotegaeus* sp. new Newfoundland record

Podopterotegaeidae
*Podopterotegaeus tectus* Aoki, 1969 new Newfoundland record

Eremaeidae
*Eueremaeus marshalli* Behan-Pelletier, 1993 new Newfoundland record

Tenuialidae
*Hafenferrefia nitidula* (Banks, 1906) new Newfoundland record

Liacaridae
*Adoristes* sp. cf. *ammonoosuci* Jacot, 1938 new Newfoundland record
*Dorycranosus* sp. new Newfoundland record

Astegistidae
*Cultroribula bicultrata* (Berlese, 1905) new Newfoundland record

Peloppiidae (= Metrioppidae, Ceratoppiidae)
*Ceratoppia bipilis* (Hermann, 1904)
*Ceratoppia quadridentata arctica* Hammer, 1955 * new Newfoundland record
*Parapyroppia* sp. new Newfoundland record
*Pyroppia* sp. a new Newfoundland record
*Pyroppia* sp. b new Newfoundland record

Carabodidae
*Carabodes labyrinthicus* (Michael, 1879)

Tectocepheidae
*Tectocepheus velatus* (Michael, 1880) *

Oppiidae
*Cosmoppia ornata* (Oudemans, 1900) new Newfoundland record
*Moritzoppia* sp. cf. *clavigera* (Hammer) new Newfoundland record
*Oppia nitens* Koch, 1835 new Newfoundland record
*Oppiella washburni* (Hammer, 1952) new Newfoundland record
*Quadroppia* sp. cf. *skookumchucki* Jacot, 1939 new Newfoundland record
*Ramusella (Insculptoppia) manifera* (Hammer, 1955) new Newfoundland record
*Subiasella* sp. new Newfoundland record

Suctobelbidae
*Allosuctobelba* sp. new Newfoundland record
*Suctobelbella longicuspis* Jacot, 1937 new Newfoundland record
*Suctobelbella* sp. cf. *acutidens* (Forsslund, 1941)
*Suctobelbella* sp.

Autognetidae
*Autogneta longilamellata* (Michael, 1885)
*Conchogneta traegardhi* (Forsslund, 1947) new Newfoundland record
*Eremobodes* sp. new Newfoundland record

Thyrisomidae
*Banksinoma lanceolata canadensis* Fujikawa, 1979 new Newfoundland record

**Pterogasterina (Poronota)**

Scheloribatidae
*Dometorina plantivaga (Berlese, 1895)* new Newfoundland record
*Liebstadia similis* (Michael, 1988)
*Liebstadia* sp. a new Newfoundland record
*Liebstadia* sp. b new Newfoundland record
*Paraleius* sp. new Newfoundland record
*Scheloribates* sp. cf. *pallidulus* (Koch, 1841)

Oribatulidae
*Phauloppia* sp. new Newfoundland record
*Zygoribatula bulanovae* Kulijew, 196 new Newfoundland record

Haplozetidae
*Haplozetes* sp. new Canadian record
*Peloribates* sp.

Xylobatidae
*Xylobates* sp. new Newfoundland record

Parakalummidae
*Neoribates aurantiacus* (Oudemans, 1914)

Chamobatidae
*Chamobates cuspidatus* (Michael, 1884) new Newfoundland record

Ceratozetidae
*Ceratozetes cuspidatus* Jacot, 1939
*Ceratozetes gracilis* (Michael, 1884)
*Ceratozetes thienemanni* Willmann, 1943
*Fuscozetes setosus* (C.L. Koch, 1839) * new Newfoundland record
*Neogymnobates luteus* (Hammer, 1955) new Newfoundland record
*Sphaerozetes arcticus* Hammer, 1952 * new Newfoundland record
*Trichoribates* sp. a new Newfoundland record
*Trichoribates* sp. b new Newfoundland record

Mycobatidae
*Mycobates incurvatus* Hammer, 1952

Phenopelopidae
*Eupelops* sp.
*Propelops canadensis* (Hammer, 1952) new Newfoundland record

Oribatellidae
*Oribatella* sp. a new Newfoundland record
*Oribatella* sp. b new Newfoundland record

Tegoribatidae
*Lepidozetes singularis* Berlese, 1910 new Newfoundland record

Achipteriidae
*Anachipteria* sp. new Newfoundland record
*Dentachipteria highlandensis* Nevin, 1974 new Newfoundland record
*Dentachipteria* sp. new Newfoundland record
*Parachipteria travei* Nevin, 1977 *

Galumnidae
*Pilogalumna* sp.

**Table 11: Oribatid mite species abundances for FDO microhabitat samples where dec. - deciduous and abundance rankings are: * = 1-5, ** = 6-10, *** = 10+ specimens collected.**

| Species | rotten wood | tree hole | bark live tree | bark dead tree | lichen from ground | lichen from tree | dec. leaf upper | dec. leaf lower | moss live tree | moss dead tree |
|---|---|---|---|---|---|---|---|---|---|---|
| *Pa. hystricinus* | | * | | | | | | | | |
| *Hy. rufulus* | * | * | | | | | *** | *** | * | ** |
| *H. rufulus* immature | * | ** | | | | | *** | *** | * | ** |
| *En. minutissimus* | *** | * | | * | * | | *** | *** | *** | *** |
| *En. minutissimus* immature | ** | | | | | | *** | *** | | ** |
| *Lio. lapponicus* | * | * | | | | | * | | * | * |
| *Sy. crenulatus* | * | *** | * | * | | | * | * | * | * |
| *St. thoreaui* | ** | *** | | * | ** | | *** | *** | *** | ** |
| *Ph. boresetosus* | * | * | | | ** | * | *** | *** | * | * |
| *Ph. compressus* | * | * | | ** | * | | ** | | * | * |
| *Phthiracarus* sp. | * | * | * | * | ** | | ** | * | ** | * |
| *Mesotritia* sp. | ** | ** | | ** | | | * | | ** | * |
| *Prot. canadaris* | * | *** | | | | | | * | * | * |
| *Rh. ardua* | * | * | | | | | * | | * | * |
| *No. anauniensis* | * | *** | | | | | * | * | ** | ** |
| *No. anauniensis* immature | * | *** | | * | | | * | | * | * |
| *Cam. biuris* | * | | | | * | | * | * | * | * |
| *Cam. lapponica* | * | * | | | | * | | * | * | * |
| *Camisia* spp. immature | * | * | | | | | | | | |
| *He. longisetosus* | * | ** | | | | | * | ** | * | *** |
| *He. longisetosus* immature | | | | | * | * | * | | | |
| *Pl. peltifer* | * | * | | | ** | | *** | *** | | * |

**Table 11 cont.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Platynothrus sp.* | * | * | | | | | ** | *** | | |
| *Platynothrus* spp. immature | * | * | | | ** | * | *** | *** | | * |
| *Malaconothrus sp.* | | | | | | | | | | |
| *Na. bryophila* | * | *** | | | | | *** | *** | * | * |
| *Na. bryophila* immature | * | *** | | | | | * | *** | * | * |
| *Hermanniella sp.* | ** | ** | | * | | | ** | ** | * | ** |
| *Ep. longitarsalis* | | * | | | | | | | | |
| *Ep. longitarsalis* immature | | * | | | | | * | | | * |
| *Epidamaeus sp.* | | * | | | | | | | * | * |
| *Cep. corae* | * | * | | | * | | ** | | * | * |
| *C. corae* immature | | * | | | * | | * | | * | * |
| *Po. tectus* | * | *** | | | | | | | | |
| *Eu. marshalli* | ** | | * | ** | | * | | | * | * |
| *Ha. nitidula* | * | * | | * | * | | ** | * | | * |
| *Adoristes sp.* | ** | * | | * | *** | ** | *** | *** | *** | *** |
| *Doryceranosus sp.* | * | | | * | * | | | | * | |
| *Cu. bicultrata* | | | | | | | | | | |
| *Ce. quadridentata* | | * | | | | | * | | * | |
| *Ce. quadridentata* immature | | | | | | | | | | |
| *Parapyroppia sp.* | | | | | | | *** | | | |
| *Pyroppia sp. a* | * | * | | | | | *** | | | |
| *Car. labyrinthicus* | ** | ** | * | * | * | * | * | | *** | ** |
| *T. velatus* | ** | * | | * | | | | | *** | *** |
| *Cos. ornata* | * | ** | | * | | | *** | * | *** | *** |
| *Oppia nitens* | * | | | * | | * | | | | |
| *O. washburni* | ** | *** | * | ** | * | * | *** | *** | *** | *** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Quadroppia sp.* | * | ** | | | | * | * | | ** | ** |
| *Allosuctobelba sp.* | | | | | | | | | | * |
| *Suctobelbella spp.* | ** | *** | * | | | * | ** | ** | ** | *** |
| *A. longilamellata* | * | | | * | | | | | | |
| *Con. traegardhi* | | ** | | | | | ** | | | * |
| *B. lanceolata* | * | ** | * | * | | | * | * | | * |
| *Do. plantivaga* | | | | * | | | * | | | * |
| *Lie. similis* | | | | | | | | | | |
| *Liebstadia sp. a* | ** | | * | | | * | * | | * | * |
| *Liebstadia sp. b* | * | | | ** | | * | * | | * | * |
| *Scheloribates sp.* | ** | ** | * | *** | | | | | ** | *** |
| *Phauloppia sp.* | | | | | | | | | * | * |
| *Z. bulanovae* | * | * | * | ** | | * | * | | ** | *** |
| *Xylobates sp.* | * | * | | | | | | | * | * |
| *Ch. cuspidatus* | * | * | | * | | | * | | * | * |
| *Cer. cuspidatus* | | * | | | | | | | | * |
| *Cer. thienemanni* | | * | | | | * | * | * | | |
| *F. setosus* | | | | | | | | | | * |
| *Neog. luteus* | | * | | * | | * | | | ** | ** |
| *Trichoribates spp.* | * | * | | | | * | * | | ** | ** |
| *M. incurvatus* | | | | | | | | | | |
| *Oribatella sp. a* | * | * | * | | | | | | | |
| *De. highlandensis* | * | * | | | | | | | | * |
| *Dentachipteria sp.* | | | | | | | | | | |
| *Par. travei* | * | ** | | * | ** | * | *** | *** | *** | *** |
| *Par. travei* immature | * | ** | | * | ** | | *** | *** | *** | *** |

**Table 12: Oribatid mite species abundances from FD60 microhabitat samples where dec. - deciduous and abundance rankings are: * = 1-5, ** = 6-10, *** = 10+ specimens collected.**

| Species | rotten wood | tree hole | bark live tree | bark dead tree | lichen from ground | lichen from tree | dec. leaf upper | dec. leaf lower | moss live tree | moss dead tree |
|---|---|---|---|---|---|---|---|---|---|---|
| *Pa. hystricinus* | | * | | | | | | | | |
| *Hy. rufulus* | | | | | | | | *** | | |
| *H. rufulus* immature | | | | | | | *** | *** | | |
| *En. minutissimus* | *** | *** | | * | | | ** | ** | * | * |
| *En. minutissimus* immature | * | | | | | | | | | * |
| *Lio. lapponicus* | | | | | | | | | | |
| *Sy. crenulatus* | ** | | | | | | | | | |
| *St. thoreaui* | * | * | | | * | | *** | *** | *** | *** |
| *Ph. boresetosus* | ** | * | | | * | | * | *** | | *** |
| *Ph. compressus* | | * | * | | * | | * | * | * | * |
| *Phthiracarus sp.* | * | * | * | | | | | | * | * |
| *Mesotritia sp.* | ** | | | | | | | | | |
| *Prot. canadaris* | | * | | | | | | | | |
| *Rh. ardua* | * | | | | * | | ** | * | * | *** |
| *No. anauniensis* | * | *** | | | | | | *** | | * |
| *No. anauniensis* immature | | *** | | | | | | | | * |
| *Cam. biuris* | | | | | | | | | * | * |
| *Cam. lapponica* | * | | | | | | | | | |
| *Cam. lapponica* immature | | | | | | | | | | |
| *He. longisetosus* | * | * | | | | | | * | | * |
| *He. longisetosus* immature | | | | | | | | | | |
| *Pl. peltifer* | | * | | | | | *** | *** | | |

Table 12 cont.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Platynothrus sp.* | | | | | | | * | *** | | |
| *Platynothrus spp.* immature | | * | | | | | *** | *** | | * |
| *Malaconothrus sp.* | | * | | | | | | * | | |
| *Na. bryophila* | ** | *** | | | | | *** | *** | | * |
| *Na. bryophila* immature | | * | | | | | *** | *** | | |
| *Hermanniella sp.* | | * | | | | | | * | | |
| *Ep. longitarsalis* | | | | | | | | | | |
| *Ep. longtarsalis* immature | | | | | | | | | | |
| *Epilamaeus sp.* | | | | | | | | | | |
| *Cep. corae* | * | * | | | | *** | | * | *** | *** |
| *C. corae* immature | | | | | * | | | | | |
| *Po. tectus* | | ** | | | | | | | | |
| *Eu. marshalli* | | | | | | | | | * | |
| *Ha. nitidula* | * | | | | | | | | | |
| *Adoristes sp.* | * | * | * | | * | * | *** | *** | ** | *** |
| *Dorycranosus sp.* | | | | | | | | | | |
| *Cu. bicultrata* | * | * | | | | | | | | |
| *Ce. quadridentata* | | | | | | * | | * | ** | |
| *Ce. quadridentata* immature | | | | | | | | | * | |
| *Parapyroppia sp.* | | | | | | | * | | | |
| *Pyroppia sp. a* | | | | | | | | | | |
| *Car. labyrinthicus* | | * | ** | | | | | | *** | |
| *T. velatus* | *** | ** | | | * | | * | ** | *** | |
| *Cos. ornata* | | ** | | | | | | | | * |
| *Oppia nitens* | | | | | | | * | *** | | * |
| *O. washburni* | *** | *** | | * | | | ** | *** | *** | ** |

**Table 12 cont.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Quadroppia sp.* | ** | ** | | | | | | * | * | * |
| *Allosuctobelba sp.* | | | | | | | | | | |
| *Suctobelbella spp.* | *** | ** | | * | | | | ** | * | * |
| *A. longilamellata* | | | | | | | | | | |
| *Con. traegardhi* | | | | | | | | | | |
| *B. lanceolata* | ** | * | | | | | | *** | | |
| *Do. plantivaga* | ** | | | | | | | | | |
| *Lie. similis* | *** | ** | * | * | * | | | | ** | *** |
| *Liebstadia sp. a* | | | | | | | | | | |
| *Liebstadia sp. b* | * | | | * | ** | | * | | | * |
| *Scheloribates sp.* | * | ** | | | | | | *** | *** | |
| *Phauloppia sp.* | | | | | | | | | | |
| *Z. bulanovae* | ** | | | | | * | | | | |
| *Xylobates sp.* | ** | * | | | | | | * | | |
| *Ch. cuspidatus* | | | | * | | * | | * | *** | * |
| *Cer. cuspidatus* | | ** | | | | | * | *** | | |
| *Cer. thienemanni* | | | | | | | | | | |
| *F. setosus* | | | | | | | | | * | * |
| *Neog. luteus* | | | * | * | | | * | * | *** | ** |
| *Trichoribates spp.* | | | | * | | | | * | *** | ** |
| *M. incurvatus* | | | | | | | | | | * |
| *Oribatella sp. a* | * | | | | | | | | * | |
| *De. highlandensis* | *** | * | | | | | | | * | |
| *Dentachipteria sp.* | | | | | | | | * | | |
| *Par. travei* | *** | *** | | | *** | | *** | *** | *** | *** |
| *Par. travei* immature | *** | * | | | *** | | *** | *** | *** | *** |

**Table 13: Oribatid mite species abundances from FD40 microhabitat samples where dec. - deciduous and adundance rankings are: * = 1-5, ** = 6-10, *** = 10+ specimens collected.**

| Species | rotten wood | tree hole | bark live tree | bark dead tree | lichen from ground | lichen from tree | dec. leaf upper | dec. leaf lower | moss live tree | moss dead tree |
|---|---|---|---|---|---|---|---|---|---|---|
| *Pa. hystricinus* | * | * | | | | | | | | |
| *Hy. rufulus* | | * | | | | | | * | | |
| *H. rufulus* immature | | * | * | | | | | *** | | |
| *En. minutissimus* | *** | ** | | | | | | *** | *** | *** |
| *En. minutissimus* immature | *** | *** | | | | | *** | | *** | *** |
| *Lio. lapponicus* | | | | | | | | | * | * |
| *Sy. crenulatus* | *** | * | | | | | * | *** | * | *** |
| *St. thoreaui* | *** | *** | | | *** | * | *** | *** | *** | *** |
| *Ph. horesetosus* | *** | *** | | | * | | ** | *** | | *** |
| *Ph. compressus* | | * | | | | | * | | | * |
| *Phthiracarus sp.* | * | * | * | | * | * | * | * | * | * |
| *Mesotritia sp.* | * | * | | | | | | * | | |
| *Prot. canadaris* | * | * | | | | | | * | | * |
| *Rh. ardua* | *** | * | | | ** | | *** | * | * | *** |
| *No. anauniensis* | * | *** | | | | | | *** | * | |
| *No. anauniensis* immature | *** | *** | | | | | | *** | | |
| *Cam. biuris* | | | | | | | | | | * |
| *Cam. lapponica* | * | | | | | | | | | |
| *Camisia spp.* immature | | | | | | | | | | |
| *He. longisetosus* | *** | | | | | | | ** | | *** |
| *He. longisetosus* immature | * | | | | | | | | | * |

**Table 13 cont.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *P. peltifer* | | * | | | | | *** | *** | | |
| *Platynothrus sp.* | | | | | | | * | *** | | |
| *Platynothrus spp.* immature | | | | | | | *** | *** | | |
| *Malaconothrus sp.* | | | | | | | * | | | |
| *Na. bryophila* | *** | *** | | | | | * | *** | | |
| *Na. bryophila* immature | * | * | | | | | | *** | | |
| *Hermanniella sp.* | *** | * | | | | | * | | | |
| *Ep. longitarsalis* | | | | | | | | | | |
| *Ep. longitarsalis* immature | | | | | | | | | | |
| *Epidamaeus sp.* | | | | | | | | | | |
| *Cep. corae* | * | * | | | | | | | | *** |
| *C. corae* immature | | | | | * | | | | | |
| *Po. tectus* | | * | | | | | | | | |
| *Eu. marshalli* | | | | | | | | | * | |
| *Ha. nitidula* | * | | | | | | | | | * |
| *Adoristes sp.* | * | * | * | * | *** | | *** | *** | * | * |
| *Dorycranosus sp.* | * | | | | | | | | | |
| *Cu. bicultrata* | | * | | | | | | | | |
| *Ce. quadridentata* | | | | | * | | | | | * |
| *Ce. quadridentata* immature | | | | | | | | | * | * |
| *Parapyroppia sp.* | * | | | | | | * | | * | |
| *Pyroppia sp. a* | * | | | | * | | | | * | * |
| *Car. labyrinthicus* | * | | | | | | | | * | * |
| *T. velatus* | *** | *** | | | | | * | *** | *** | *** |
| *Cos. ornata* | | | ** | | | | | | * | |
| *Oppia nitens* | | * | | | | | | ** | | * |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *O. washburni* | *** | *** | | * | | | * | *** | *** | *** |
| *Quadroppia sp.* | *** | | | | | | | | | |
| *Allosuctobelba sp.* | | | | | | | | | | |
| *Suctobelbella spp.* | *** | * | | | | | | *** | | |
| *A. longilamellata* | | | | | | | | | | |
| *Con. traegardhi* | | | | | | | | | | |
| *B. lanceolata* | * | * | * | | | | | * | | |
| *Do. plantivaga* | | | | | | | | | | |
| *Lie. similis* | *** | ** | * | * | | | * | | | * |
| *Liebstadia sp. a* | | | | | | | | | | |
| *Liebstadia sp. b* | | | | | | * | | | | * |
| *Scheloribates sp.* | *** | ** | | | | | | | *** | *** |
| *Phauloppia sp.* | | | | | | | | | | |
| *Z. bulanovae* | * | | | | | | | | *** | * |
| *Xylobates sp.* | *** | * | | | | | | * | *** | |
| *Ch. cuspidatus* | | * | | * | * | * | | | ** | * |
| *Cer. cuspidatus* | * | *** | | | | | | * | | |
| *Cer. thienemanni* | * | *** | | | * | | | | * | |
| *F. setosus* | | | | | | | | | *** | * |
| *Neog. luteus* | * | | | | | | | * | * | *** |
| *Trichoribates spp.* | * | * | | | * | * | | * | | *** |
| *M. incurvatus* | | | | | | | | | | |
| *Oribatella sp. a* | * | * | | | | | | | * | |
| *De. highlandensis* | * | | | | | | | | | |
| *Dentachipteria sp.* | | | | | | | | | ** | *** |
| *Par. travei* | *** | *** | | | *** | * | *** | *** | *** | *** |
| *Par. travei* immature | *** | | | | * | | *** | *** | *** | *** |

samples (i.e. deciduous leaves, tree moss and tree hole). The most common species, *Oppiella washburni* and *Adoristes* sp., occurred in every habitat.

Members of *Platynothrus* showed a particular affinity for the deciduous leaves samples. *Platynothrus peltifer* was abundant in both upper and lower deciduous leaves samples whereas *Platynothrus* sp. occurred mainly in the lower compact layers.

Some species, though not common, showed regular occurrence in certain microhabitats. *Camisia biuris* was found in moss samples from dead and live trees whereas *Podopterotegaeus tectus* and *Palaeacarus hystricinus* were regularly present in all tree hole samples. *Fuscozetes setosus*, which occurred only in soil samples from FD40 sites, also occurred in tree moss samples from FD0, FD60 and FD40.

Few species were abundant in the bark and lichen samples. Most notable were the members of the supercohort Mixonomata, particularly those of the Phthiracaridae (*Steganacarus thoreaui*, *Phthiracarus boresetosus*, *Pthiracarus compressus*, *Phthiracarus* sp.), which occurred repeatedly in these habitats. *Adoristes* sp. was fairly common in the lichen samples, especially those from the ground.

*Eueremaeus marshalli* was unique to the microhabitat samples, regularly occurring in tree associated samples such as dead tree bark and rotten wood.

### 3.4.2 SOIL SAMPLES

#### 3.4.2.1 Collection Fluid Effects

To assess the effects of different collection fluids on extraction efficiency, samples were collected in either water, 70% ethanol or a 50:50 mixture of 70% ethanol and

Kahle's solution. One-way analysis of variance performed on log transformed data indicated no significant difference in oribatid mite species diversity or abundance among the three collection fluids.

### 3.4.2.2 Sampling Efficiency

Cumulative number of species per sample for FD areas (Figure 15) tended to level off for each sampling year as a total of ten soil samples in a series was approached. However, in 1994, the FD40 curve continued to increase to ten samples suggesting additional samples would have been required to obtain most of the species present.

Similar graphs for FE July and August 1994 data (Figure 16) show the same levelling effect though not to the same extent as observed in the FD data. The July curves showed FEO and FE60 still increasing whereas in August the FE40 curve was still rising. As in the FD sites, a few additional samples may have collected previously undetected species.

### 3.4.2.3 FD Sites

#### 3.4.2.3.1 Density

Mean oribatid mite density per 1000 $cm^3$ over the three sampling years for each of the FD sites ranged from 343.9 to 1894.0 per sample (Table 14, Figures 17, 18 and 19) with highly variable individual species abundances (Table 15). For each sampling date, there was no significant difference among the three age areas.

Oribatid mite density was significantly lower in 1992 than 1993 and 1994 in all areas except for the FD40 August 1992 sample. The two regrowth areas showed an

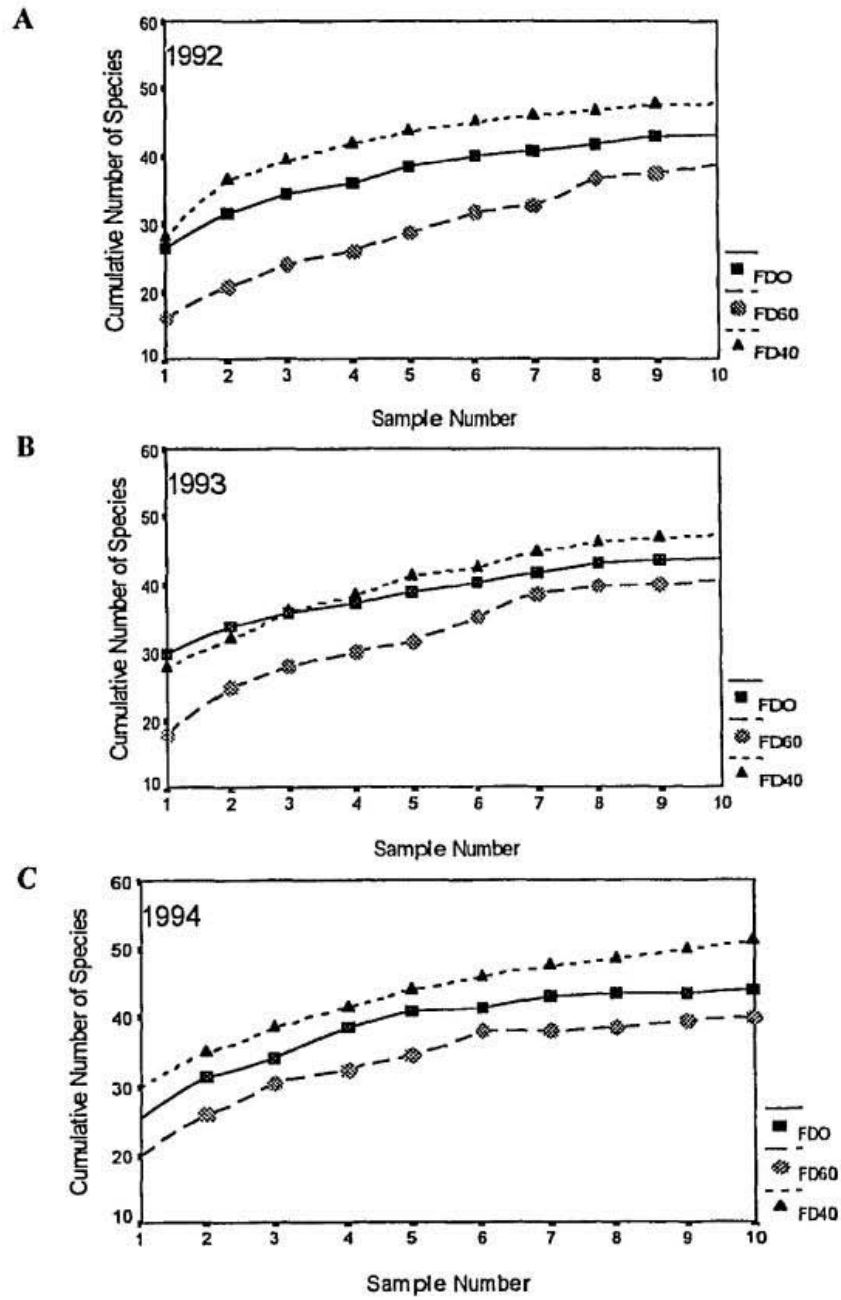



**Figure 15: Yearly mean cumulative number of oribatid mite species from a series of ten soil samples from FDO, FD60 and FD40 for 1992 (A), 1993(B) and 1994 (C).**

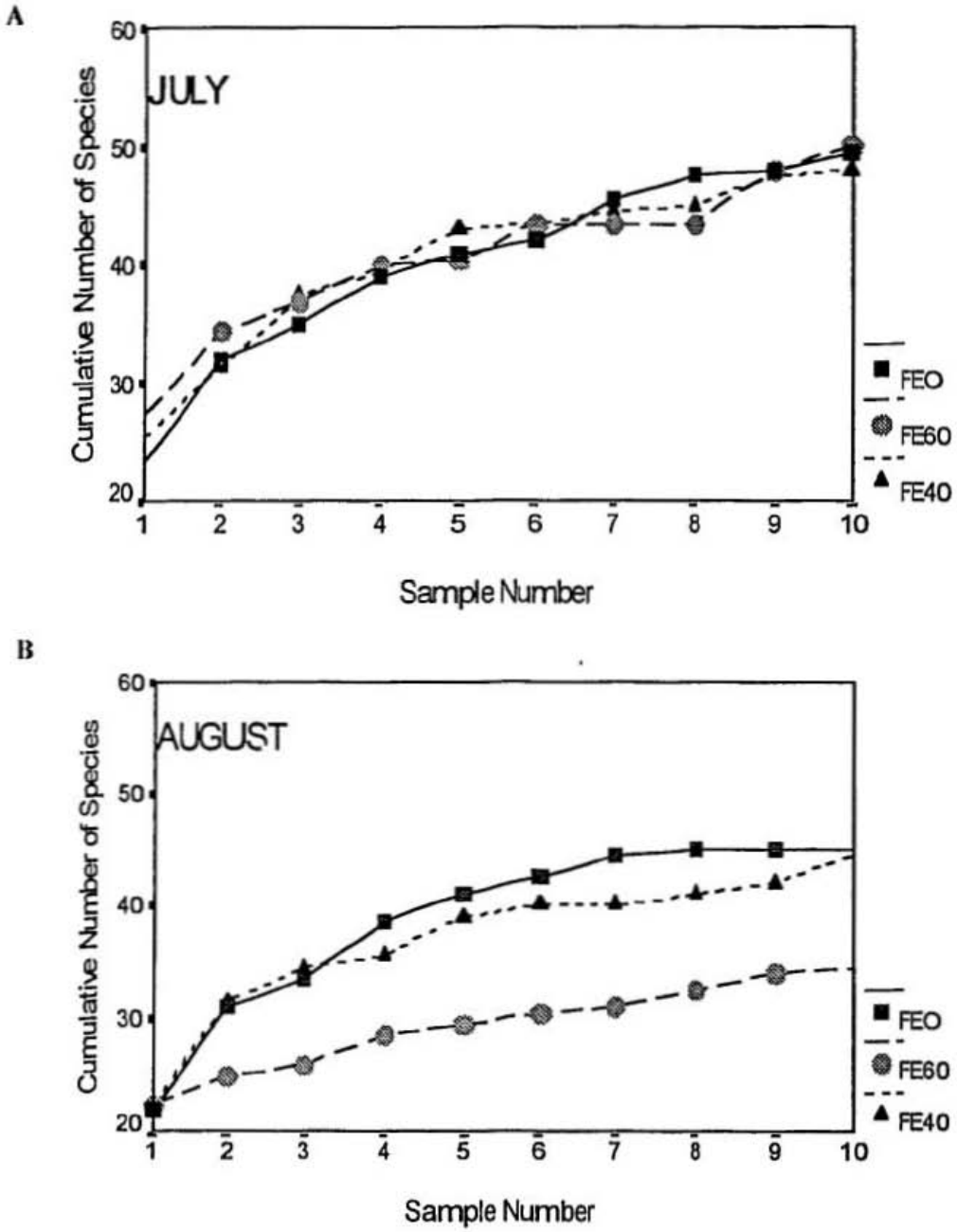



**Figure 16: Cumulative number of oribatid mite species from a series of ten soil samples from FEO, FE60 and FE40 for July (A) and August (B) 1994.**

**Table 14: Mean and standard error for oribatid mite density per 1000 cm $^3$ soil sample for 1992, 1993 and 1994 sampling dates from FDO, FD60 and FD40 areas.**

| Site | Mean Number Per Sample (Standard Error) | | |
|---|---|---|---|
| | 1992 n=20 | 1993 n=30 | 1994 n=10 |
| FDO-1 | 655 (36) | 886 (59) | 1233 (96) |
| FDO-2 | 735 (62) | 1378 (77) | 1380 (106) |
| FD60-5 | 344 (48) | 888 (81) | 1131 (144) |
| FD60-6 | 1070 (170) | 1232 (127) | 1894 (276) |
| FD40-3 | 910 (135) | 1681 (102) | 1733 (187) |
| FD40-4 | 504 (71) | 791 (44) | 850 (78) |

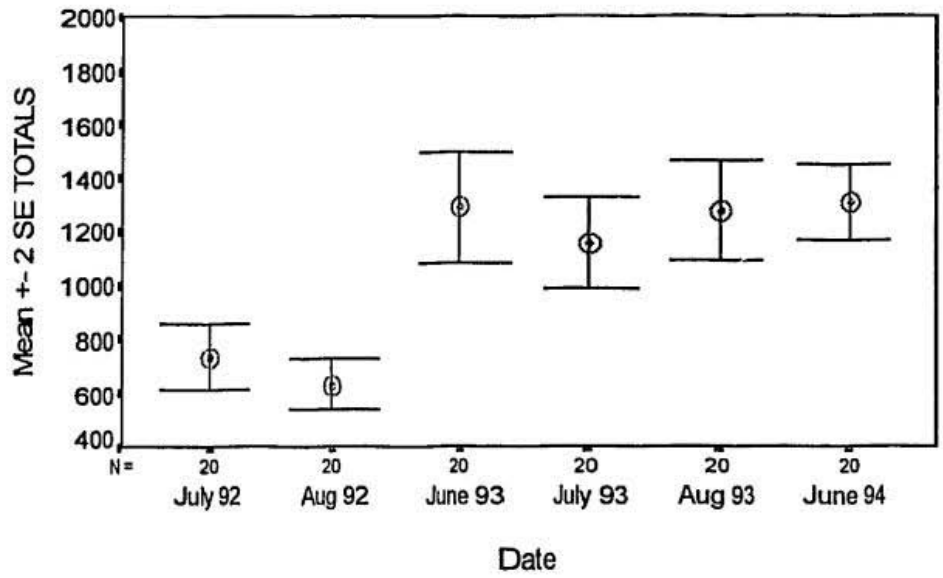



**Figure 17: Mean oribatid mite densities (number per 1000 cm³) for six sampling periods from FDO.**

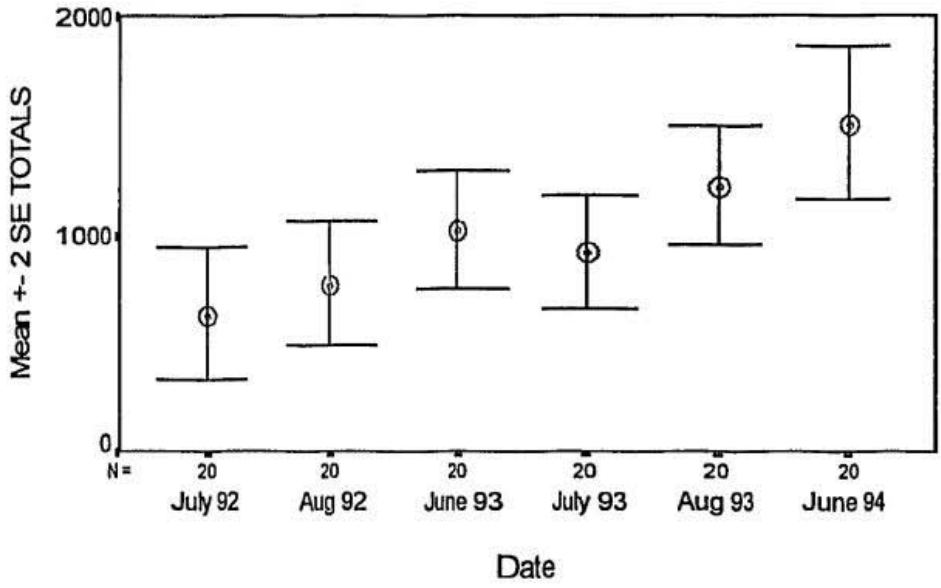



**Figure 18: Mean oribatid mite densities (number per 1000 cm³) for six sampling periods from FD60.**

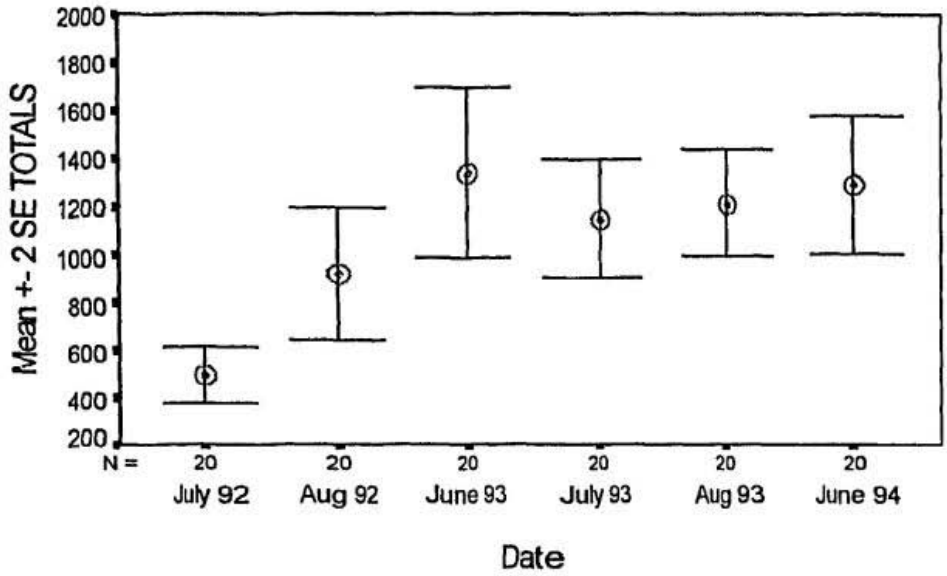



**Figure 19: Mean oribatid mite densities (number per 1000 cm$^3$) for six sampling periods from FD40.**

**Table 15: Mean (n=60) density (number per 1000 $cm^3$) of oribatid mite species in FDO-1, 2; FD60-5, 6; FD40-3, 4 sites. Species order follows Table 14 and species with 0 values were recorded from either microhabitat or FE soil samples.**

| SPECIES | FDO-1 | FDO-2 | FD60-5 | FD60-6 | FD40-3 | FD40-4 |
|---|---|---|---|---|---|---|
| *Pa. hystricinus* | 1.27 | 1.85 | 0.42 | 0.23 | 1.20 | 1.22 |
| *Hy. rufulus* | 4.87 | 8.00 | 1.82 | 0.35 | 16.32 | 1.87 |
| *Hy. rufulus* Imm. | 18.33 | 26.87 | 3.43 | 1.80 | 70.92 | 4.35 |
| *En. minutissimus* | 55.78 | 52.48 | 30.97 | 149.71 | 37.80 | 10.70 |
| *En. minutissimus* Imm. | 46.35 | 39.43 | 15.52 | 78.13 | 12.55 | 2.92 |
| *Lio. lapponicus* | 5.98 | 7.22 | 0.00 | 0.00 | 7.92 | 6.18 |
| *Sy. crenulatus* | 40.95 | 41.63 | 1.67 | 1.58 | 41.70 | 27.90 |
| *G. majestus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *St. thoreaui* | 85.32 | 55.50 | 59.47 | 70.32 | 119.08 | 82.68 |
| *Ph. boresetosus* | 1.97 | 3.93 | 8.58 | 15.72 | 8.27 | 1.87 |
| *Ph. compressus* | 0.95 | 1.93 | 2.67 | 3.12 | 1.52 | 0.45 |
| *Phthiracarus sp.* | 0.37 | 0.43 | 2.18 | 2.03 | 0.97 | 0.55 |
| *Mesotritia sp.* | 0.50 | 1.02 | 0.15 | 0.27 | 0.15 | 0.15 |
| *Prot. canadaris* | 7.28 | 3.88 | 1.97 | 4.75 | 5.88 | 2.33 |
| *Euphthiracarus sp.* | 0.02 | 0.00 | 0.00 | 0.13 | 0.42 | 0.00 |
| *Rh. ardua* | 5.92 | 2.50 | 4.62 | 6.28 | 11.82 | 7.78 |
| *No. ananniensis* | 5.20 | 12.98 | 4.03 | 0.00 | 14.08 | 4.07 |
| *No. palustris* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Nothrus* Imm. | 31.45 | 63.13 | 7.02 | 0.17 | 55.53 | 16.82 |
| *Cam. biuris* | 0.00 | 0.00 | 0.05 | 0.03 | 0.08 | 0.00 |
| *Cam. lapponica* | 3.03 | 2.57 | 1.03 | 1.47 | 1.15 | 0.58 |
| *Cam. lapponica* Imm. | 3.62 | 5.53 | 0.72 | 2.07 | 2.80 | 2.15 |
| *He. longisetosus* | 2.13 | 6.40 | 2.48 | 1.87 | 8.12 | 2.98 |

Table 15 cont.

| | | | | | | |
|---|---|---|---|---|---|---|
| *He. longisetosus* Imm. | 0.72 | 1.63 | 0.97 | 0.62 | 4.12 | 1.82 |
| *Pl. peltifer* | 11.55 | 14.82 | 8.00 | 3.22 | 9.27 | 5.02 |
| *Platynothrus sp.* | 0.70 | 2.78 | 13.07 | 4.60 | 12.03 | 0.72 |
| *Platynothrus* Imm. | 55.85 | 100.33 | 57.90 | 28.72 | 93.82 | 24.82 |
| *Malaconothrus sp.* | 2.28 | 0.15 | 2.02 | 0.85 | 4.40 | 10.53 |
| *Malaconothrus* Imm. | 0.40 | 0.08 | 0.38 | 0.30 | 0.67 | 1.80 |
| *Na. bryophila* | 18.53 | 19.57 | 10.02 | 32.40 | 68.20 | 12.92 |
| *Na. bryophila* Imm. | 26.67 | 19.78 | 12.37 | 47.70 | 114.43 | 21.17 |
| *Hermanniella sp.* | 1.48 | 1.67 | 0.27 | 1.40 | 0.78 | 1.52 |
| *Gymnodamaeus sp.* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ep. longitarsalis* | 0.03 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ep. longitarsalis* Imm. | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Epidamaeus sp.* | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.02 |
| *Cep. corae* | 5.43 | 0.97 | 2.40 | 0.45 | 0.62 | 0.20 |
| *Cep. corae* Imm. | 0.38 | 0.08 | 0.07 | 0.02 | 0.05 | 0.00 |
| *Eupterotegaeus sp.* | 0.02 | 0.02 | 0.00 | 0.00 | 0.03 | 0.05 |
| *Po. tectus* | 0.07 | 0.25 | 0.20 | 0.10 | 1.00 | 0.23 |
| *Ha. nitidula* | 0.12 | 0.10 | 0.07 | 0.00 | 0.05 | 0.20 |
| *Adoristes sp.* | 8.53 | 20.58 | 7.85 | 13.95 | 21.62 | 18.27 |
| *Dorycranosus sp.* | 0.00 | 0.00 | 0.02 | 0.00 | 0.02 | 0.00 |
| *Cu. bicultrata* | 0.72 | 0.25 | 0.25 | 0.37 | 0.32 | 0.22 |
| *Ce. bipilis* | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.02 |
| *Ce. quadridentata* | 0.08 | 0.18 | 0.00 | 0.03 | 0.92 | 1.23 |
| *Ceratoppia* Imm. | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.35 |
| *Parapyroppia sp.* | 4.12 | 7.87 | 0.13 | 0.02 | 7.18 | 3.38 |
| *Pyroppia sp. a* | 0.58 | 0.63 | 0.17 | 0.02 | 1.22 | 3.12 |
| *Pyroppia sp. b* | 0.00 | 0.03 | 0.00 | 0.00 | 0.12 | 0.23 |
| *Car. labyrinthicus* | 0.25 | 0.42 | 0.45 | 0.07 | 0.18 | 0.08 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *T. velatus* | 11.78 | 18.48 | 10.17 | 3.15 | 81.07 | 25.02 |
| *Tectocepheus sp.* | 0.07 | 0.15 | 0.18 | 0.00 | 0.02 | 0.00 |
| *Tectocepheus* Imm. | 0.68 | 0.33 | 0.10 | 0.02 | 0.35 | 1.10 |
| *Cos. ornata* | 23.68 | 16.08 | 1.28 | 1.50 | 3.43 | 1.77 |
| *Moritzoppia sp.* | 0.03 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| *Oppia nitens* | 0.00 | 0.00 | 0.02 | 0.05 | 9.03 | 1.43 |
| *O. washburni* | 190.63 | 313.83 | 182.13 | 294.22 | 249.63 | 146.13 |
| *Quadroppia sp.* | 20.63 | 21.52 | 25.90 | 5.32 | 33.72 | 17.78 |
| *Ra. manifera* | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 |
| *Subiasella sp.* | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| *Allosuctobelba sp.* | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Suctobelbella spp.* | 93.63 | 97.45 | 54.48 | 80.02 | 75.27 | 40.28 |
| *A. longilamellata* | 0.23 | 0.03 | 0.02 | 0.02 | 0.00 | 0.13 |
| *Con. traegardhi* | 1.07 | 2.57 | 0.00 | 0.03 | 0.12 | 0.05 |
| *Eremobodes sp.* | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *B. lanceolata* | 9.13 | 7.58 | 13.78 | 8.40 | 12.57 | 7.97 |
| *Do. plantivaga* | 0.00 | 0.03 | 0.00 | 0.02 | 0.00 | 0.07 |
| *Lie. similis* | 0.05 | 0.00 | 0.02 | 0.02 | 0.22 | 0.08 |
| *Liebstadia sp. a* | 0.18 | 0.05 | 0.20 | 0.07 | 0.18 | 0.42 |
| *Liebstadia sp. b* | 0.08 | 0.23 | 0.42 | 0.18 | 0.62 | 0.20 |
| *Paraleius sp.* | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 |
| *Scheloribates* sp. | 3.10 | 1.43 | 12.68 | 12.17 | 16.87 | 17.20 |
| *Phauloppia* sp. | 0.00 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 |
| *Z. bulanovae* | 0.15 | 0.17 | 0.12 | 0.02 | 0.03 | 0.05 |
| *Haplozetes* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Peloribates* sp. | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 |
| *Xylobates* sp. | 0.32 | 0.45 | 1.32 | 0.23 | 11.08 | 2.23 |
| *Neor. aurantiacus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Ch. cuspidatus* | 0.05 | 0.07 | 0.05 | 0.52 | 0.33 | 0.47 |
| *Cer. cuspidatus* | 0.77 | 0.68 | 5.37 | 8.53 | 3.10 | 1.35 |
| *Cer. gracilis* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Cer. thienemanni* | 0.92 | 1.97 | 4.93 | 33.63 | 7.53 | 1.13 |
| *F. setosus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.37 | 0.30 |
| *Neog. luteus* | 0.32 | 0.20 | 1.38 | 0.13 | 0.02 | 0.03 |
| *Sp. arcticus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Trichoribates* spp. | 0.33 | 1.08 | 1.05 | 0.38 | 0.85 | 0.93 |
| Ceratozetidae Imm. | 0.02 | 0.20 | 0.10 | 1.38 | 0.57 | 0.05 |
| *M. incurvatus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Eupelops* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Prop. canadensis* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Oribatella* spp. | 0.00 | 0.02 | 0.37 | 0.05 | 0.02 | 0.03 |
| *Le. singularis* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Anachipteria* sp. | 0.00 | 0.00 | 0.85 | 0.02 | 0.03 | 0.00 |
| *D. highlandensis* | 0.00 | 0.30 | 0.35 | 0.07 | 1.23 | 0.28 |
| *Dentachipteria* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.57 | 0.00 |
| *P. travei* | 48.42 | 55.00 | 68.97 | 131.73 | 64.77 | 55.28 |
| *P. travei* Imm. | 101.23 | 94.18 | 95.50 | 231.40 | 99.23 | 98.10 |
| *Pilogalumna* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 |

increase in total density from July to August in 1992 whereas oribatid populations in FDO appeared to decrease in August 1992. In 1993, all three age areas showed a slight decrease in total numbers from June to July followed by an increase in August. Oribatid abundance in the June samples of 1994 were higher than in the 1993 August samples, particularly those of the FD60 area (Figure 18). In comparison with June 1993, June 1994 densities were higher in FDO and FD60 whereas FD40 had lower oribatid numbers.

**3.4.2.3.2. Species Distribution**

Species diversity varied among the three age areas of the FD forest type. Three species, *Epidamaeus longitarsalis*, *Allosuctobelba* sp. and *Eremobodes* sp., were unique to FDO, *Paraleius* sp. and *Peloribates* sp. were unique to FD60 and *Ramusella manifera*, *Subiasella* sp., *Fuscozetes setosus*, *Dentachipteria* sp., and *Pilogalumna* sp. occurred only in FD40.

The abundance of several other species differed noticeably from one age class to another. *Cosmoppia ornata* had a higher abundance in FDO whereas *Ceratozetes cuspidatus* and *Ceratozetes thienemanni* occurred in higher numbers in FD60. *Malaconothrus* sp., *Tectocepheus velatus* and particularly *Oppia nitens*, which was absent from FDO and rare in FD60, had a higher occurrence in FD40. In contrast, some species occurred rarely or not at all such as *Synchthonius crenulatus* and *Liochthonius lapponicus* in FD60.

The histograms of Figure 20 (A-C) indicate the number of species occurring at various log mean abundance levels in the FD sites. In all three age classes, a small number

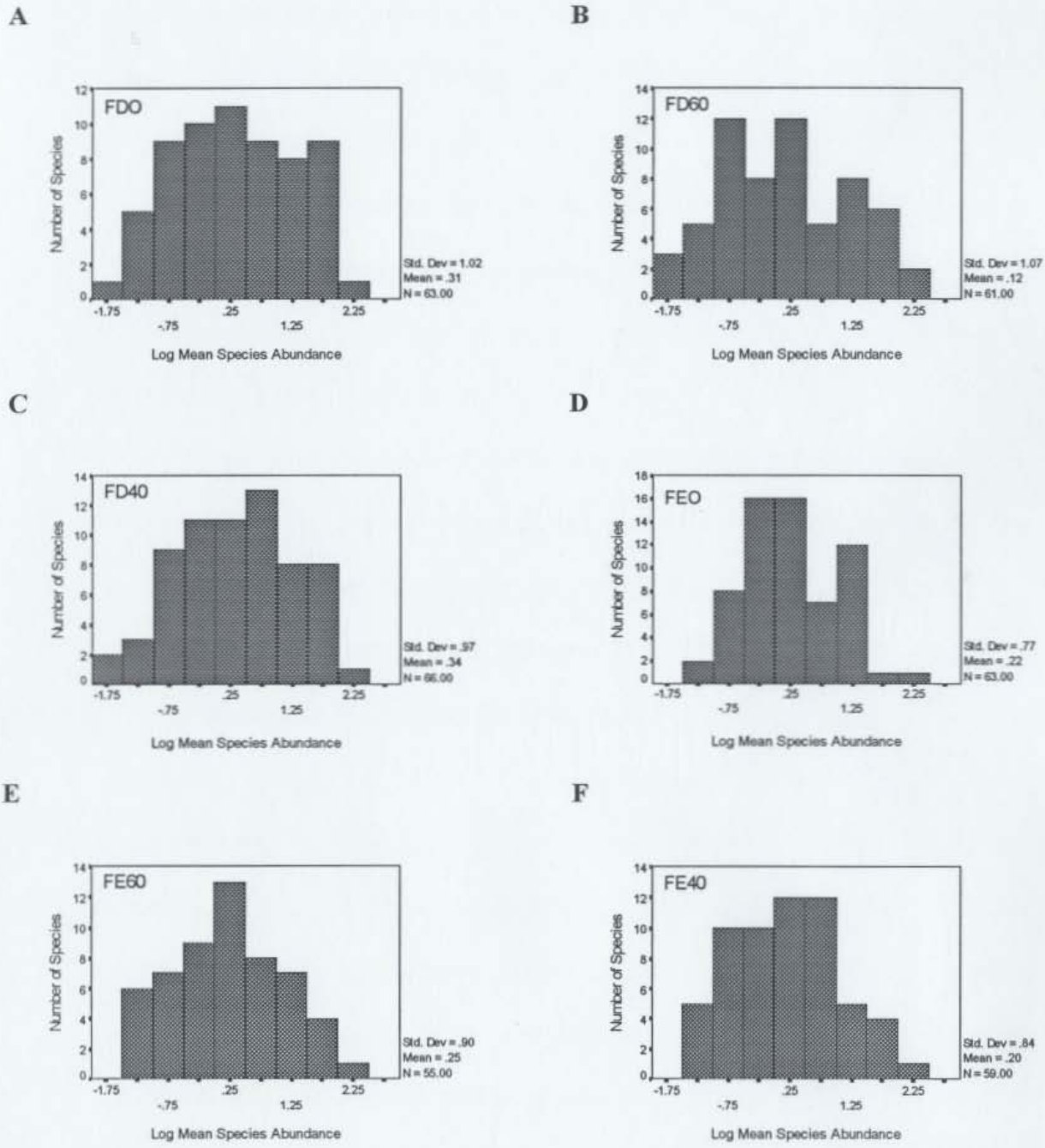



**Figure 20: Number of oribatid mite species at various log mean abundances from FDO (A), FD60 (B), FD40 (C), FEO (D), FE60 (E) and FE40 (F).**

of common species constituted the majority of the oribatid mites. Most species occurred in relatively low numbers ( 2 or fewer/sample).

#### 3.4.2.3.3 Common Species

The most common species were *Eniochthonius minutissimus*, *Synchthonius crenulatus*, *Steganacarus thoreaui*, *Nanhermannia bryophila*, *Tectocepheus velatus*, *Oppiella washburni*, *Suctobelbella* spp. and *Parachipteria travei* in both the FD and FE forest types (Figures 21, 22 and 23).

The relative abundance of each common species was comparable between the two replicate sites within FDO, FD60 and FD40 age areas, therefore the numbers were combined for each area. However, one notable exception was *E. minutissimus* which occurred at a percent abundance of 6.0 and 16.7 in FD60-5 and FD60-6, respectively.

The relative abundance of the common species within each area was consistent for the three sampling years (Table 16). The most abundant oribatid species in all three age areas was *Oppiella washburni* with a percent abundance of 27.3 - 33.2. However, relative abundance of most species varied significantly between the three age areas. FDO had significantly higher values for *Suctobelbella* spp. and significantly lower for *Pa. travei* whereas percent abundance for *Sy. crenulatus* was significantly lower in FD60. Values for *E. minutissimus* and *Oppiella washburni* were significantly lower in the FD40 samples whereas *St. thoreaui*, *Na. bryophila* and *Te. velatus* values were significantly higher.

#### 3.4.2.3.4 Vertical Distribution

Approximately 20% of the total oribatid mites collected in soil samples from all

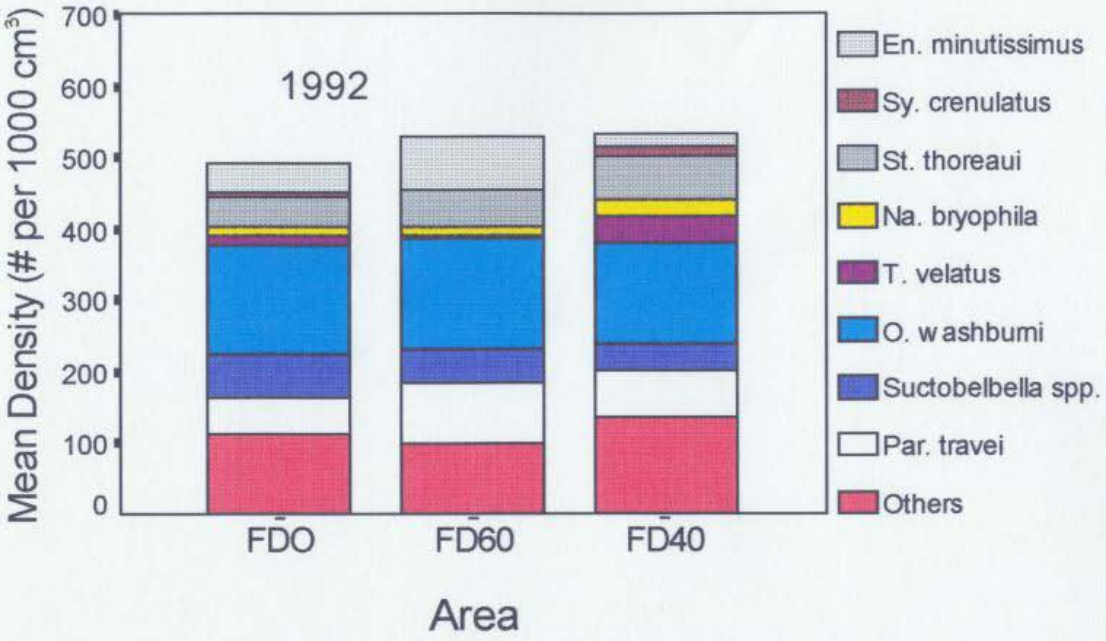



**Figure 21: Mean density (number per 1000 cm³) of dominant adult oribatid mite species in 1992 soil samples (n=20) from FDO, FD60 and FD40.**

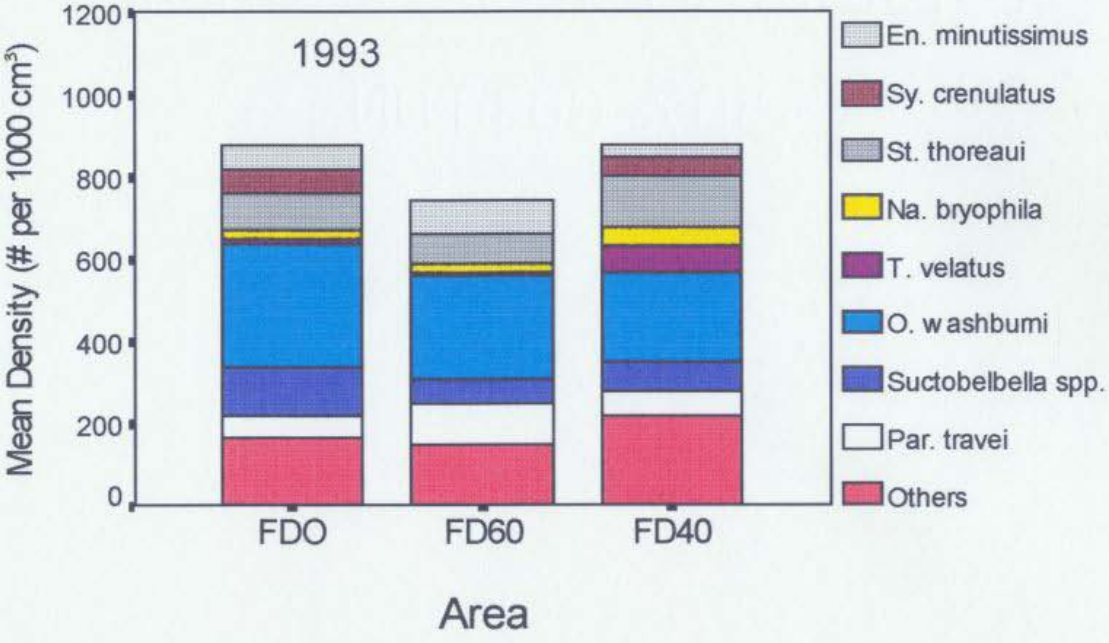



**Figure 22: Mean density (number per 1000 cm³) of dominant adult oribatid mite species in 1993 soil samples (n=30) from FDO, FD60 and FD40.**

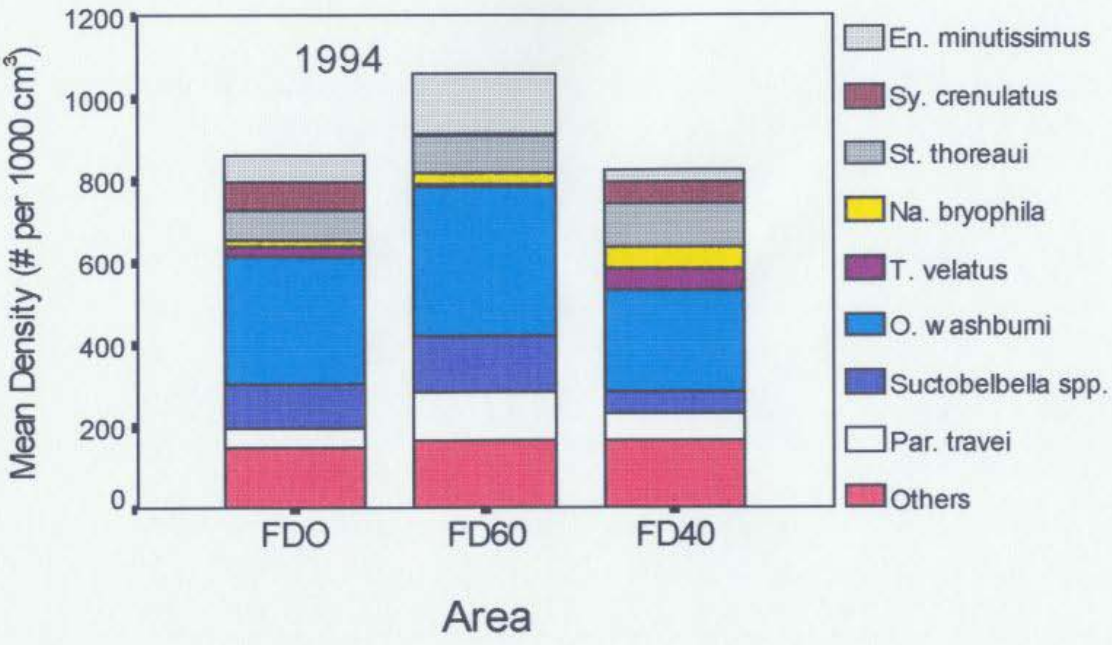



**Figure 23: Mean density (number per 1000 $cm^3$) of dominant adult oribatid mite species in 1994 soil samples (n=10) from FDO, FD60 and FD40.**

**Table 16: Mean (6 sampling dates) relative abundance (%) of dominant adult oribatid mite species from FDO, FD60 and FD40 soil samples where * indicates significant difference among the three ages.**

| SPECIES | FDO | | FD60 | | FD40 | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| *En. minutissimus* | 7.7 | 1.8 | 11.3 | 6.3 | 2.8* | 1.2 |
| *Sy. crenulatus* | 5.3 | 3.0 | 0.3* | 0.2 | 4.8 | 2.1 |
| *St. thoreaui* | 9.2 | 2.9 | 9.4 | 1.8 | 13.2* | 2.7 |
| *Na. bryophila* | 2.4 | 0.6 | 2.6 | 1.0 | 4.8* | 2.8 |
| *T. velatus* | 2.2 | 0.8 | 1.0 | 0.8 | 6.6* | 2.8 |
| *O. washburni* | 33.2 | 7.1 | 32.1 | 3.2 | 27.3* | 3.8 |
| *Suctobelbella* spp. | 12.5* | 1.9 | 9.9 | 2.6 | 7.3 | 0.9 |
| *Par. travei* | 7.4* | 2.8 | 13.9 | 3.6 | 9.3 | 3.2 |
| Others | 20.1 | 2.9 | 19.6 | 6.2 | 23.9 | 2.7 |

areas occured in the lower 5cm subsamples (Figure 24). This percentage was fairly consistent for all sampling dates in the FDO area (Figure 24A), but fluctuated slightly in the regrowth areas. For 1992, the lower subsample percentage in FD60 (Figure 24B), decreased from July to August while it steadily increased from June to August in 1993 and reached its highest value in June 1994. A similar pattern occured in FD40 (Figure 24C), with the exception of June 1994 where the percentage of the total oribatid number in the lower 5cm subsample was lower than August 1993.

Relative abundances of the most common oribatid species showed vertical variation (Figure 25, 26 and 27). In all three areas, the smaller mite species, *Oppiella washburni* and *Suctobelbella* spp, composed the majority of the total oribatid mites in the lower 5 cm soil subsample. Larger mites, such as *Steganacarus thoreaui* and *Parachipteria travei*, had higher relative abundances in the upper 5 cm subsamples. Immature *Platynothrus* spp were more abundant in the lower 5cm subsamples in FD60 and FD40 but less abundant in FDO lower subsamples.

**3.4.2.3.5 Rarefaction**

Rarefaction curves (Figures 28, 29 and 30) were used to compare species numbers between the FD sites. These curves indicate the possible number of oribatid mite species occurring in samples of various sizes. For all six sampling dates, sites FDO-1 and 2 had similar species richness which was always intermediate to that of FD60-5, 6 and FD40-3, 4. The lowest richness was consistently represented by FD60-6, but the FD60-5 site, had a much higher richness that varied somewhat among the sampling dates. For all dates but

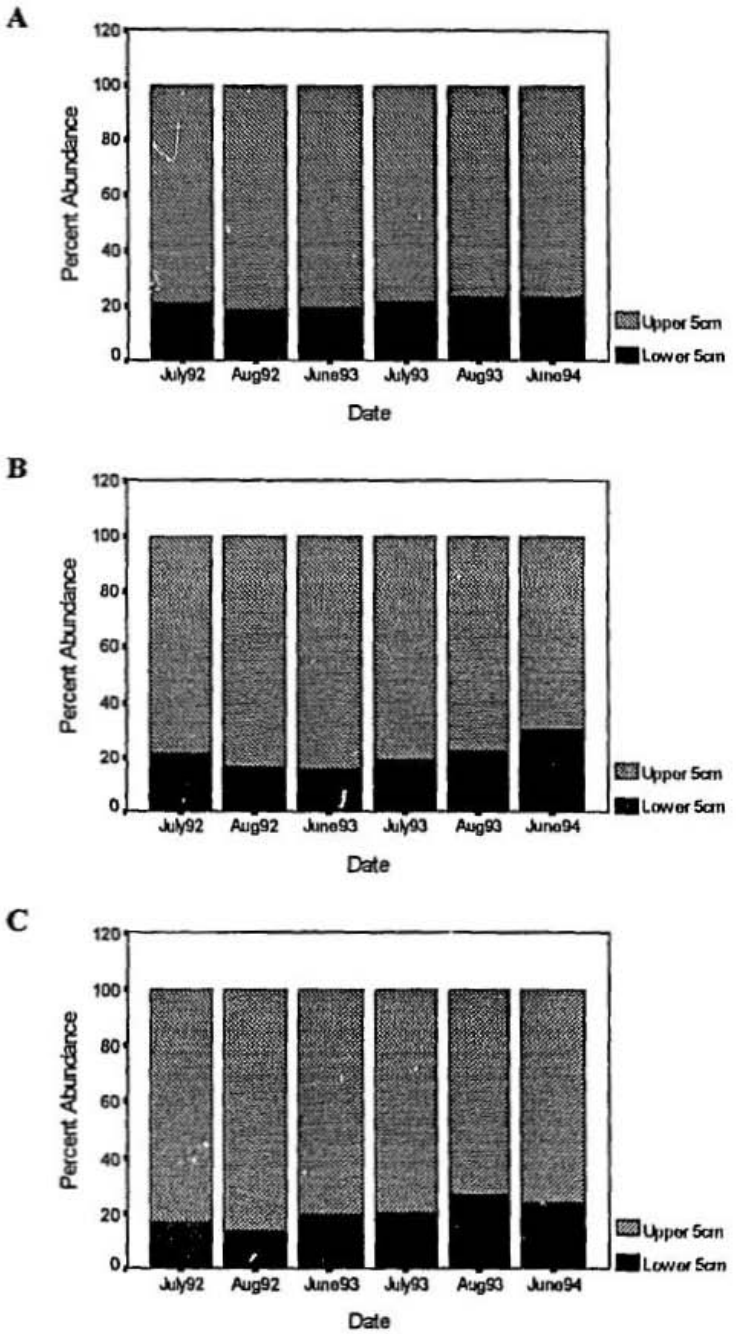
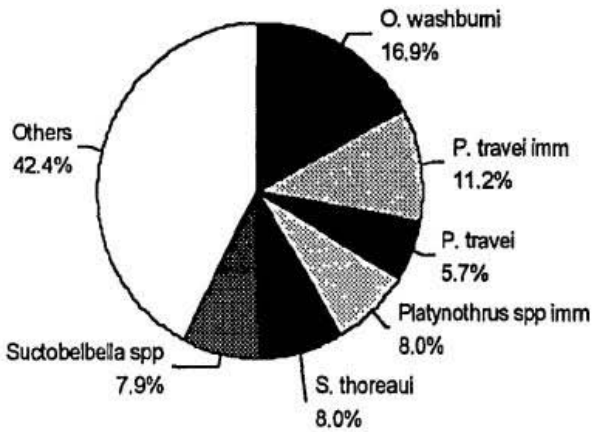



**Figure 24: Mean percent abundance of oribatid mites in upper and lower 5 cm soil subsamples from FDO (A), FD60 (B) and FD40 (C).**

A




B

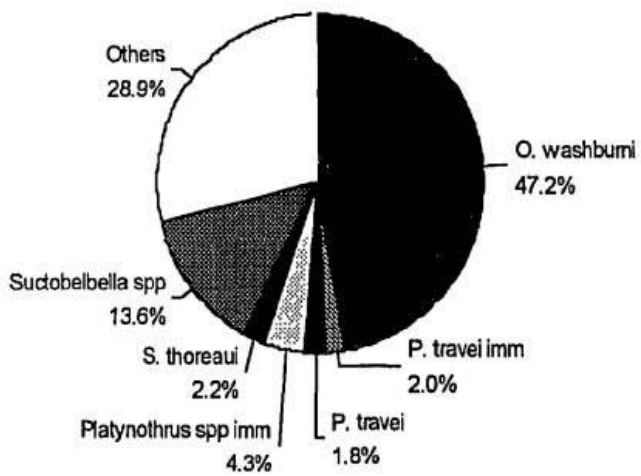
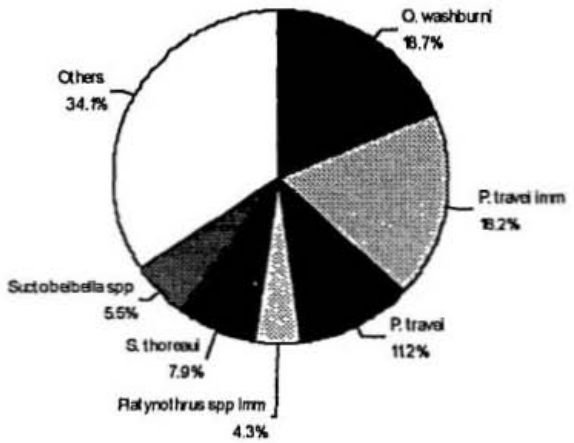



**Figure 25: Relative abundance (%) of common oribatid mite species in upper (A) and lower (B) 5 cm soil subsamples from FDO.**

A




B

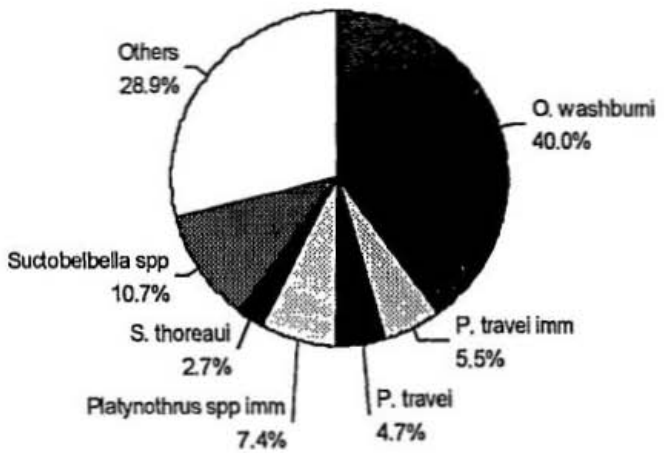
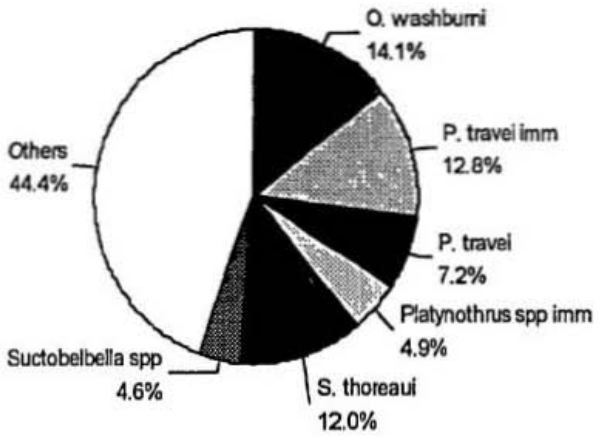



**Figure 26: Relative abundance (%) of common oribatid mite species in upper (A) and lower (B) 5 cm soil subsamples from FD60.**

A




B

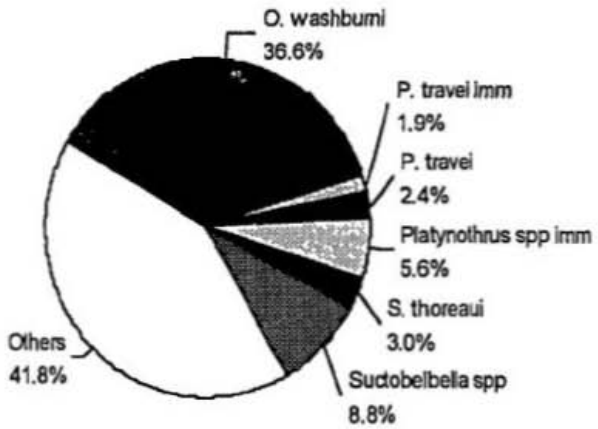



**Figure 27: Relative abundance (%) of common oribatid mite species in upper (A) and lower (B) 5 cm soil subsamples from FD40.**

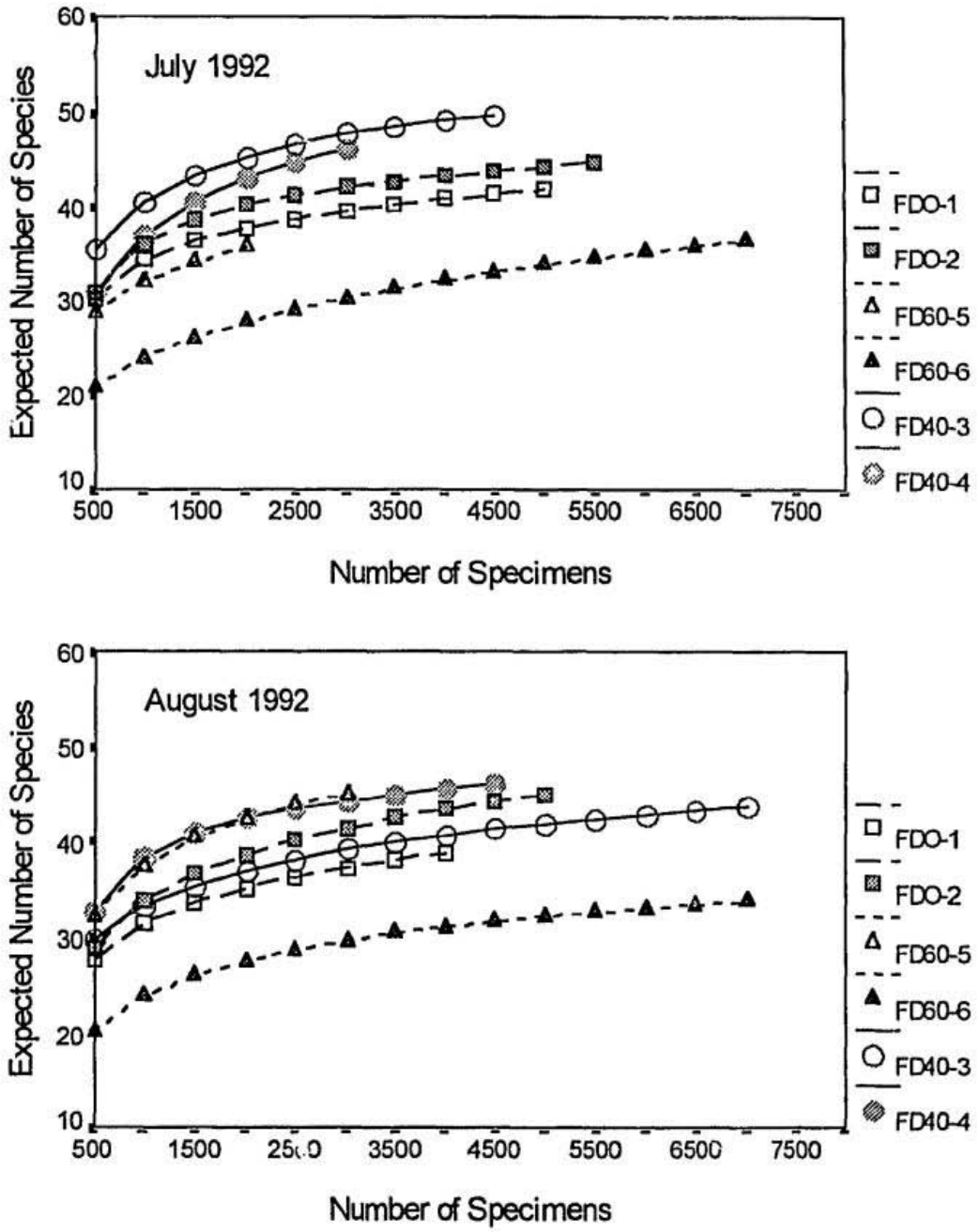



**Figure 28: Rarefaction curves for 1992 FD sites showing expected number of oribatid species occuring in samples of various sizes.**

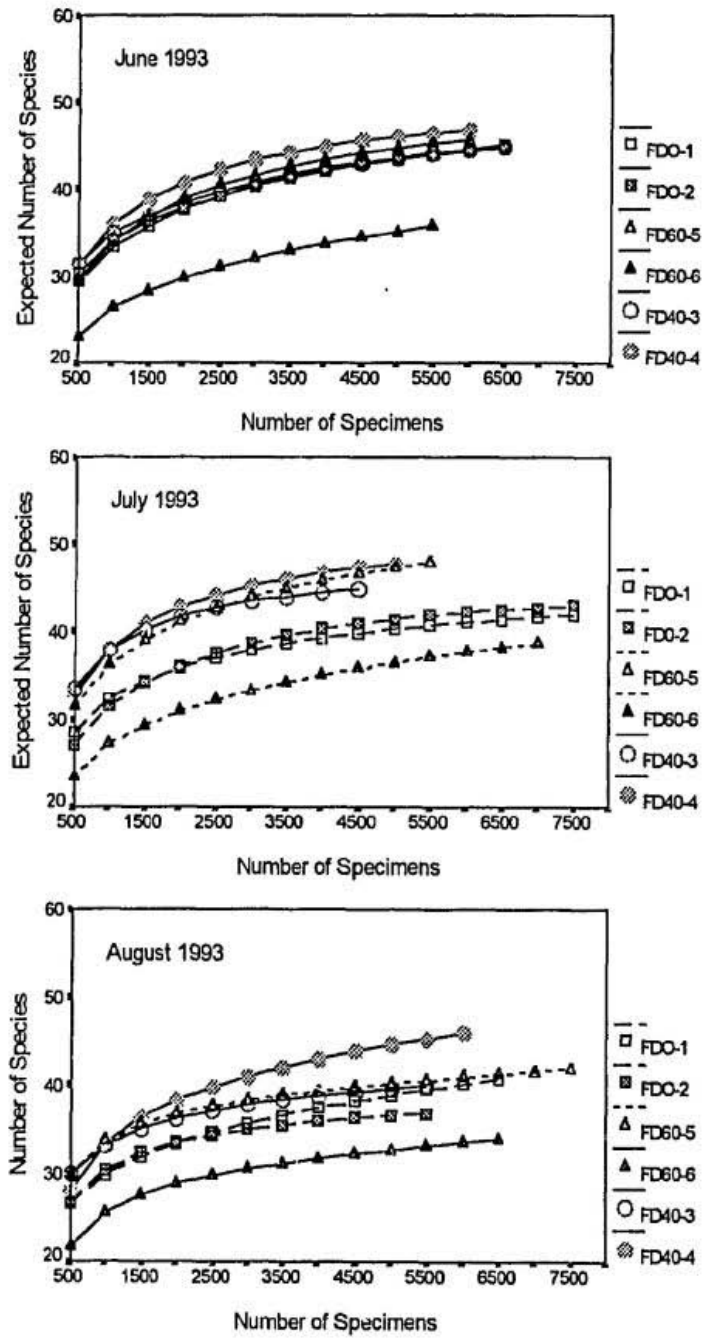



**Figure 29: Rarefaction curves for 1993 FD sites showing expected number of oribatid species occuring in samples of various sizes.**

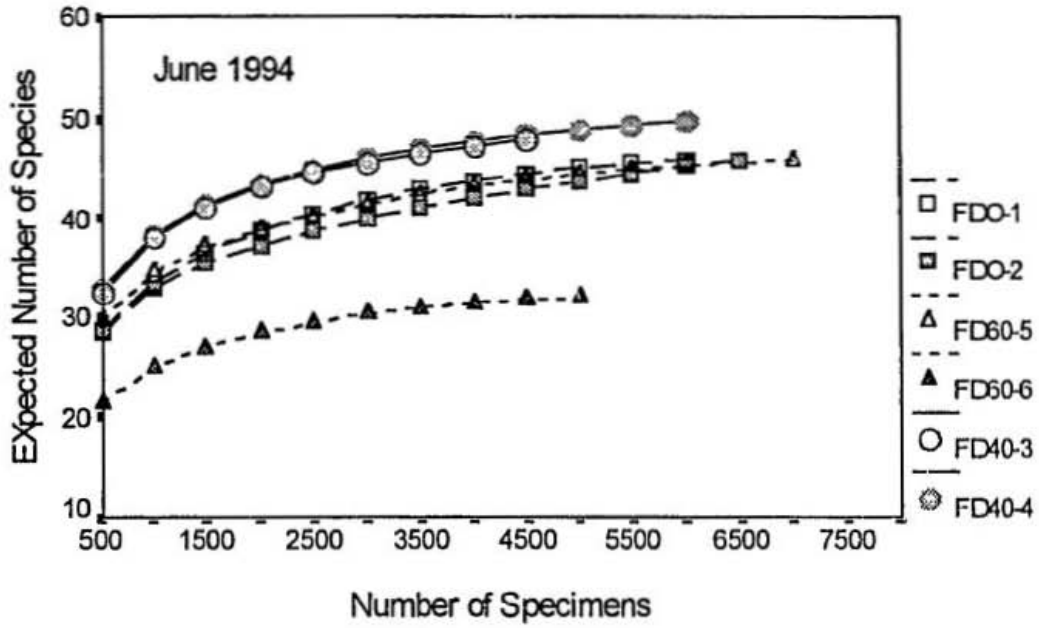



**Figure 30: Rarefaction curves for 1994 FD sites showing expected number of oribatid species occuring in samples of various sizes.**

July 1992 and June 1994, species richness for the FD60-5 site was higher than that of the FDO sites. The FD40-4 site had the highest richness for all dates except July 1992 where the FD40-3 site was richest.

**3.4.2.3.6 Diversity**

The upper 5cm subsamples for all FD sites, except June 1993 FD60-6, had higher abundance and species numbers than the lower subsamples resulting in higher diversity indices (Tables 17, 18 and 19). Diversity values for the upper subsamples ranged from 3.06 to 4.06 whereas lower subsamples ranged from 2.07 to 3.55. The aberrant June 1993 FD60-6 site had relatively low numbers with fairly high species diversity and the highest observed evenness value (0.71) in the lower 5cm subsample.

Diversity values for the upper subsamples, tended to be higher in FD40 followed by FDO and finally FD60 for all three sampling years. FD60-6 consistently had the lowest diversity and evenness values in the upper subsamples. In the lower subsamples, FDO tended to have the lower diversity and evenness values.

Graphs of the diversity values for the FD areas (Figure 31) correspond with species richness graphs (Figures 28, 29 and 30). These values again indicate higher diversity in the FD40 sites followed by the FDO and FD60 sites, respectively.

For all FD sites, evenness values were less than .75 showing that all species in the samples were not equally abundant. This was particularly true of the lower 5cm subsamples which had consistently lower evenness values than the corresponding upper subsample, for all but June 1993 FD60-6 and July 1992 FD40-3.

**Table 17: Number of specimens, species, Shannon-Wiener (H') and evenness indices for oribatid mites collected from FDO-1, 2; FD60-5, 6 and FD40-3, 4 sites in 1992.**

| MEASURE | DATE | FDO-1 | | FDO-2 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | July | 3994 | 1052 | 4084 | 1476 |
| | August | 3388 | 731 | 3811 | 1218 |
| Total number of species (n=10) | July | 41 | 29 | 42 | 37 |
| | August | 36 | 30 | 41 | 33 |
| Shannon-Wiener Diversity (H') | July | 3.78 | 2.37 | 3.76 | 2.79 |
| | August | 3.82 | 3.26 | 3.62 | 2.20 |
| Evenness | July | .69 | .47 | .68 | .52 |
| | August | .72 | .64 | .66 | .42 |

| MEASURE | DATE | FD60-5 | | FD60-6 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | July | 1650 | 412 | 5381 | 1992 |
| | August | 2517 | 555 | 6625 | 2018 |
| Total number of species (n=10) | July | 33 | 26 | 36 | 24 |
| | August | 44 | 30 | 32 | 25 |
| Shannon-Wiener Diversity (H') | July | 3.75 | 3.13 | 3.16 | 2.81 |
| | August | 3.82 | 3.01 | 3.06 | 2.72 |
| Evenness | July | .72 | .64 | .59 | .59 |
| | August | .68 | .59 | .59 | .56 |

**Table 17 cont.**



| MEASURE | DATE | FD40-3 | | FD40-4 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | July | 4312 | 481 | 2559 | 757 |
| | August | 7647 | 1152 | 3142 | 1299 |
| Total number of species (n=10) | July | 51 | 31 | 46 | 31 |
| | August | 46 | 29 | 45 | 36 |
| Shannon-Wiener Diversity (H') | July | 4.01 | 3.55 | 3.72 | 2.99 |
| | August | 3.99 | 3.15 | 3.85 | 3.21 |
| Evenness | July | .69 | .69 | .66 | .58 |
| | August | .70 | .62 | .69 | .60 |

**Table 18: Number of specimens, species, Shannon-Wiener (H') and evenness indices for oribatid mites collected from FDO-1, 2; FD60-5, 6 and FD40-3, 4 sites in 1993.**

| MEASURE | DATE | FDO-1 | | FDO-2 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | June | 6777 | 2140 | 7314 | 1545 |
| | July | 6375 | 1232 | 7001 | 3160 |
| | August | 5458 | 1786 | 6329 | 3545 |
| Total number of species (n=10) | June | 46 | 31 | 42 | 31 |
| | July | 41 | 31 | 45 | 33 |
| | August | 40 | 29 | 37 | 26 |
| Shannon-Wiener Diversity (H') | June | 3.62 | 2.79 | 3.78 | 2.48 |
| | July | 3.66 | 2.82 | 3.63 | 2.21 |
| | August | 3.68 | 2.97 | 3.78 | 2.07 |
| Evenness | June | .64 | .55 | .68 | .48 |
| | July | .67 | .55 | .65 | .42 |
| | August | .67 | .59 | .71 | .42 |

**Table 18 cont.**

| MEASURE | DATE | FD60-5 | | FD60-6 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | June | 3624 | 1672 | 6049 | 565 |
| | July | 4657 | 1000 | 7275 | 1840 |
| | August | 4894 | 2799 | 6849 | 2465 |
| Total number of species (n=10) | June | 44 | 35 | 33 | 26 |
| | July | 44 | 34 | 41 | 29 |
| | August | 40 | 33 | 32 | 29 |
| Shannon-Wiener Diversity (H') | June | 3.87 | 3.15 | 3.09 | 3.47 |
| | July | 3.79 | 3.15 | 3.24 | 2.95 |
| | August | 3.65 | 2.56 | 3.1 | 2.81 |
| Evenness | June | .69 | .60 | .594 | .71 |
| | July | .68 | .60 | .59 | .59 |
| | August | .67 | .49 | .61 | .56 |

| MEASURE | DATE | FD40-3 | | FD40-4 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | June | 8832 | 2859 | 5247 | 1190 |
| | July | 8225 | 3128 | 4504 | 800 |
| | August | 8230 | 3559 | 3963 | 2109 |
| Total number of species (n=10) | June | 47 | 39 | 47 | 35 |
| | July | 48 | 43 | 49 | 32 |
| | August | 44 | 38 | 43 | 33 |
| Shannon-Wiener Diversity (H') | June | 4.01 | 3.49 | 3.84 | 3.38 |
| | July | 3.99 | 2.97 | 3.91 | 3.30 |
| | August | 4.06 | 3.18 | 3.68 | 2.95 |
| Evenness | June | .71 | .64 | .67 | .64 |
| | July | .70 | .54 | .68 | .64 |
| | August | .73 | .59 | .66 | .57 |

**Table 19: Number of specimens, species, Shannon-Wiener (H') and evenness indices for oribatid mites collected from FDO-1, 2; FD60-5, 6 and FD40-3, 4 sites in 1994.**

| MEASURE | DATE | FDO-1 | | FDO-2 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | June | 6117 | 1884 | 6573 | 2705 |
| Total number of species (n=10) | June | 47 | 33 | 45 | 36 |
| Shannon-Wiener Diversity (H') | June | 3.68 | 2.80 | 3.73 | 2.20 |
| Evenness | June | .65 | .54 | .66 | .41 |

| MEASURE | DATE | FD60-5 | | FD60-6 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | July | 5620 | 2988 | 9512 | 3276 |
| Total number of species (n=10) | July | 43 | 41 | 35 | 31 |
| Shannon-Wiener Diversity (H') | July | 3.62 | 2.71 | 3.14 | 2.86 |
| Evenness | July | .65 | .49 | .59 | .56 |

| MEASURE | DATE | FD40-3 | | FD40-4 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | July | 7500 | 2765 | 4559 | 1710 |
| Total number of species (n=10) | July | 52 | 41 | 51 | 35 |
| Shannon-Wiener Diversity (H') | July | 3.98 | 3.22 | 3.87 | 2.75 |
| Evenness | July | .69 | .59 | .67 | .52 |

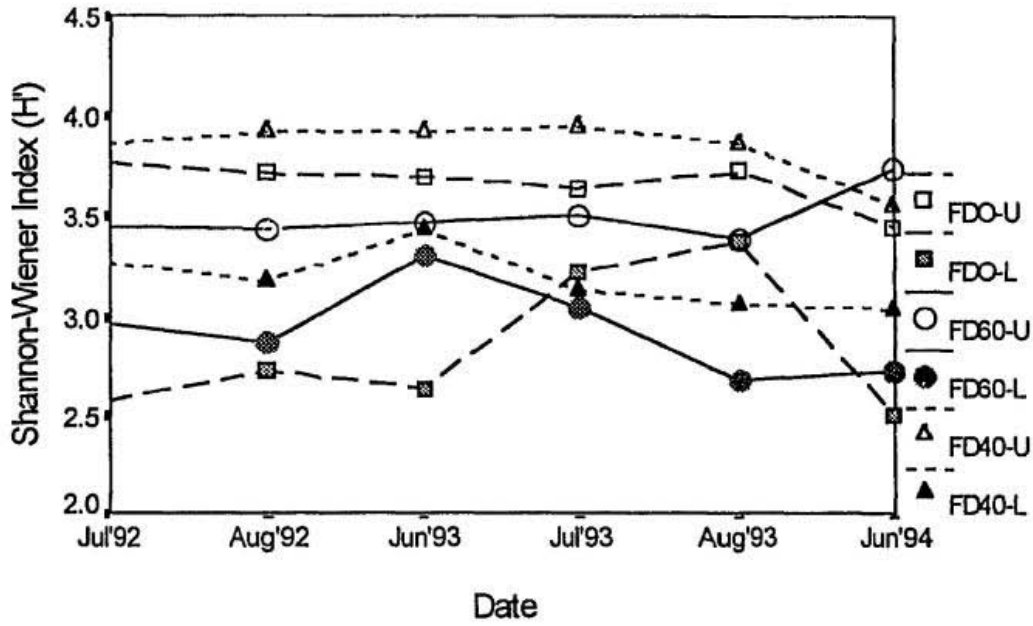



**Figure 31: Shannon-Wiener diversity indices (H') mean values for adult oribatid mite populations in upper (U) and lower (L) 5 cm soil subsamples from FDO, FD60 and FD40.**

**3.4.2.3.7 Ordination**

The scatterplot of FD sites on the first three PCA factors (Figure 32) , calculated from mean densities of adult oribatid species, grouped the two replicate sites of both the FDO and FD60 forest areas. The sites of the FD60 area showed the closest association to one another. Conversely, the two sites of the FD40 area were placed far apart on the factor 1 axis, indicating variability between the sites.

Table 20 lists species with PCA factor 1 and 2 eigenvalues greater or less than .700/-.700, respectively. Based on these values, some species with strong positive association with the FDO sites included *Platynothrus peltifer*, *Conchogneta traegardhi*, *Allosuctobelba* sp., *Camisia lapponica*, *Epidamaeus longitarsalis* and *Mesotritia* sp.. The FD60 sites were characterized by *Ceratozetes cuspidatus* while FD40 sites were characterized by *Rhysotritia ardua* and *Scheloribates* sp.. The separation of the two FD40 sites in Figure 32 may have resulted from the much higher occurrence of *Podopterotegaeus tectus*, *Oppia nitens*, *Heminothrus longisetosus* and *Nanhermannia bryophila* in FD40-3.

**3.4.2.4 FE Sites**

**3.4.2.4.1 Density**

Mean density per 1000 $cm^3$ for individual oribatid species for the two 1994 sampling dates varied between the FE sites (Table 21). Generally, individual species densities were lower than in the FD sites except for *Phthiracarus compressus*, *Platynothrus* sp., immature *Platynothrus* spp. and *Pilogalumna* sp.. Total mean density

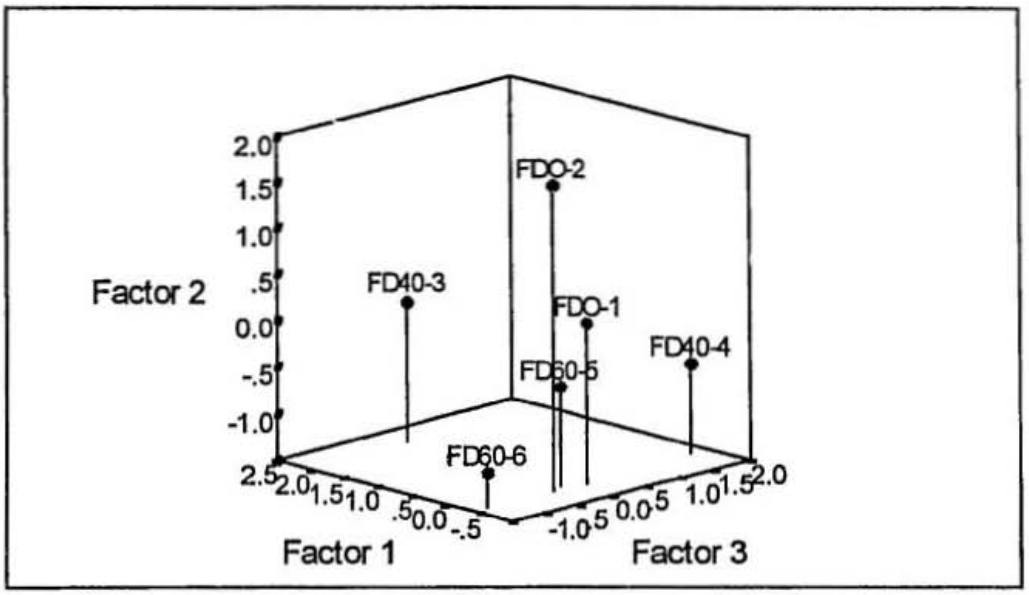



**Figure 32: Ordination of FDO-1, 2; FD60-5, 6; FD40-3, 4 sample sites based on mean densities of adult oribatid mite species.**

**Table 20: Oribatid mite species with principle components analysis eigenvalues greater / lesser than .700/-.700 on factors 1 and 2 based on data from FDO-1, 2; FD60-5, 6 and FD40- 3, 4 sites.**

| Species | Factor 1 | Factor 2 | Species | Factor 1 | Factor 2 |
|---|---|---|---|---|---|
| *Allosuctobelba sp.* | -.207 | .888 | *Na. bryophila* | .943 | -.132 |
| *Cam. biuris* | .800 | -.327 | *No. anauniensis* | .492 | .853 |
| *Cam. iapponica* | -.025 | .872 | *Ra. manifera* | .999 | .009 |
| *Con. traegardhi* | -.263 | .937 | *Oppia nitens* | .989 | -.036 |
| *Cer. cuspidatus* | -.023 | -.700 | *Pa. hystricinus* | .129 | .859 |
| *De. highlandensis* | .957 | .089 | *Parapyroppia sp.* | .487 | .802 |
| *Dentachipteria sp.* | .999 | .009 | *Pilogalumna sp.* | .999 | .009 |
| *Ep. longitarsalis* | -.207 | .888 | *Pl. peltifer* | .063 | .942 |
| *Euphthiracarus sp.* | .945 | -.164 | *Po. tectus* | .981 | .097 |
| *F. setosus* | .730 | -.174 | *Rh. ardua* | .828 | -.439 |
| *He. longisetosus* | .932 | .176 | *Scheloribates sp.* | .473 | -.713 |
| *Hy. rufulus* | .920 | .365 | *St. thoreaui* | .851 | -.214 |
| *Lie. similis* | .931 | -.135 | *Subiasella sp.* | .999 | .009 |
| *Liebstadia sp. b* | .842 | -.030 | *T. velatus* | .967 | .117 |
| *Mesotritia sp.* | -.333 | .883 | *Xylobates sp.* | .987 | -.043 |

**Table 21: Mean (n=20) density (number per 1000 cm$^3$) of oribatid mite species in FEO-7, 8; FE60-11, 12 and FE40-9, 10 forest sites. Species order follows Marshall, Reeves and Norton (1987) and species with 0 values for all sites were recorded from FDmicrohabitat or soil samples.**

| SPECIES | FEO-7 | FEO-8 | FE60-11 | FE60-12 | FE40-9 | FE40-10 |
|---|---|---|---|---|---|---|
| *Pa. hystricinus* | 0.10 | 3.20 | 0.35 | 1.45 | 0.20 | 0.85 |
| *Hy. rufulus* | 3.40 | 4.40 | 0.00 | 1.30 | 3.65 | 2.20 |
| *Hy. rufulus* imm. | 7.65 | 4.45 | 0.40 | 1.50 | 2.80 | 4.55 |
| *En. minutissimus* | 20.15 | 35.60 | 3.50 | 13.15 | 2.65 | 9.80 |
| *En. minutissimus* imm. | 6.95 | 14.95 | 1.05 | 5.95 | 0.60 | 2.20 |
| *Lio. lapponicus* | 2.10 | 4.05 | 0.35 | 0.45 | 1.00 | 2.30 |
| *Sy. crenulatus* | 5.20 | 21.65 | 20.60 | 17.20 | 7.00 | 22.90 |
| *G. majestus* | 0.00 | 4.95 | 0.05 | 0.00 | 0.00 | 0.00 |
| *St. thoreaui* | 17.30 | 37.05 | 98.65 | 56.85 | 33.70 | 49.10 |
| *Ph. boresetosus* | 2.85 | 0.80 | 2.70 | 2.75 | 1.65 | 2.20 |
| *Ph. compressus* | 3.95 | 2.60 | 10.00 | 8.60 | 4.40 | 7.00 |
| *Phthiracarus* sp. | 3.05 | 1.00 | 8.00 | 11.35 | 6.45 | 2.70 |
| *Mesotritia* sp. | 0.05 | 0.00 | 0.05 | 0.00 | 0.00 | 0.10 |
| *Prot. canadaris* | 0.30 | 4.60 | 0.80 | 1.50 | 0.15 | 1.90 |
| *Euphthiracarus* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Rh. ardua* | 0.35 | 5.30 | 1.05 | 0.90 | 0.50 | 2.05 |
| *No. anauniensis* | 0.80 | 1.25 | 1.95 | 1.90 | 0.20 | 2.10 |
| *No. palustris* | 0.95 | 0.03 | 0.05 | 2.35 | 0.00 | 0.35 |
| *Nothrus* imm. | 9.05 | 10.05 | 10.80 | 21.35 | 0.70 | 13.90 |
| *Cam. biuris* | 0.15 | 0.25 | 0.05 | 0.00 | 0.00 | 0.05 |
| *Cam. lapponica* | 0.30 | 0.60 | 0.35 | 1.35 | 0.00 | 0.30 |
| *Camisia* imm. | 0.75 | 0.65 | 0.30 | 0.15 | 0.05 | 0.95 |
| *He. longisetosus* | 1.20 | 1.60 | 0.15 | 0.20 | 0.05 | 0.95 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *He. longisetosus* imm. | 0.15 | 1.10 | 0.05 | 0.15 | 0.00 | 0.10 |
| *Pl. peltifer* | 13.30 | 6.20 | 5.25 | 7.10 | 16.25 | 7.20 |
| *Platynothrus* sp. | 21.70 | 3.80 | 35.75 | 6.15 | 7.00 | 5.05 |
| *Platynothrus* imm. | 88.80 | 52.65 | 93.85 | 35.00 | 176.40 | 54.80 |
| *Malconothrus* sp. | 0.15 | 4.05 | 16.00 | 0.60 | 12.20 | 2.65 |
| *Malaconothrus* imm. | 0.10 | 1.90 | 7.35 | 0.20 | 10.30 | 1.50 |
| *Na. bryophila* | 19.60 | 5.65 | 43.20 | 14.70 | 13.10 | 25.25 |
| *Na. bryophila* imm. | 16.85 | 4.95 | 42.45 | 14.80 | 6.60 | 15.10 |
| *Hermanniella* sp. | 2.50 | 0.15 | 0.15 | 0.10 | 0.05 | 0.45 |
| *Gymnodamaeus* sp. | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ep. longitarsalis* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ep. longitarsalis* imm. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Epidamaeus* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Cep. corae* | 1.65 | 3.75 | 0.85 | 0.75 | 0.40 | 2.20 |
| *Cep. corae* imm. | 0.10 | 0.15 | 0.05 | 0.00 | 0.00 | 0.00 |
| *Eupterotegaeus* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Po. tectus* | 0.15 | 0.00 | 0.00 | 0.45 | 0.05 | 0.05 |
| *Ha. nitidula* | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 |
| *Adoristes* sp. | 1.15 | 3.95 | 1.75 | 3.05 | 3.30 | 0.70 |
| *Dorycranosus* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Cu. bicultrata* | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.05 |
| *Ce. bipilis* | 0.15 | 0.55 | 0.00 | 0.10 | 0.00 | 0.00 |
| *Ce. quadridentata* | 0.10 | 1.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ceratoppia* imm. | 0.10 | 1.05 | 0.00 | 0.05 | 0.00 | 0.00 |
| *Parapyroppia* sp. | 0.65 | 0.55 | 0.40 | 0.95 | 0.75 | 0.10 |
| *Pyroppia* sp. a | 0.15 | 0.00 | 0.00 | 0.05 | 0.05 | 0.00 |
| *Pyroppia* sp. b | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.05 |
| *Car. labyrinthicus* | 0.10 | 0.50 | 0.00 | 0.05 | 0.05 | 0.10 |

**Table 21 cont.**

| | | | | | | |
|---|---|---|---|---|---|---|
| *T. velatus* | 23.35 | 25.40 | 2.55 | 4.15 | 0.80 | 5.60 |
| *Tectocepheus* sp. | 29.05 | 5.80 | 0.50 | 8.65 | 6.05 | 0.60 |
| *Tectocepheus* imm. | 23.60 | 6.05 | 1.00 | 11.75 | 27.25 | 1.90 |
| *Cos. ornata* | 0.50 | 0.00 | 0.00 | 2.95 | 0.00 | 0.70 |
| *Moritzoppia* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Oppia nitens* | 0.00 | 0.00 | 0.00 | 0.00 | 4.80 | 1.90 |
| *O. washburni* | 90.20 | 205.95 | 80.85 | 125.60 | 71.30 | 205.50 |
| *Quadroppia sp.* | 13.10 | 16.35 | 8.35 | 13.10 | 11.85 | 11.35 |
| *Ra. manifera* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Subiasella* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Allosuctobelba* sp. | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 |
| *Suctobelbella* spp. | 6.00 | 31.85 | 21.35 | 35.15 | 12.75 | 43.90 |
| *A. longilamellata* | 0.05 | 0.00 | 0.05 | 0.05 | 0.10 | 0.05 |
| *Con. traegardhi* | 0.15 | 0.50 | 1.05 | 0.00 | 0.15 | 0.05 |
| *Eremobodes* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *B. lanceolata* | 0.05 | 0.65 | 5.70 | 6.85 | 0.05 | 1.30 |
| *Do. plantivaga* | 0.00 | 0.00 | 0.10 | 0.00 | 0.03 | 0.00 |
| *Lie. similis* | 2.50 | 0.05 | 0.20 | 0.05 | 0.00 | 0.00 |
| *Liebstadia sp.* a | 0.10 | 0.10 | 0.25 | 0.25 | 0.05 | 0.05 |
| *Liebstadia sp.* b | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.05 |
| *Paraleius* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Scheloribates* sp. | 0.20 | 5.70 | 0.40 | 7.20 | 0.10 | 8.65 |
| *Phauloppia* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Z. bulanovae* | 0.15 | 0.05 | 0.05 | 0.10 | 0.10 | 0.25 |
| *Haplozetes* sp. | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Peloribates* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Xylobates* sp. | 1.80 | 0.50 | 0.10 | 0.05 | 0.40 | 0.35 |
| *Neor. aurantiacus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 |

**Table 21 cont.**

| | | | | | | |
|---|---|---|---|---|---|---|
| *Ch. cuspidatus* | 0.95 | 1.40 | 0.05 | 0.05 | 0.00 | 0.00 |
| *Cer. cuspidatus* | 0.05 | 4.35 | 0.75 | 6.60 | 1.00 | 4.10 |
| *Cer. gracilis* | 0.00 | 0.30 | 1.00 | 1.60 | 7.95 | 4.55 |
| *Cer. thienemanni* | 0.80 | 3.20 | 1.70 | 5.10 | 1.35 | 4.40 |
| *F. setosus* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| *Neog. luteus* | 0.25 | 5.55 | 6.30 | 1.60 | 0.20 | 0.30 |
| *Sp. arcticus* | 0.00 | 0.90 | 0.05 | 0.00 | 1.65 | 0.05 |
| *Trichoribates* spp. | 1.65 | 0.30 | 0.50 | 0.15 | 0.85 | 0.50 |
| Ceratozetidae imm. | 0.15 | 1.30 | 1.10 | 2.45 | 5.10 | 5.35 |
| *M. incurvatus* | 0.00 | 0.05 | 0.00 | 0.05 | 0.15 | 0.20 |
| *Eupelops* sp. | 1.80 | 0.85 | 0.65 | 0.35 | 0.00 | 1.05 |
| *Prop. canadensis* | 0.60 | 5.00 | 0.05 | 0.15 | 0.35 | 2.05 |
| *Oribatella* spp. | 0.05 | 0.05 | 0.10 | 0.00 | 0.10 | 0.30 |
| *Le. singularis* | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 |
| *Anachipteria* sp. | 1.05 | 1.85 | 0.05 | 1.45 | 5.75 | 3.65 |
| *De. highlandensis* | 0.00 | 0.00 | 0.15 | 0.00 | 0.25 | 0.45 |
| *Dentachipteria* sp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Par. travei* | 18.50 | 10.45 | 71.70 | 40.00 | 30.70 | 35.35 |
| *Par. travei* imm. | 29.80 | 22.10 | 60.50 | 53.85 | 37.00 | 44.70 |
| *Pilogalumna* sp. | 0.55 | 0.05 | 0.00 | 0.00 | 1.15 | 0.25 |

for FE sites ranged from 501.2 to 886.1 and tended to be considerably lower than FD density values (Table 22, Figures 33, 34 and 35). Mean total density of the three age classes ranged from 555 to 771 with FE60 showing the highest density. Both FEO and FE40 had higher oribatid densities in August 1994 than in July 1994, the difference being significant in FE40. Oribatid density in FE60 however, decreased from July to August 1994.

#### 3.4.2.4.2 Species Distribution

The FE sites contained several unique species that did not occur in FD sites. These included *Gozmanyina majestus*, *Nothrus palustris*, *Gymnodamaeus* sp., *Haplozetes* sp., *Neoribates aurantiacus*, *Ceratozetes gracilis*, *Sphaerozetes arcticus*, *Mycobates incurvatus*, *Eupelops* sp., *Propelops canadensis* and *Lepidozetes singularis*.

Among the three age areas, species diversity varied with *Gymnodamaeus* sp. occurring only in FEO, *Hafenferrefia nitidula*, *Allosuctobelba* sp. and *Lepidozetes singularis* unique to FE60 and *Oppia nitens* and *Neoribates aurantiacus* occurring only in FE40.

Other species showing differing abundance levels among the age classes include *Eniochthonius minutissimus* and *Tectocepheus velatus* were more abundant in FEO whereas *Steganacarus thoreaui*, *Phthiracarus* sp., *Phthiracarus compressus*, *Parachipteria travei* and *Banksinoma lanceolata* had higher numbers in FE60. Both *Ceratozetes gracilis* and *Anachipteria* sp were more abundant in FE40. In contrast, species such as *Liochthonius lapponicus* and *Hypochthonius rufulus* were absent or rare

**Table 22: Mean number of oribatid mites and standard error per soil sample for July and August 1994 sampling dates from FEO, FE60 and FE40 sites.**

| Site | Mean Number (n=20) | Standard Error |
|---|---|---|
| FEO-7 | 501 | 41 |
| FEO-8 | 608 | 63 |
| FE60-11 | 655 | 36 |
| FE60-12 | 886 | 59 |
| FE40-9 | 542 | 70 |
| FE40-10 | 633 | 41 |

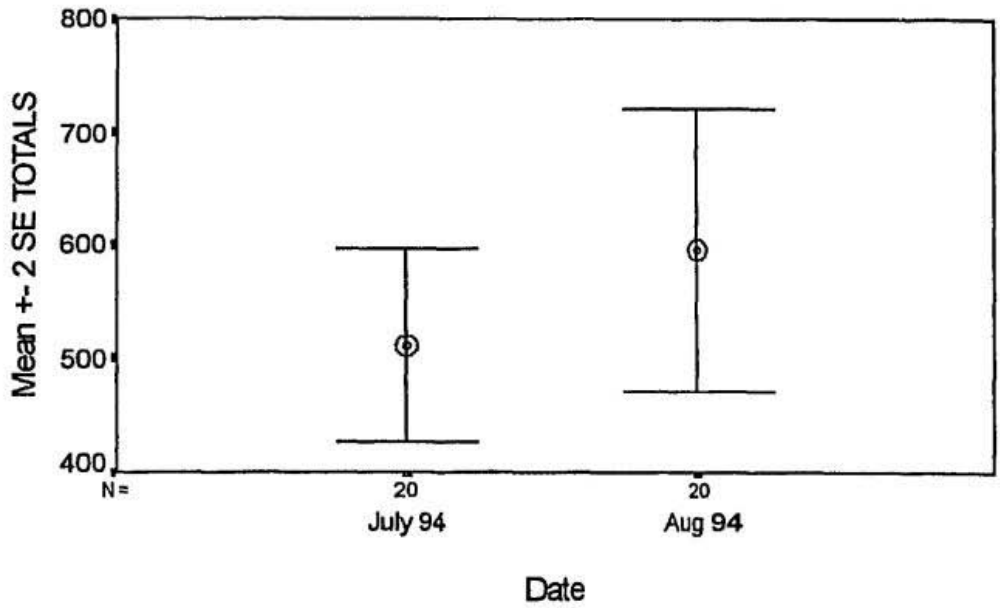



**Figure 33: Mean oribatid mite densities (number per 1000 cm$^3$) for two sampling dates from FEO.**

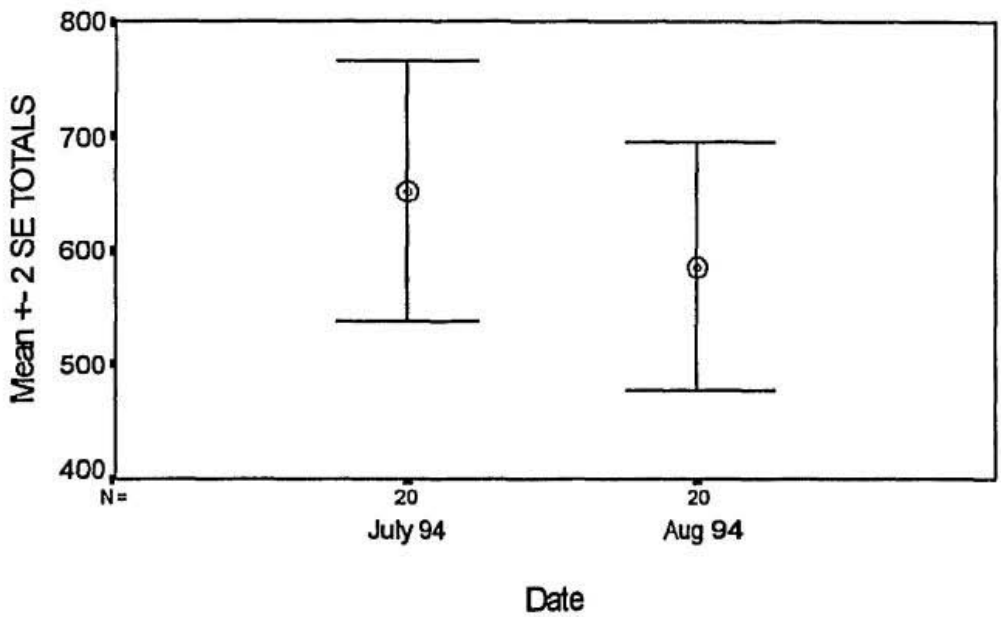



**Figure 34: Mean oribatid mite densities (number per 1000 cm$^3$) for two sampling dates from FE60.**

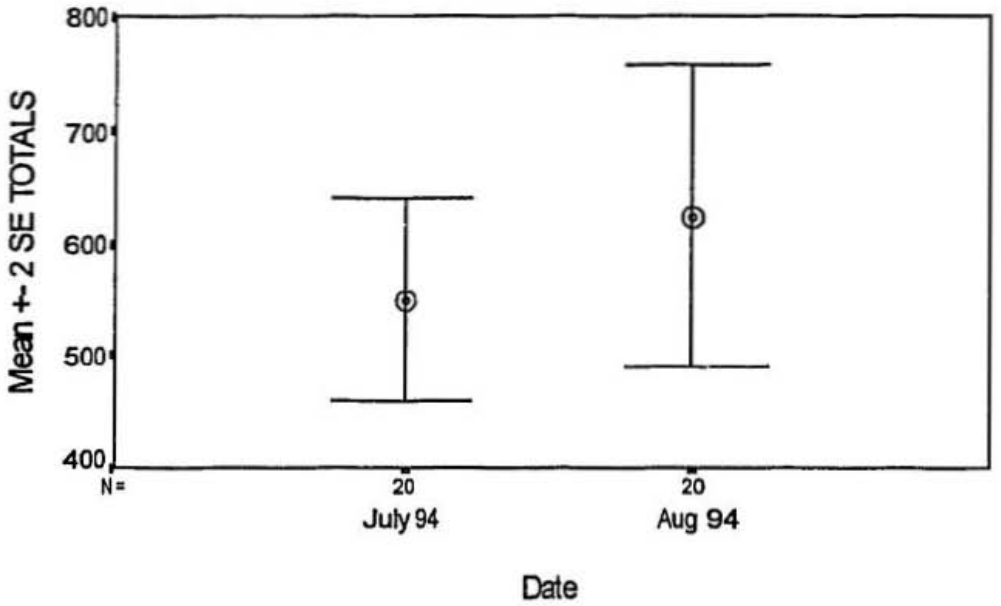



**Figure 35: Mean oribatid mite densities (number per 1000 cm³) for two sampling dates from FE40.**

in FE60.

The number of species at various log mean abundance levels in the FE sites are indicated in Figure 20 (C-D). Again a few common species dominated the oribatid mite population of each FE age class. A majority of the species were represented by approximately two specimens per sample or fewer.

**3.4.2.4.3 Common Species**

The most common species in FE sites were the same as those in FD sites (Figure 36). The species with the highest percent abundance, again, was *Oppiella washburni* which ranged from 22.59 to 35.32 (Table 23). Variation in the abundance of common species among the FE areas was less pronounced than in the FD areas. Here, only three species differed significantly among the FE areas: *Eniochthonius minutissimus* and *Tectocepheus velatus* which were both higher in FDO and *Parachipteria travei* which was higher in FE60.

**3.4.2.4.4 Vertical Distribution**

Approximately 20% of the total oribatid specimens in the 10 cm deep soil samples from the FE areas, occurred in the lower 5cm subsamples (Figure 37). This percentage was the same in FEO for the July and August, 1994 sampling dates. However, in both the FE60 and the FE40 areas, the proportion of mites in the lower subsample decreased from July to August.

As in the FD areas, the relative abundance of the smaller *Oppiella washburni* and *Suctobelbella* spp. was greater in the lower 5 cm soil subsample in all FE age areas

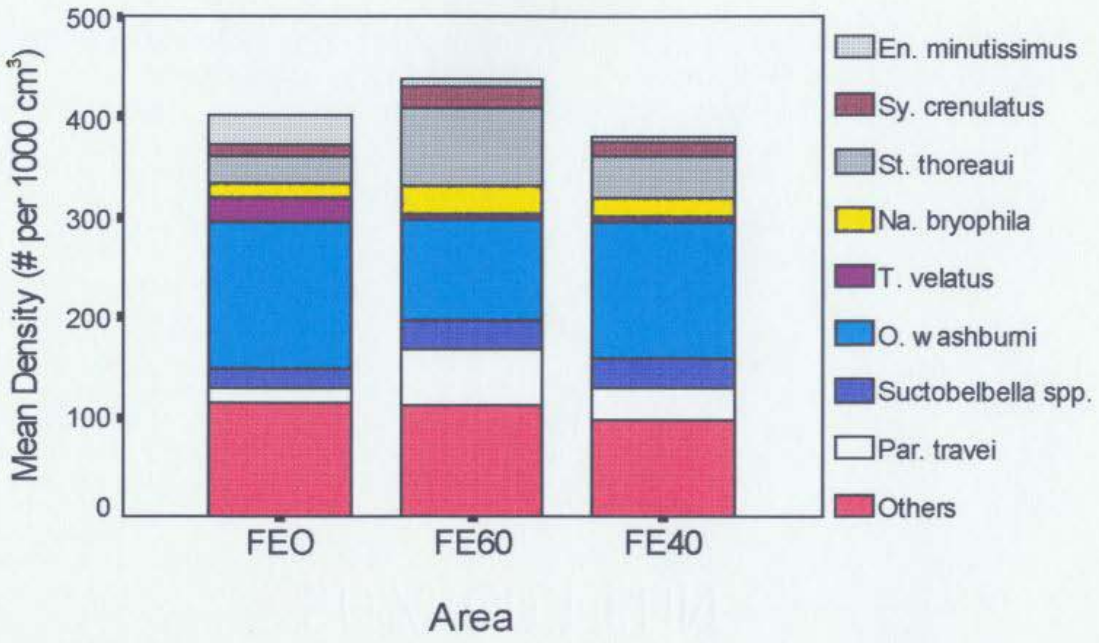



**Figure 36: Mean density (number per 1000 $cm^3$) of dominant adult oribatid mite species in 1994 soil samples (n=20) from FEO, FE60 and FE40.**

**Table 23: Mean (2 sampling dates) relative abundance (%) of dominant adult oribatid mite species from FEO, FE60 and FE40 soil samples where * indicates significant difference among the three ages.**

| SPECIES | FEO | | FE60 | | FE40 | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| *En. minutissimus* | 6.7* | 1.2 | 1.9 | 1.5 | 1.5 | 0.8 |
| *Sy. crenulatus* | 3.0 | 1.8 | 4.3 | 2.9 | 3.6 | 1.4 |
| *St. thoreaui* | 6.9 | 2.8 | 18.0 | 7.9 | 11.2 | 2.6 |
| *Na. bryophila* | 3.6 | 3.0 | 6.8 | 4.7 | 5.1 | 1.7 |
| *T. velatus* | 6.2* | 1.8 | 0.8 | 0.6 | 0.7 | 0.5 |
| *O. washburni* | 35.3 | 8.3 | 22.6 | 12.8 | 33.6 | 13.5 |
| *Suctobelbella* spp. | 4.2 | 2.7 | 6.5 | 2.5 | 6.9 | 3.0 |
| *Par. travei* | 4.2 | 3.0 | 12.6* | 3.6 | 9.2 | 2.4 |
| Others | 30.0 | 9.6 | 25.9 | 1.3 | 28.2 | 13.4 |

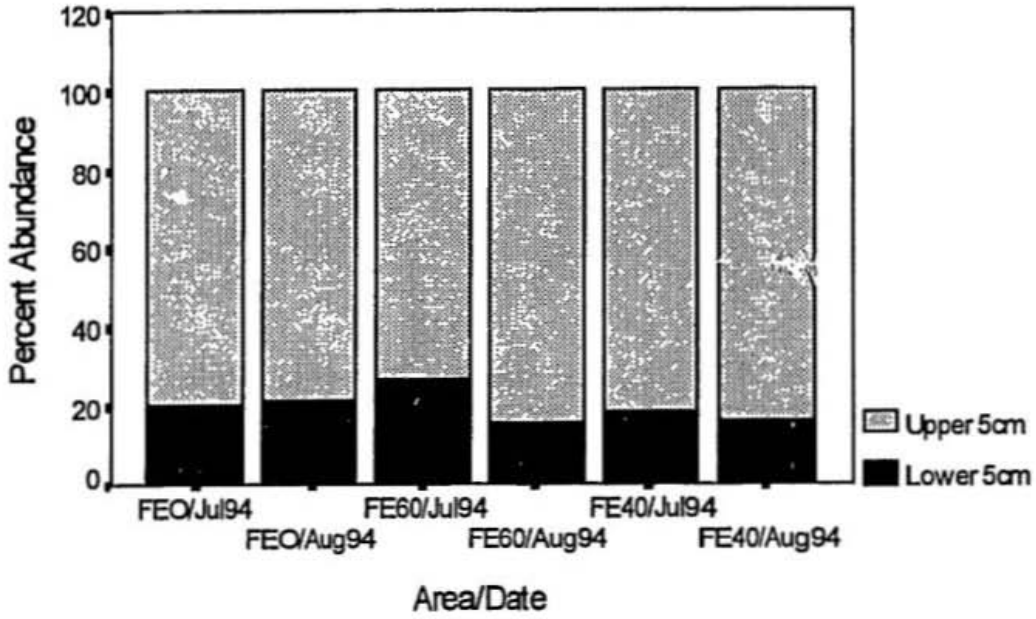



**Figure 37: Mean percent abundance of oribatid mites in upper and lower 5 cm soil subsamples from FEO, FE60 and FE40.**

(Figures 38, 39 and 40). The larger species, *Parachipteria travei* and *Steganacarus thoreaui*, were both relatively less abundant in the lower subsample. The relative abundance of immature *Platynothrus* spp., which was lower in the lower subsample in FEO and FE40 and was similar in the upper and lower subsamples of FE60, was higher in FE areas than in FD areas.

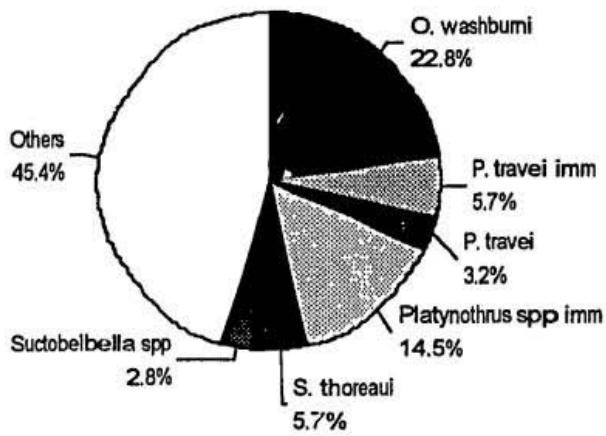
**3.4.2.4.5 Rarefaction**

Species numbers were compared between the FE sites with rarefaction curves (Figure 41). Species richness in the FE sites was fairly uniform for July 1994 with the highest richness occurring in FEO-7, 8. However, the rarefaction curves show separation for the August 1994 data. Here, the FE60- 11, 12 sites had the lowest richness while FEO-8 had the highest.

**3.4.2.4.6 Diversity**

Total abundance and species numbers for the FE sites are shown in Table 24. Shannon-Wiener diversity indices for the FE sites ranged from 3.13 - 4.02 in upper subsamples and from 2.63 - 3.65 in lower subsamples. Again these sites displayed higher diversity in the upper 5cm of the soil samples. Generally, diversity and evenness in the upper subsamples were higher in FEO followed by FE60 and FE40 however, in the lower subsample values tended to be higher in FE40. The graph of diversity values for the FE areas (Figure 42), did not reflect the pattern previously indicated by the rarefaction analysis for August 1994. According to the diversity indices, FE60, which had the lowest species richness, was as diverse as FEO. This variation may have resulted from the

A




B

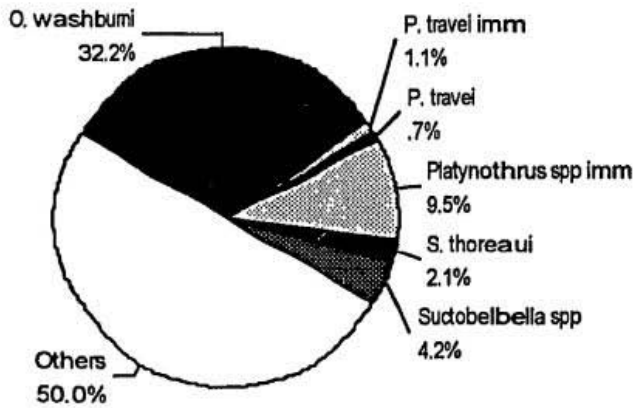
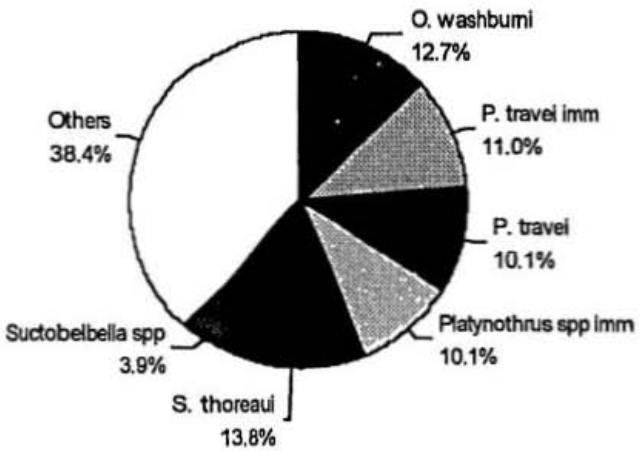



**Figure 38: Relative abundance (%) of common oribatid mite species in upper (A) and lower (B) 5 cm soil subsamples from FEO.**

A




B

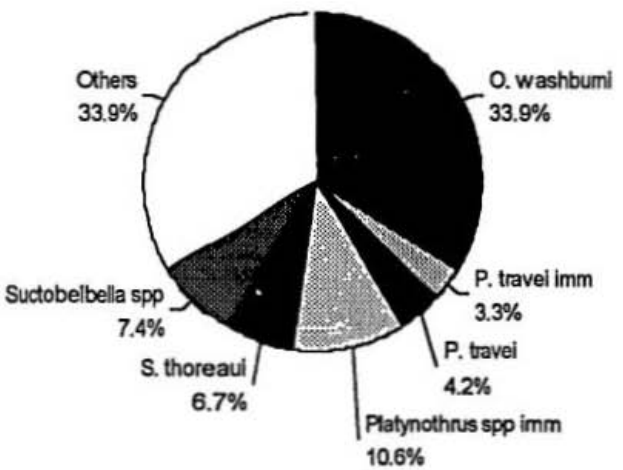
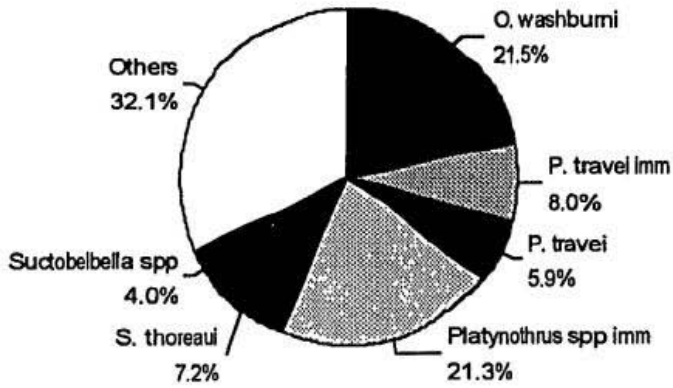



**Figure 39: Relative abundance (%) of common oribatid mite species in upper (A) and lower (B) 5 cm soil subsamples from FE60.**

A




B

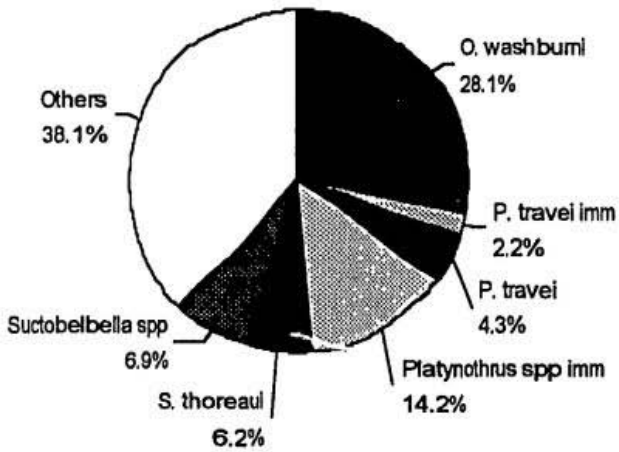



**Figure 40: Relative abundance (%) of common oribatid mite species in upper (A) and lower (B) 5 cm soil subsamples from FE40.**

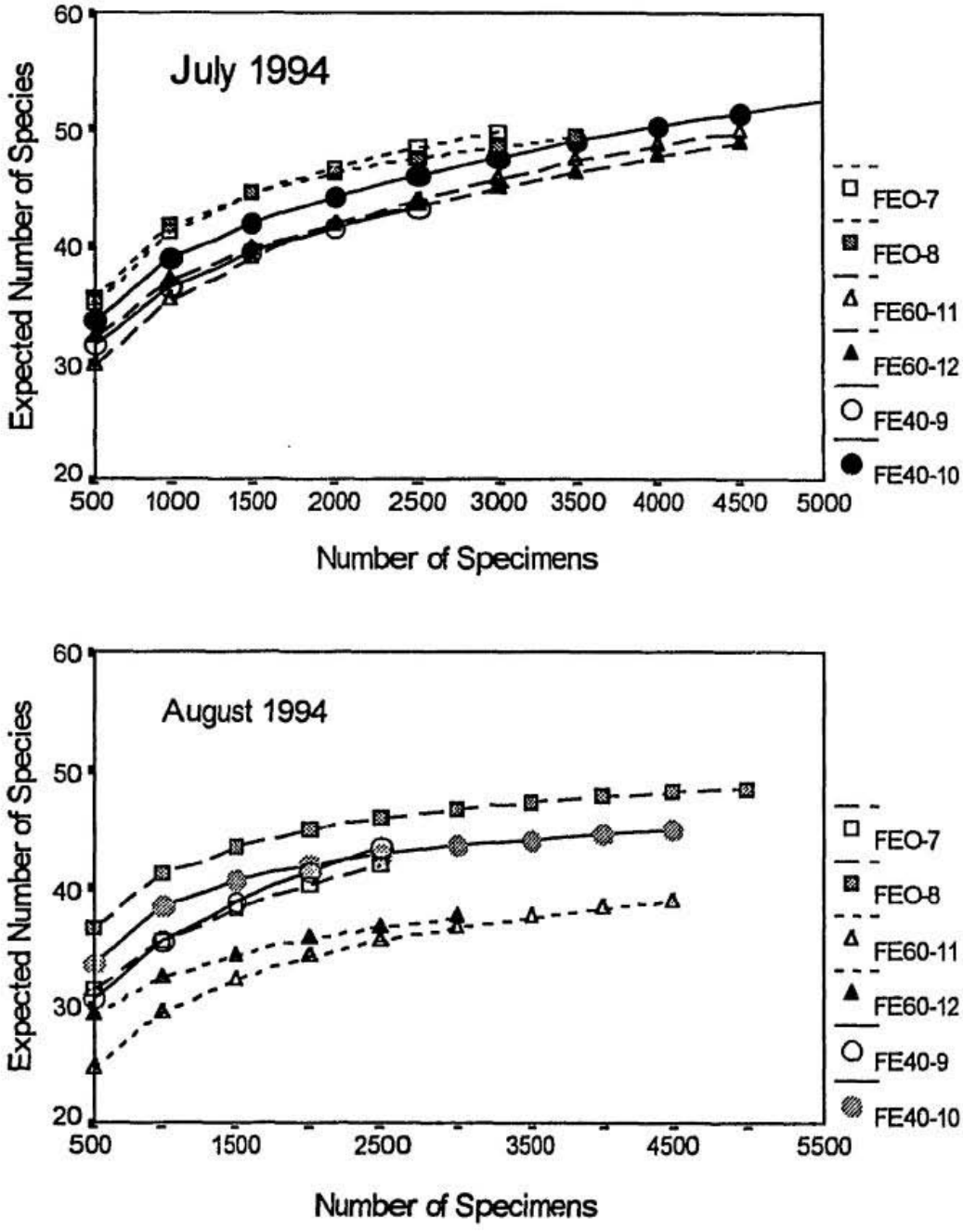



**Figure 41: Rarefaction curves for 1994 FE sites showing expected number of oribatid species occuring in samples of various sizes.**

**Table 24: Number of specimens, species, Shannon-Wiener (H') and evenness indices for oribatid mites collected from FEO-7, 8; FE60-11, 12 and FE40-9, 10 in 1994.**

| MEASURE | DATE | FEO-7 | | FEO-8 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | July | 3042 | 437 | 2932 | 950 |
| | August | 2444 | 419 | 3572 | 2284 |
| Total number of species (n=10) | July | 51 | 26 | 48 | 36 |
| | August | 42 | 26 | 48 | 39 |
| Shannon-Wiener Diversity (H') | July | 3.84 | 3.18 | 3.56 | 2.64 |
| | August | 3.90 | 2.84 | 3.83 | 2.68 |
| Evenness | July | .68 | .68 | .64 | .51 |
| | August | .72 | .60 | .69 | .51 |

| MEASURE | DATE | FE60-11 | | FE60-12 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | July | 3831 | 748 | 3282 | 1642 |
| | August | 4020 | 534 | 2591 | 821 |
| Total number of species (n=10) | July | 47 | 27 | 48 | 33 |
| | August | 38 | 26 | 36 | 32 |
| Shannon-Wiener Diversity (H') | July | 3.69 | 2.67 | 3.59 | 2.63 |
| | August | 3.34 | 3.22 | 3.76 | 3.48 |
| Evenness | July | .66 | .56 | .64 | .52 |
| | August | .64 | .47 | .73 | .70 |

| MEASURE | DATE | FE40-9 | | FE40-10 | |
|---|---|---|---|---|---|
| | | Upper 5cm | Lower 5cm | Upper 5cm | Lower 5cm |
| Total number of individuals (n=10) | July | 2531 | 321 | 4030 | 1203 |
| | August | 2370 | 279 | 3314 | 1218 |
| Total number of species (n=10) | July | 42 | 26 | 50 | 36 |
| | August | 44 | 24 | 43 | 32 |
| Shannon-Wiener Diversity (H') | July | 3.63 | 3.30 | 3.13 | 2.92 |
| | August | 4.02 | 3.65 | 3.66 | 2.90 |
| Evenness | July | .67 | .70 | .56 | .56 |
| | August | .74 | .80 | .68 | .58 |

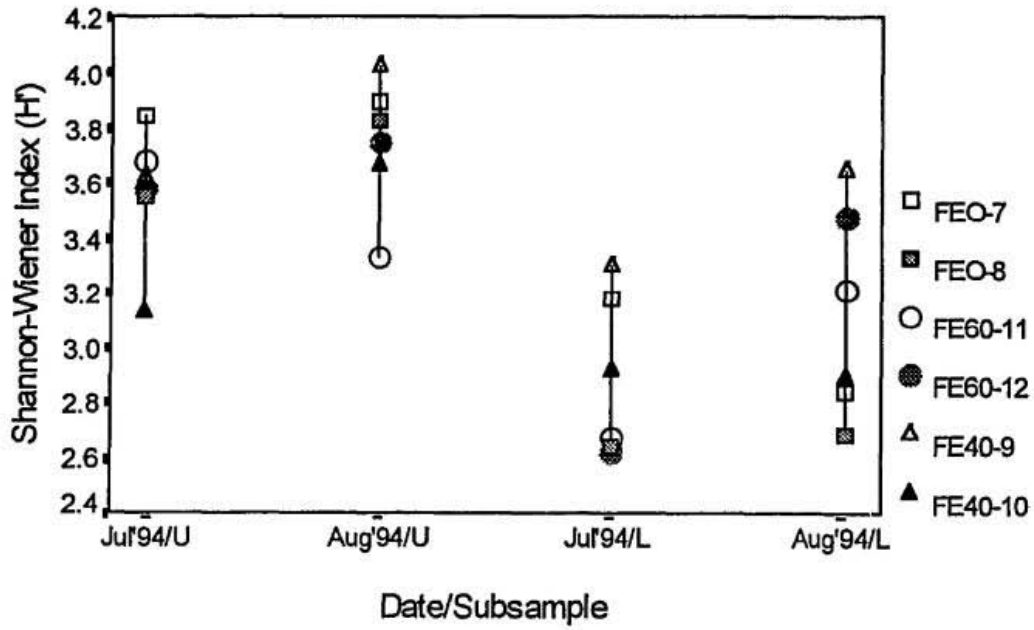



**Figure 42: Shannon-Wiener diversity values (H') for adult oribatid mite populations in upper (U) / lower (L) 5cm soil subsamples from FE-7, 8; FE60-11, 12 and FE40-9, 10.**

separation of the data into upper and lower 5cm subsamples for the calculations of diversity.

#### 3.4.2.4.7 Ordination

The scatter plot of PCA factors 1-3 of the FE forest type site data (Figure 43) grouped the two FE60 and the two FE40 sites close together. The FEO sites, however, were not grouped until factor three, indicating some dissimilarity between the sites.

The close proximity of the FE60, FE40 and FEO-7 sites on factor 1, as indicated by the PCA factor values of species in Table 25, resulted from a relatively high abundance of *Autogneta longilamellata* and *Phthiracarus boresetosus*. Conversely, FEO-8 contained high numbers of *Protoribotritia canadaris, Rhysotritia ardua, Palaeacarus hystricinus, Gozmanyina majestus* and *Liochthonius lapponicus.*

Factor 2 showed separation of FEO-7 from the other five sites based on the abundance of species such as *Xylobates* sp., *Trichoribates* sp., *Eupelops* sp. and *Hermanniella* sp..

## 3.5 COMMUNITY STRUCTURE

### 3.5.1 Cluster Analysis

Cluster analysis of species presence/absence data from the soil samples (Figure 44) showed clear separation of the two forest types, FD and FE. Within the FD forest type, sites of the same aged forest grouped together and three main clusters based on age are obvious. The same distinct age class separation was not present in the FE sites. However, FEO and FE40 showed grouping of sites whereas of the four FE60 sites, two grouped

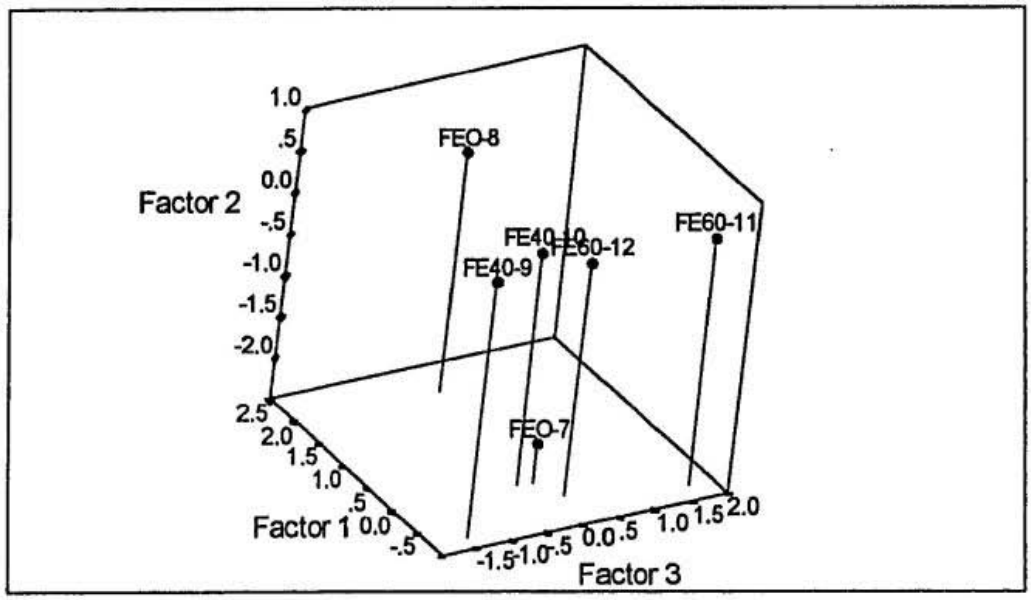



**Figure 43: Ordination of FEO-7, 8; FE60-11, 12 and FE40-9, 10 sample sites based on mean densities of adult oribatid mite species per sample.**

**Table 25: Oribatid mite species with principle components analysis eigenvalues greater/lesser than .700 /-.700 on factors 1 and 2 based on data from FEO-7, 8; FE60-11, 12 and FE40-9, 10 sites.**

| Species | Factor 1 | Factor 2 | Species | Factor 1 | Factor 2 |
|---|---|---|---|---|---|
| *A. longilamellata* | -.859 | .054 | *Liebstadia* sp. b | .739 | .271 |
| *Cam. biuris* | .900 | -.342 | *Lio. lapponicus* | .921 | -.157 |
| *Car. labyrinthicus* | .986 | .073 | *O. washburni* | .738 | .249 |
| *Cep. corae* | .956 | -.057 | *Pa. hystricinus* | .884 | .345 |
| *Ce. bipilis* | .955 | -.055 | *Par. travei* | -.700 | .377 |
| *Ch. cuspidatus* | .856 | -.440 | *Ph. boresetosus* | -.722 | -.443 |
| *Cu. bicultrata* | .739 | .271 | *Prop. canadensis* | .962 | .170 |
| *En. minutissimus* | .939 | -.273 | *Prot. canadaris* | .924 | .327 |
| *Eupelops* sp. | .300 | -.835 | *Pyroppia* sp. | -.232 | -.894 |
| *G. majestus* | .952 | .195 | *Quadroppia* sp. | .803 | -.166 |
| *Gymnodamaeus* sp. | .953 | .192 | *Rh. ardua* | .939 | .326 |
| *Haplozetes* sp. | -.029 | -.995 | *T. velatus* | .794 | -.596 |
| *He. longisetosus* | .861 | -.420 | *Trichoribates* spp. | -.216 | -.861 |
| *Hermaniella* sp. | -.011 | -.993 | *Xylobates* sp. | .143 | -.951 |
| *Lie. similis* | -.041 | -.991 | *Ce. quadridentata* | .964 | .103 |

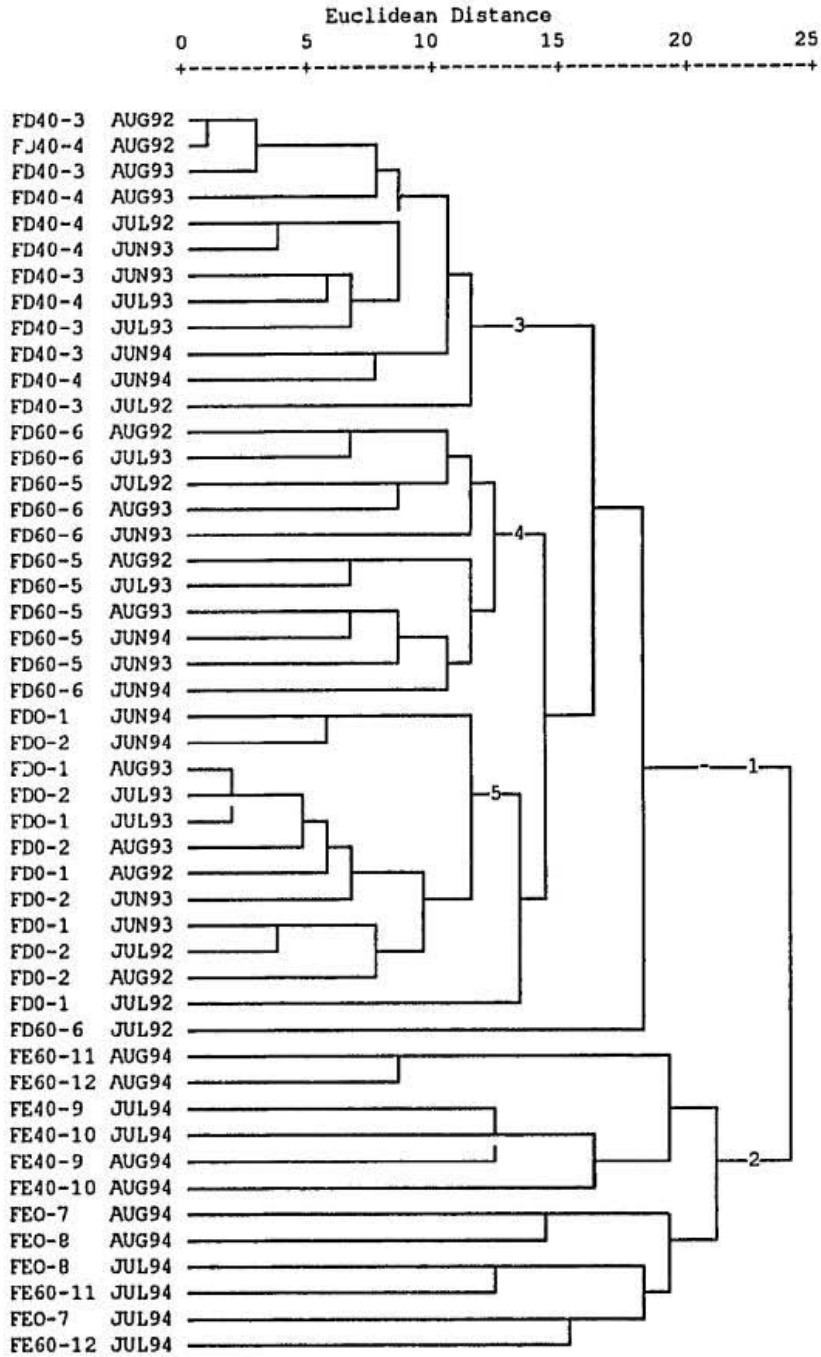



**Figure 44: Cluster analysis of oribatid mite species presence/absence data from FDO-1, 2; FD60-5, 6; FD40-3, 4; FEO-7, 8; FE60-11, 12 and FE40-9, 10 sites using between group linkageof squared euclidean distances.**

with each of FEO and FE40.

Similar analysis was performed combining the microhabitat data from the FDO, FD60 and FD40 areas with soil sample data from the FD and FE areas (Figure 45). The first clustering division separated the soil and microhabitat samples into two distinct groups. Further division of the soil samples repeated the separation of the FD and FE forests types observed in Figure 44. Higher clustering of the microhabitat samples generally showed grouping of the tree associated bark and lichen samples. The moss and deciduous leaves samples formed another group with rotten wood and tree hole samples interspersed.

### 3.5.2 TWINSPAN

Divisions in TWINSPAN reflect different abundances of 'indicator species' between groups and may be used to classify samples external to the analysis into any of these groups (Carleton 1985). The first division in TWINSPAN analysis of oribatid diversity and abundance data (Figure 46) showed a clear distinction between the FD and FE forest types based on different abundances of *Adoristes* sp., *Anachipteria* sp. and *Ceratozetes gracilis* (Table 26). *Adoristes* sp. was higher in FD whereas *Anachipteria* sp. had a lower occurrence and *Ceratozetes gracilis* did not occur in FD. The grouping of the 1992 FD60-5 samples with the FE samples was due to low numbers of *Adoristes* sp. combined with high *Anachipteria* sp. numbers. They differ from the FE sites, however, in the absence of *Ceratozetes gracilis* which was recovered only from FE forest. Within FE, forest age classes showed some separation but not as clearly as among the FD forest sites.

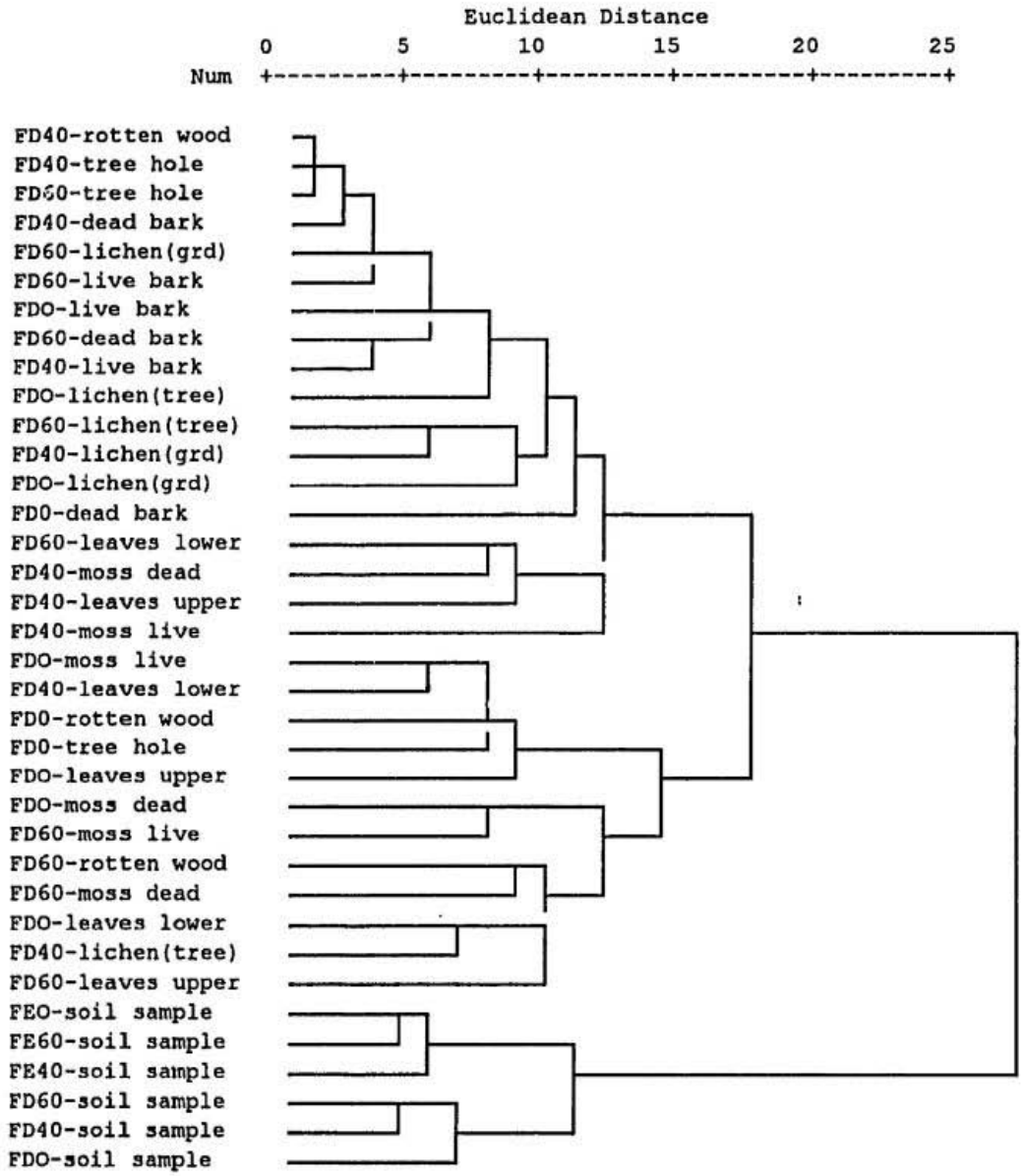



**Figure 45: Cluster analysis of oribatid mite species presence/absence data from FDO, FD60, FD40, FEO, FE60 and FE40 soil samples and FD microhabitat samples where: lichen (grd) - lichen covered branches from ground; moss live and dead-moss from live and dead trees; leaves upper/lower -upper loose/lower compacted deciduous leaves.**

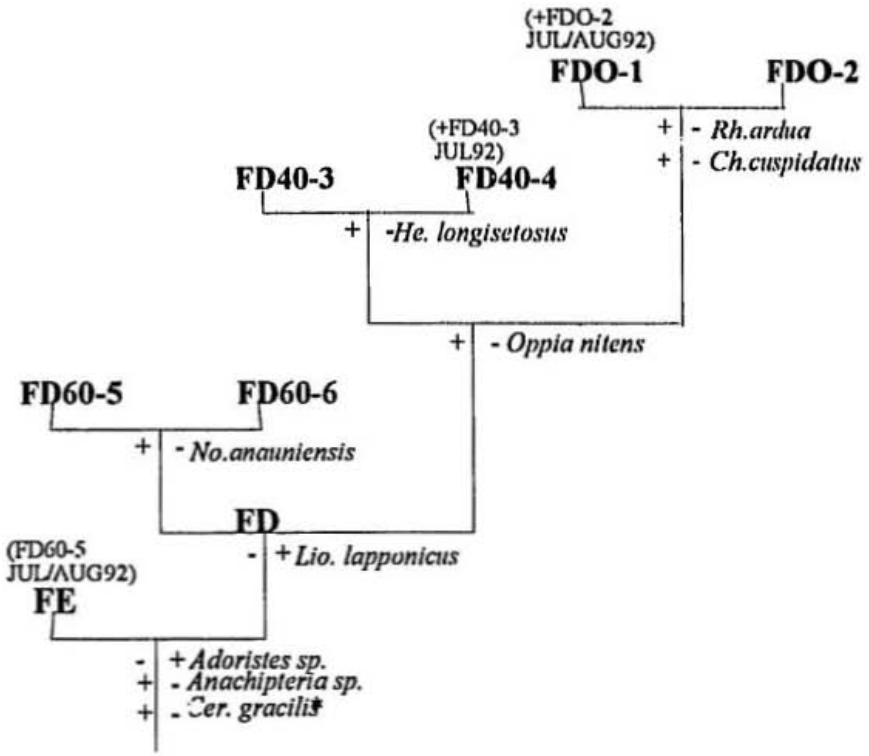



**Figure 46: Dendrogram of TWINSPAN analysis of adult oribatid mite data from FDO-1, 2; FD60-5, 6; FD40-3, 4; FEO-7, 8; FE60-11, 12 and FE40-9, 10 sites. Relative abundance of indicator species (*) on each side of the division is shown with +/- signs.**

**Table 26: Mean abundance of indicator mite species for each division in the TWINSPAN analysis of soil sample data from FDO-1, 2; FD60-5, 6; FD40-3, 4; FEO-7, 8; FE60-11, 12 and FE40-9, 10 sites. Species are represented by the following numbers: 1 - *Adoristes* sp., 2 - *Anachipteria* sp., 3 - *Cer. gracilis*, 4 - *Lio. lapponicus*, 5 - *No. anauniensis*, 6- *Oppia nitens*, 7 - *He. longisetosus*, 8 - *Rh. ardua*, 9 - *Cer. cuspidatus*. The - sign indicates that a site has already been classified.**

| SITE | SPECIES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| FD0-1 (All 6 dates) | 85 | 0 | 0 | 59 | 52 | 0 | 21 | 59 | 8 |
| FDO-2 (All) | 206 | 0 | 0 | 72 | 130 | 0 | 64 | 25 | 7 |
| FDO-2 July 1992 | 133 | 0 | 0 | 13 | 84 | 0 | 16 | 22 | 21 |
| FDO-2 August 1992 | 289 | 0 | 0 | 21 | 84 | 0 | 53 | 45 | 10 |
| FD60-5 (All) | 79 | 8.5 | 0 | 0 | 40 | - | - | - | - |
| FD60-5 July 1992 | 30 | 20 | 0 | - | - | - | - | - | - |
| FD60-5 August 1992 | 66 | 4 | 0 | - | - | - | - | - | - |
| FD60-6 (All) | 112 | 0.2 | 0 | 0 | 0 | - | - | - | - |
| FD40-3 (All) | 216 | 0.3 | 0 | 79 | 141 | 90 | 81 | - | - |
| FD40-3 July 1992 | 144 | 0 | 0 | 75 | 53 | 28 | 28 | - | - |
| FD40-4 (All) | 183 | 0 | 0 | 62 | 41 | 14 | 30 | - | - |
| FE (All) | 23 | 23 | 26 | - | - | - | - | - | - |

The old FE sites and FE60-12 from July 1994 were separated from the other FE sites and the two FD60 sites due to high *Chamobates cuspidatus* and *Tectocepheus velatus* numbers and lower *Dentachipteria highlandensis* numbers.

The FD forest displayed definite grouping of similar aged sites. FD60 sites were grouped due to the absence of *Liochthonius lapponicus*, a species relatively abundant in FDO and FD40 sites. The presence of the 'indicator species' *Oppia nitens* in FD40 separated these sites from those of FDO.

### 3.5.3 Ordination

A composite scatterplot of FD sites on PCA factor 1 values of soil, vegetation and adult mite data is presented in Figure 47. The two FDO sites are closely related on all three axis indicating that they were more similar to one another than to any of the other sites. The two replicate sites within the FD60 area show variability on the soil and vegetation axes though they were closely associated on the mite axis. Dissimilarity was greatest between the two sites of the FD40 area which were highly separated on all three axes.

## 3.6 SPECIES NOTES

***Paleacarus hystricinus*** Trägärdhi, 1932

Determined using Balogh and Mahunka (1983)

Distribution: Holarctic

Specimens of *P. hystricinus* occurred in relatively low abundance (0.2 to 0.8) in soil samples of all FD and FE sites and were evenly distributed between the upper and

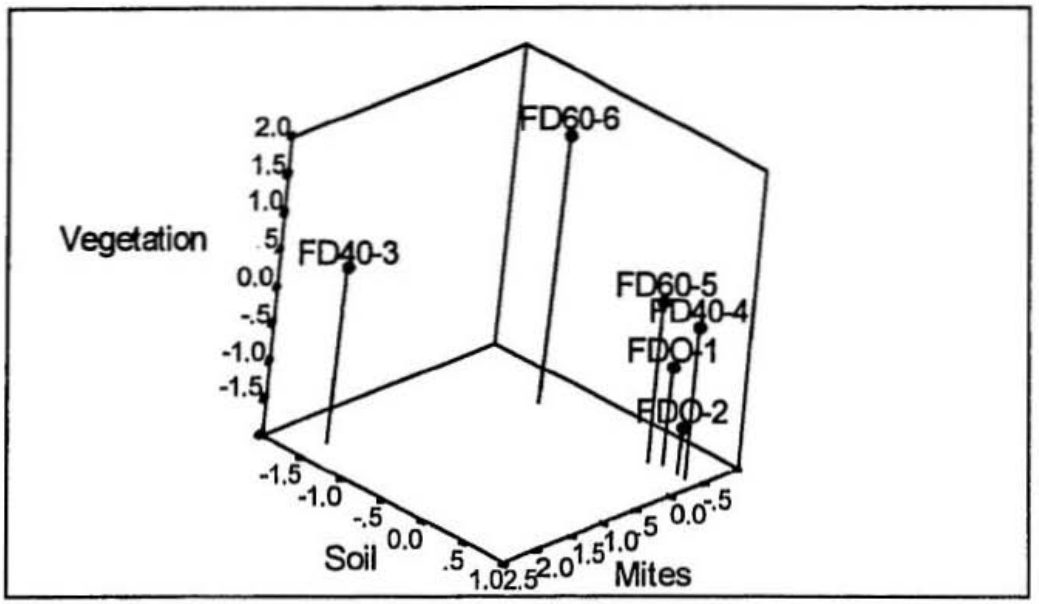



**Figure 47: Scatter plot of principle components analysis factor ones from analysis of mean site values for LFH soil, vegetation and adult oribatid mite data from FDO-1, 2; FD60-5, 6 and FD40-3, 4 sites.**

lower 5 cm subsamples. They were also collected in FD tree hole and rotten wood microhabitat samples. These small, pale coloured mites have a thin cuticle and were not found in the drier microhabitats where they could dessicate.

***Hypochthonius rufulus*** C.L. Koch, 1835

Determined using Balogh and Mahunka (1983)

Distribution: Holarctic

Both adult and immature *H. rufulus* were collected in low abundance (0.3 to 18.8) in soil samples from all FD and FE sites, and from microhabitat samples on or close to the ground. Abundance was consistently high in the lower-compacted deciduous leaf samples.

*Hypochthonius rufulus* immatures consistently out-numbered adults in the FD upper 5 cm soil subsamples, and were more abundant in June 1993 and 1994 (Figure 48) than in other sampling dates. Adult abundance was generally stable, although abundance was slightly higher in June 1993. Both adults and immatures occurred throughout the soil profile, but densities were much higher in the upper 5 cm soil subsamples compared to the lower subsamples.

***Eniochthonius minutissimus*** (Berlese, 1903)

Determined using Balogh and Mahunka (1983)

Distribution: Cosmopolitan

Both adult and immature *E. minutissimus*, one of the most abundant species

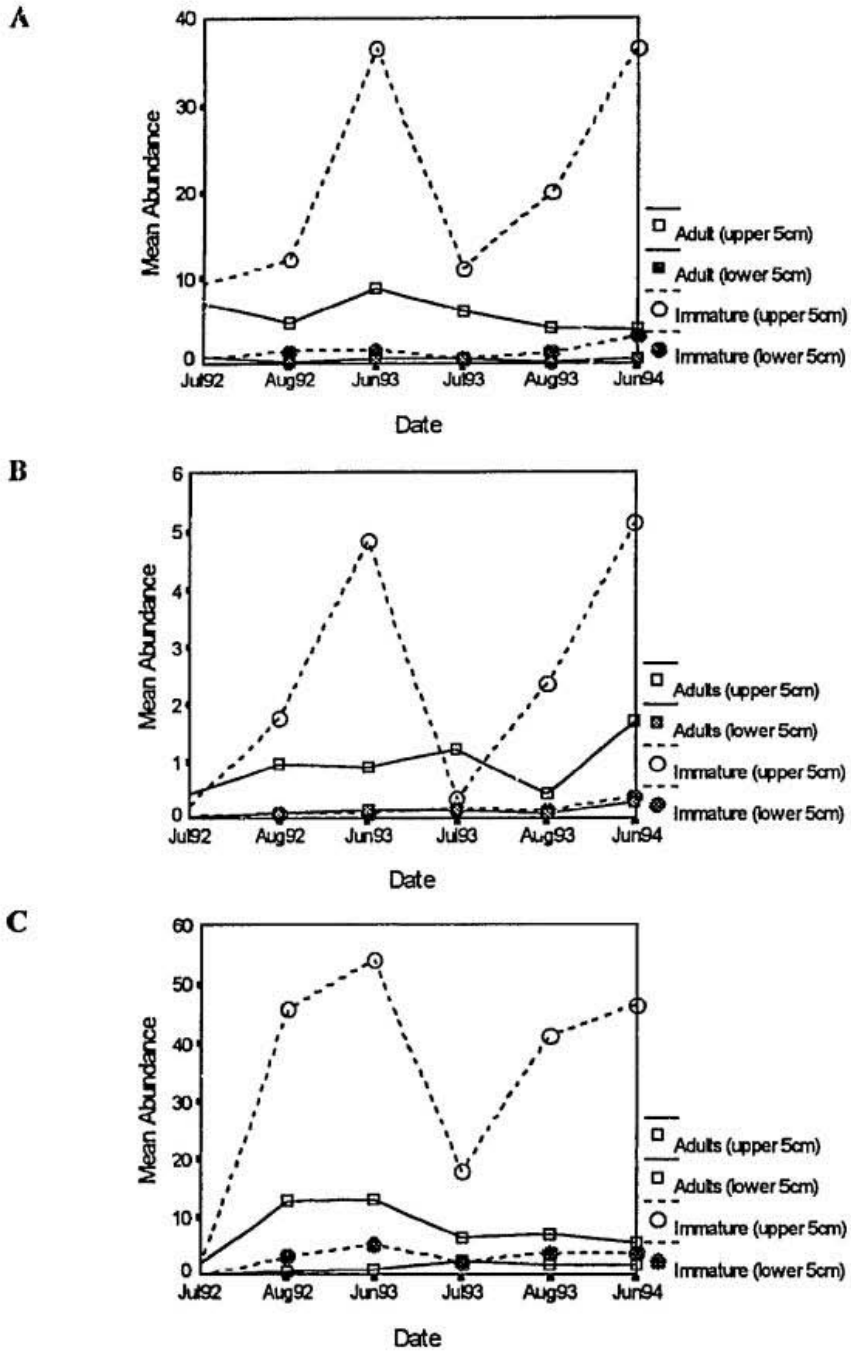



**Figure 48: Seasonal and vertical distribution of *Hypochthonius rufulus* in upper and lower 5 cm soil subsamples from FDO (A), FD60 (B) and FD40 (C).**

collected (0.7 to 45.1), occurred in soil samples from all FD and FE sites and in all ground level microhabitat samples. Generally, adults and immatures were more abundant in FD than in FE soil samples.

No clear seasonal pattern of abundance was evident among the three FD age classes (Figure 49). Unlike *Hypochthonius rufulus*, adult *E. minutissimus* were usually more abundant than immatures in both upper and lower subsamples. Very few specimens occurred below 5 cm in the soil profile. Notably, this species is known to sequester calcium, probably obtained from feeding, in its cuticle (Norton and Behan-Pelletier, 1991).

***Liochthonius lapponicus*** (Trägärdh, 1910)

Determined using Balogh and Mahunka (1983)

Distribution: Holarctic; new Newfoundland record

Specimens did not occur in either the soil or microhabitat samples of FD60 where materials tended to be dry, but occurred in low abundance (0.2 to 3.5) in soil samples of the remaining FD and FE sites. Specimens occurred throughout the soil profile with the majority in the upper 5 cm subsamples. These small mites occurred only in ground level microhabitat samples.

***Synchthonius crenulatus*** (Jacot, 1938)

Determined using Balogh and Mahunka (1983)

Distribution: Holarctic; new Newfoundland record

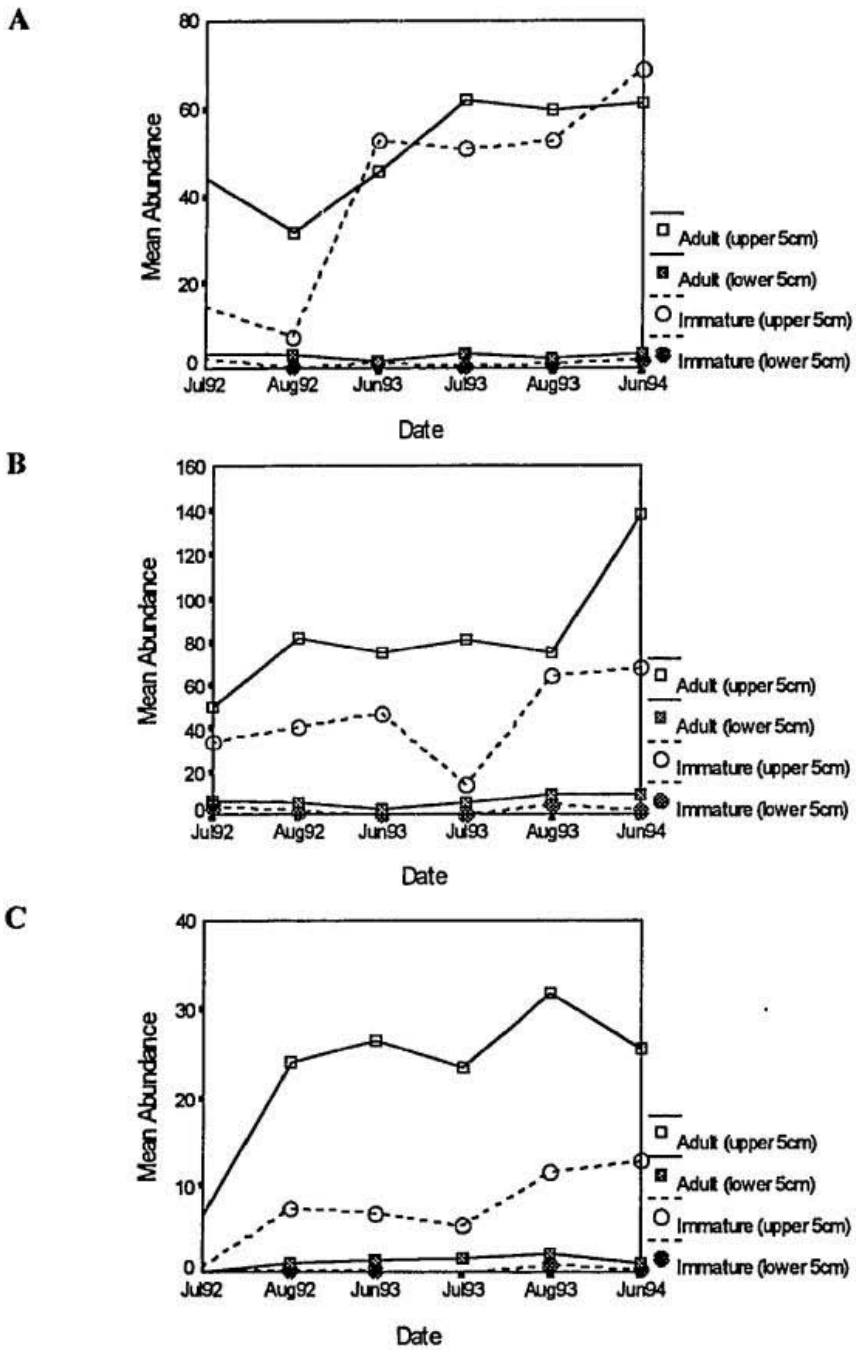



**Figure 49: Seasonal and vertical distribution of *Eniochthonius minutissimus* in upper and lower 5 cm soil subsamples from FDO(A), FD60 (B) and FD40 (C).**

These mites occurred in moderate abundance (0.8 to 20.7) in soil samples from all FD and FE sites, primarily in the upper 5 cm subsamples. Specimens also occurred in all microhabitat samples except the lichen samples.

***Gozmanyina majestus*** (Marshall and Reeves, 1971)

Determined using Norton (1992a) and Marshall and Reeves (1971)

Distribution: Nearctic; new Newfoundland record

Specimens occurred in low numbers (1.2) throughout the soil profile in FEO but were absent from regrowth forest sites except one specimen that was collected from FE60. These small mites may require a moist environment as they did not occur in the drier FD sites.

***Steganacarus thoreaui*** Jacot, 1930

Determined using Balogh and Mahunka (1983) and Niedbala (1992)

Distribution: Holarctic; new Newfoundland record

Individuals of *S. thoreaui* occurred in fairly high abundance (13.6 to 50.4), predominantly in the upper 5 cm soil subsamples, in all FD and FE sites and in most microhabitat samples except bark of live trees. Specimens were abundant in samples of upper and lower deciduous leaf layers and moss from live and dead trees.

***Phthiracarus boresetosus*** Jacot, 1930

Determined using Balogh and Mahunka (1983) and Niedbala (1992)

Distribution: Holarctic; new Newfoundland record

Individuals of *P. boresetosus* occurred in low abundance (0.9 to 6.1) in soil samples from all FD and FE sites. Although specimens occurred throughout the soil profile, the majority were concentrated in the upper 5 cm subsamples. Specimens occurred in most FD microhabitats except tree bark and were consistently abundant in the lower deciduous leaf samples.

***Phthiracarus compressus*** Jacot, 1930

Determined using Balogh and Mahunka (1983) and Niedbala (1992)

Distribution: Nearctic; new Newfoundland record

Specimens occurred in low abundance (0.5 to 4.7) in all soil samples from FD and FE sites, primarily in the upper 5 cm subsamples. They also occurred sparsely in all microhabitat samples except tree lichen.

***Phthiracarus* sp.**

Determined using Balogh and Mahunka (1983) and Niedbala (1992)

Taxonomic Notes: This appears to be an undescribed species as specimens could not be associated with any of the species listed by Marshall, Reeves and Norton (1987).

The species occurred in low abundance (0.2 to 4.8) in soil samples and was

abundant in the upper 5 cm subsamples. Numbers were highest in FE. Specimens occurred sparsely in all microhabitat samples.

***Mesotritia* sp.**

Determined using Balogh and Mahunka (1983)

Distribution: New Newfoundland record

Individuals of *Mesotritia* sp. occurred in very low abundance (0.01 to 0.4), primarily in the upper 5 cm soil subsamples, of all FD sites and some FE sites. Abundance was highest in FDO. It was collected in most microhabitat samples.

***Protoribotritia canadaris*** Jacot, 1938

Determined using Balogh and Mahunka (1983) and Jacot (1938)

Distribution: Nearctic; new Newfoundland record

Specimens of *P. canadaris* occurred at relatively low abundance (0.5 to 2.8) in soil samples of all FD and FE sites, with lower abundances generally in FE sites. Numbers were evenly distributed between the upper and lower 5 cm soil subsamples in FE, but they were concentrated in the upper 5 cm subsample in FD. It also occurred in various microhabitat samples but was absent from trees.

***Euphthiracarus* sp.**

Determined using Balogh and Mahunka (1983)

Distribution: New Newfoundland record

Individuals of *Euphthiracarus* sp. occurred sparsely (0.03 to 0.1), primarily in the upper 5 cm soil subsamples, in FD sites. The species was not found in any microhabitat samples.

***Rhysotritia ardua*** (C.L. Koch, 1841)

Determined using Balogh and Mahunka (1983)

Distribution: Cosmopolitan

Specimens of *R. ardua* occurred in low abundance (0.5 to 4.9) in soil samples of all FD and FE sites, with highest abundances in FD sites. Although it occurred in both upper and lower 5 cm subsamples, numbers were higher in the upper layer. It occurred most microhabitat samples collected from the soil surface.

***Nothrus anauniensis*** Canestrini and Fanzago, 1876

Determined using Balogh and Mahunka (1983)

Distribution: Cosmopolitan; new Newfoundland record

Adult and immature *N. anauniensis* occurred in soil samples from both FD and FE sites. Immature specimens were common (1.8 to 23.7), particularly in the FD sites and were consistently more abundant than the adults (0.5 to 4.5). They also occurred in all microhabitat samples except those from tree or branch surfaces and were particularly abundant in the tree hole samples.

The seasonal pattern of abundance varied among the three ages of FD forest (Figures 50). FDO showed an increase in immatures, in the upper and lower 5 cm soil subsamples, from June to August 1993, FD60 showed an decrease from June 1993 to July 1993 followed by a slight increase in August 1993 and FD40 showed an increase from June to July 1993 followed by a decrease in August 1993. Immatures tended to be more abundant than adults and occurred predominantly in the upper 5 cm soil subsamples. However numbers in FDO and FD40 were also high in the lower 5 cm subsamples. Adult numbers were consistent throughout the summer with most adults occurring in the upper 5 cm subsamples.

***Nothrus palustris*** C. L. Koch, 1839

Determined using Balogh and Mahunka (1983)

Distribution: Holarctic; new Newfoundland record

Individuals of *N. palustris* occurred in low numbers (0.1 to 0.6) in FE soil samples. Specimens were predominantly found in the upper 5 cm subsamples.

***Camisia biuris*** (C.L. Koch, 1839)

Determined using Balogh and Mahunka (1983)

Distribution: Holarctic; new Newfoundland record

Specimens occurred rarely (0.01 to 0.1) in soil samples from all FD and FE sites except FDO, primarily in the upper 5 cm subsamples. It occurred in most microhabitat

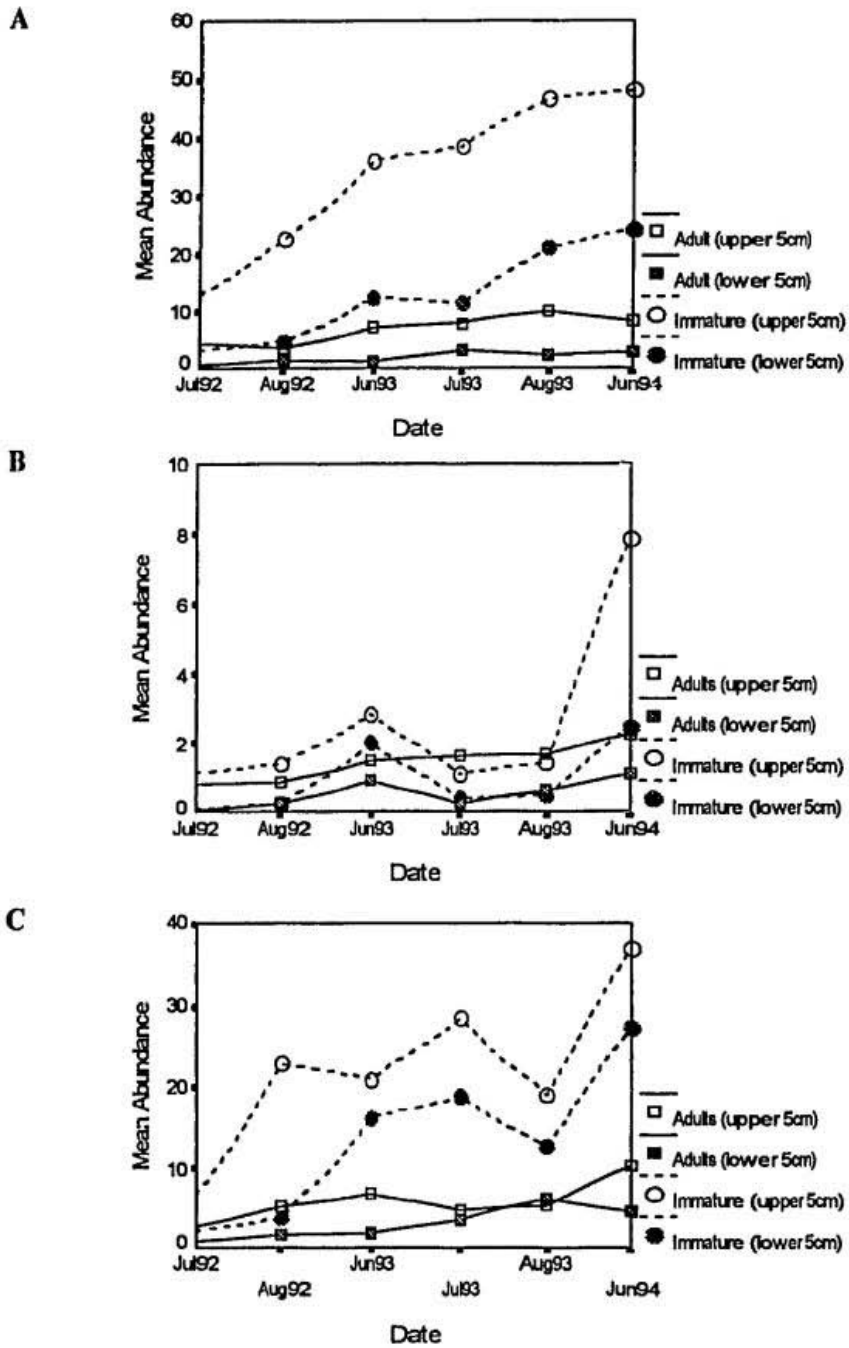



**Figure 50: Seasonal and vertical distribution of *Nothrus anauniensis* in upper and lower 5 cm soil subsamples from FDO (A), FD60 (B) and FD40 (C).**

samples.

***Camisia lapponica*** (Trägärdh, 1910)

Determined using Balogh and Mahunka (1983)

Distribution: Holarctic; new Newfoundland record

Both adult and immature *C. lapponica* occurred in low numbers (0.1 to 2.3) in soil samples from all FD and FE sites. Numbers were higher in FD sites with the highest abundance occurring in the FDO sites. Specimens occurred regularly but in low numbers in the rotten wood microhabitat samples and were sporadic in several other microhabitat samples.

Adults and immatures, occured predominantly in the upper 5 cm soil subsamples and had their highest abundance in June 1993, followed by a decrease in numbers in July and August 1993 (Figure 51).

***Heminothrus longisetosus*** Willman, 1925

Determined using Balogh and Mahunka (1983)

Distribution: Holarctic; new Newfoundland record

Both adult and immature *Heminothrus longisetosus* occurred in low numbers (0.03 to 2.8) in soil samples from all FD and FE sites, predominantly in the upper 5 cm subsamples. The distribution of adult and immature stages differed between different microhabitats with adults only collected from tree hole, lower deciduous leaf and moss

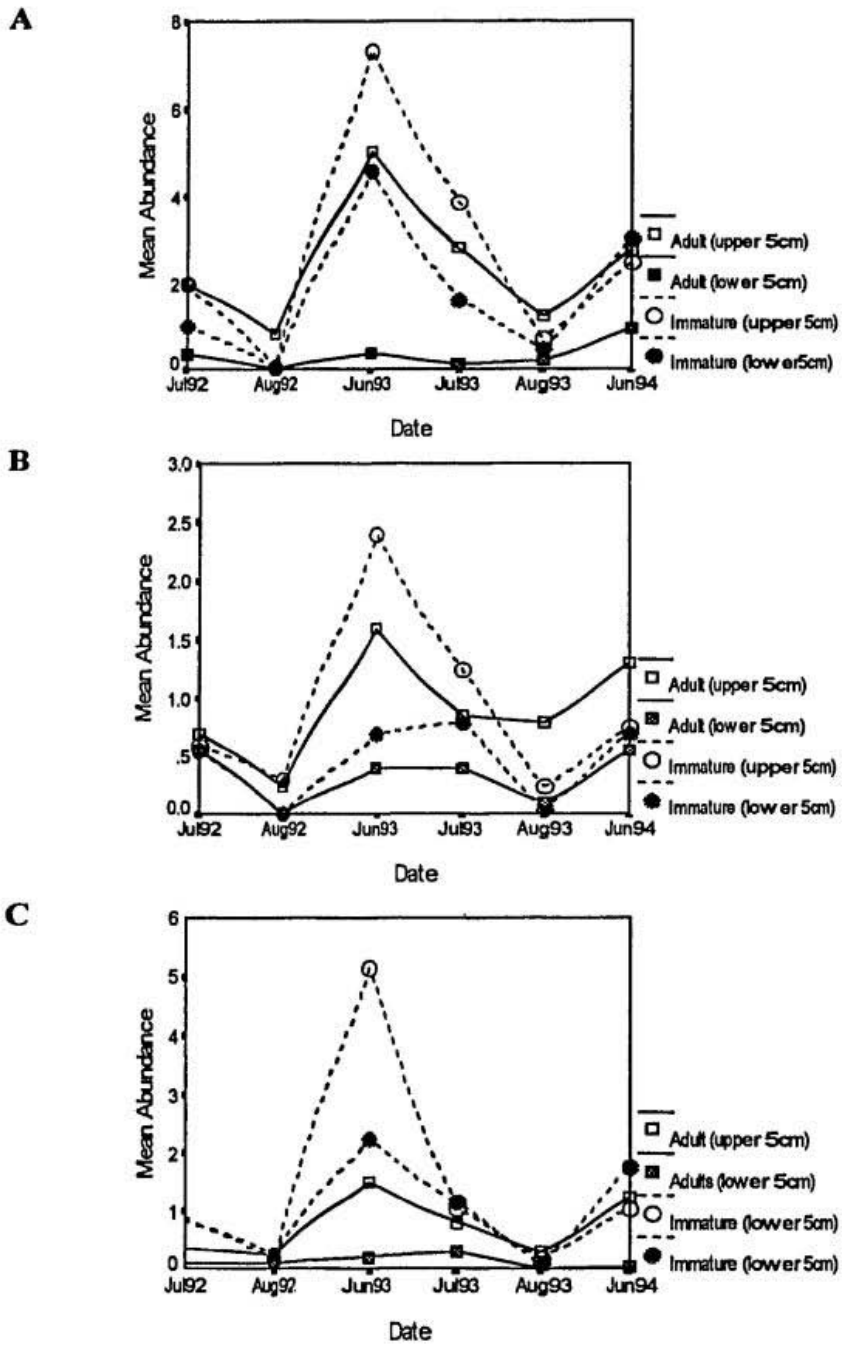



**Figure 51: Seasonal and vertical distribution of *Camisia lapponica* in upper and lower 5 cm soil subsamples from FDO (A), FD60 (B) and FD40 (C).**

from live trees samples. Immatures only occurred in the lichen samples.

***Platynothrus peltifer*** (C.L. Koch, 1839)

Determined using Balogh and Mahunka (1983)

Distribution: Cosmopolitan

Both adult and immature *P. peltifer* were collected in moderately high numbers (3.1 to 6.6) in soil samples from all FD and FE sites. The immature stages of *P. peltifer* and *Platynothrus* sp. could not be separated and their combined densities ranged from 21.7 to 57.8. The majority of the specimens occurred in the upper 5 cm subsamples. *P. peltifer* adults and associated immatures were consistently abundant in the deciduous leaf samples and also occurred in several other soil level microhabitat samples.

***Platynothrus* sp.**

Determined using Balogh and Mahunka (1983)

Taxonomic Notes: Specimens could not be associated with any of the species listed by Marshall, Reeves and Norton (1987) or Balogh and Mahunka (1983).

Adult *Platynothrus* sp. occurred in moderate abundance (0.9 to 10.5) in soil samples from all FD and FE sites. Immature stages of *Platynothrus peltifer* and *Platynothrus* sp. could not be separated and their combined densities ranged from 21.7 to 57.8. Specimens occurred predominantly in the upper 5 cm subsamples. Abundance was generally higher in FE sites than in FD sites. *Platynothrus* sp. adults were consistently

abundant in lower deciduous leaf microhabitat samples, but also occurred in other microhabitat samples.

**22. *Malaconothrus* sp.**

Determined using Balogh and Mahunka (1983) and Aoki (1969)

Both adult and immature *Malaconothrus* sp. occurred in low numbers (0.1 to 4.2) in soil samples from all FD and FE sites. Specimens occurred in both upper and lower 5 cm subsamples but were found primarily in the upper layer. Adults were also collected in low numbers from tree hole and deciduous leaf microhabitat samples.

***Nanhermannia bryophila*** (species to be described by Norton and Behan-Pelletier)

Determined using Balogh and Mahunka (1983) and personal communication with Dr. V. Behan-Pelletier.

Distribution: New Newfoundland record

Both adult and immature specimens occurred in moderate numbers (5.4 to 33.9) in the FD and FE soil samples, primarily in the upper subsamples. Specimens also occurred in several microhabitat samples. Adults and immatures occurred in consistently high numbers in the lower compacted layer of deciduous leaves and adults regularly occurred in tree hole samples.

Numbers of adults and immatures decreased from June to July 1993 and increased in August 1993 in the upper subsamples (Figure 52). In the lower subsamples, immatures

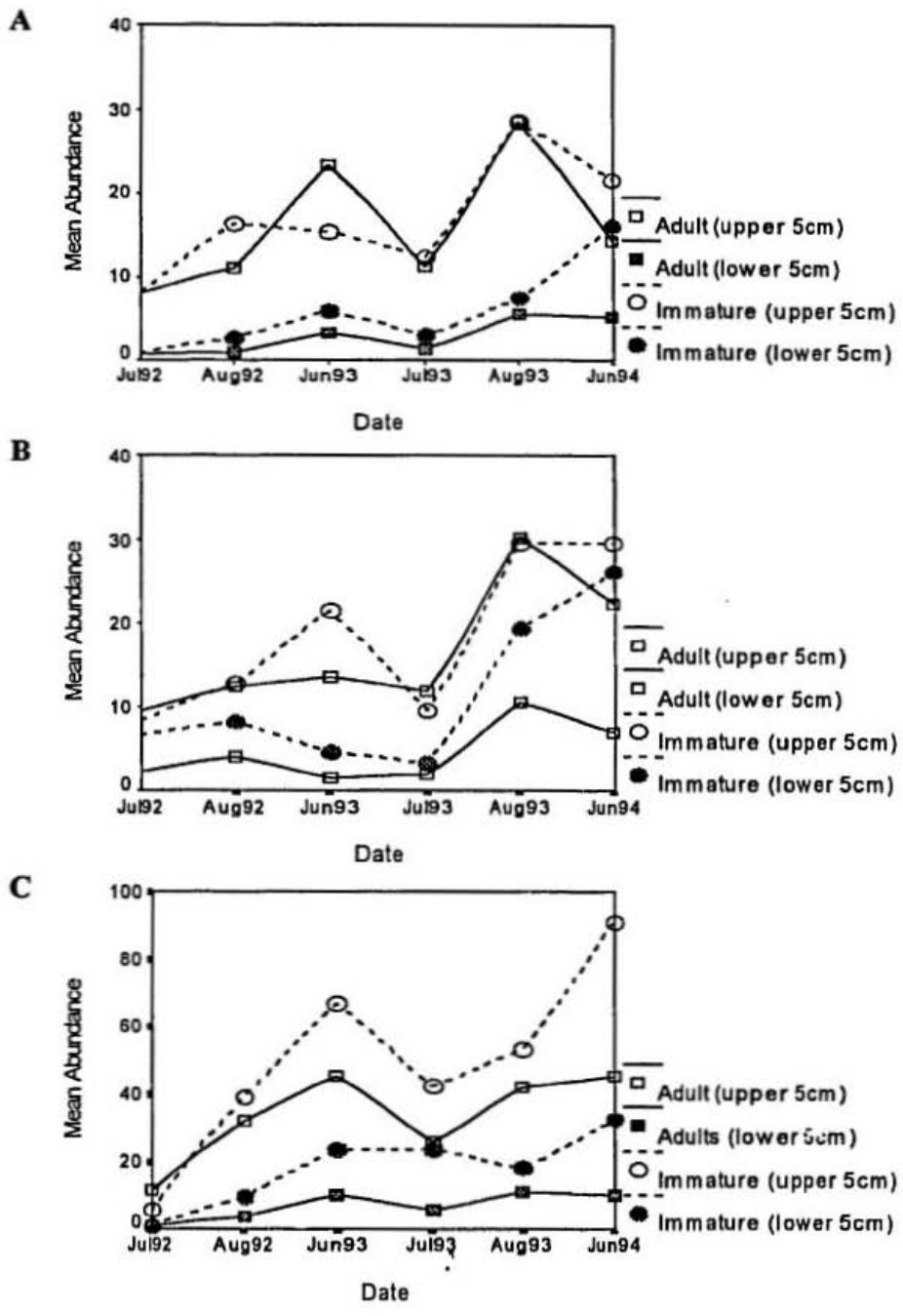



**Figure 52: Seasonal and vertical distribution of *Nanhermannia bryophila* in upper and lower 5 cm soil subsamples from FDO (A), FD60 (B) and FD40 (C).**

were more abundant than adults and displayed a similar distribution pattern to the upper subsamples.

***Hermanniella* sp.**

Determined using Balogh and Mahunka (1983)

Taxonomic Notes: Specimens resemble the description of *Hermanniella subnigra* (Ewing, 1909) but as no figures or comparative specimens were available and because the description is vague, definite identification was not possible.

Distribution: New Newfoundland record

Specimens occurred in low numbers (0.1 to 0.8), predominantly in the upper 5 cm soil subsamples, in all sites. Abundance was relatively higher in FD sites than in FE sites. It also occurred in most microhabitat samples.

***Gymnodamaeus* sp.**

Determined using Norton (1992b)

Taxonomic Notes: Identification is not positive as the only specimen found was damaged.

***Epidamaeus longitarsalis*** (Hammer, 1952)

Determined using Noorton (1992b) and Hammer (1952)

Distribution: Holarctic; new Newfoundland record

Adult and immature *E. longitarsalis* occurred rarely (0.01 to 0.03) in upper 5 cm

soil subsamples and in microhabitat samples from only the FDO sites. The FDO microhabitat samples in which specimens occurred included tree hole, upper deciduous leaf layer and moss from a dead tree.

***Epidamaeus* sp.**

Determined using Balogh (1963)

One specimen of *Epidamaeus* sp. occurred in soil samples of both FD60 and FD40 and rarely in the FDO microhabitat samples including tree hole, upper deciduous leaf layer and moss from a dead tree.

***Cepheus corae*** Jacot, 1928

Determined using Norton (1992b) Hammer (1955)

Distribution: Nearctic

Adult and immature *C. corae* occurred in low numbers (0.01 to 1.6), predominantly in the upper 5 cm soil subsamples, from most FD and FE sites. They also occurred in most microhabitat samples except on tree bark.

***Eupterotegaeus* sp.**

Determined using Norton (1992b) and Balogh (1963)

Taxonomic Notes: Similar to *Eupterotegaeus dentatus* however, fovea are larger and lamellae are more shoe-shaped and larger.

Specimens occurred in low numbers (0.01 to 0.02), predominantly in the upper 5 cm soil subsamples from both FDO and FD40, but no specimens were collected from microhabitat samples.

***Podopterotegaeus tectus*** Aoki, 1969

Determined using Norton (1992b) and Aoki (1969)

Distribution: New Newfoundland record

Specimens occurred rarely (0.03 to 0.3) in soil samples from all FD sites and most FE sites. Specimens tended to be most abundant in lower 5 cm subsamples. They were also collected from tree hole and rotten wood samples.

***Eueremaeus marshalli*** Behan-Pelletier, 1993

Determined using Behan-Pelletier (1993)

Distribution: Nearctic; new Newfoundland record

Individuals of *E. marshalli* occurred in low numbers in only tree-related microhabitat samples including: rotten wood, bark from live and dead trees, lichen covered branches from trees and moss from live and dead trees. These findings concurred with previous habitat accounts by Behan-Pelletier (1993) who examined specimens from lichen, bark and moss habitats.

***Hafenferrefia nitidula*** (Banks, 1906)

Determined using Banks (1906)

Distribution: Nearctic; new Newfoundland record

Specimens occurred rarely (0.01 - 0.06) in soil samples, primarily in the upper 5 cm subsamples, from most FD and FE60 sites as well as in microhabitat samples from the soil surface.

***Adoristes* sp.**

Determined using Balogh (1963)

Individuals of *Adoristes* sp. occurred in moderate numbers (1 to 10), primarily in the upper 5 cm soil subsamples, from all FD and FE sites with highest abundance in FD sites. They also occurred in the all microhabitat samples and were consistently abundant in deciduous leaf samples.

***Dorycranosus* sp.**

Determined using Norton (1992b) and Gilyarov (1975)

Distribution: New Newfoundland record

One specimen was collected in the upper 5 cm soil subsamples of each of FD60 and FD40. Individuals were collected from several tree-related microhabitat samples: rotten wood, bark from live tree, lichen covered branches from ground, and moss from live tree samples.

***Cultroribula bicultrata*** (Berlese, 1905)

Determined using Gilyarov (1975)

Distribution: Holarctic; new Newfoundland record

Specimens of *C. bicultrata* occurred rarely (0.01 to 0.2) in soil samples from all FD sites and on one sampling occasion in each of FEO and FE40. Specimens occurred primarily in the upper 5 cm subsamples in FDO, in the lower 5 cm subsamples in FD60 and throughout the samples in FD40. Specimens also occurred in rotten wood and tree hole microhabitats, correspondimg to other habitat data for rotting Douglas fir that had reached the mycorrhizal invasion stage of decay where *C. bicultrata* was one of the dominant species (Seastedt, Reddy and Cline 1989).

***Ceratoppia bipilis*** (Hermann, 1804)

Determined using Norton (1992b) and Gilyarov (1975)

Distribution: Holarctic

Specimens occurred rarely (0.01 to 0.1) in soil samples, primarily in the upper 5 cm subsamples. Specimens were not found in any microhabitats.

***Ceratoppia quadridentata arctica*** Hammer, 1955

Determined using Norton (1992b) and Hammer (1955)

Distribution: Holarctic; new Newfoundland record

Specimens occurred rarely (0.01 to 0.5), primarily in the upper 5 cm soil

subsamples, in most FD and FEO sites. It also occurred in several ground level microhabitat samples.

***Parapyroppia* sp.**

Determined using Norton (1992b)

Distribution: New Newfoundland record

Individuals of *Parapyroppia* sp. occurred in low numbers (0.04 to 3), primarily in upper 5 cm soil subsamples, in all FD and FE sites. Specimens occurred in several diverse microhabitats including rotten wood, deciduous leaf and moss from live trees.

***Pyroppia* sp. a**

Determined using Norton (1992b) and Gilyarov (1975)

Distribution: New Newfoundland record

Individuals of *Pyroppia* sp. a occurred in low numbers (0.01 to 1.1), primarily in the upper 5 cm soil subsamples, from all FD and most FE sites. It was also collected in several microhabitat samples.

***Pyroppia* sp. b**

Determined using Norton (1992b) and Gilyarov (1975)

Taxonomic Notes: *Pyroppia* sp. b was larger than *Pyroppia* sp. a

Specimens occurred rarely (0.01 to 0.1) in soil samples from most sites. It did not

occur in any microhabitat samples.

***Carabodes labyrinthicus*** (Michael, 1879)

Determined using Reeves (1992)

Distribution: Holarctic

Specimens of *C. labyrinthicus* occurred rarely (0.01 to 0.2), primarily in the upper 5 cm soil subsamples, in all FD and most FE sites. It was also collected in all microhabitat samples except the lower layer of deciduous leaves.

***Tectocepheus velatus*** (Michael, 1880)

Determined using Gilyarov (1975)

Distribution: Cosmopolitan

Both adult and immature *T. velatus* occurred in moderate numbers (1.6 to 26.5) in soil samples from all FD and FE sites. Adults and immatures were most abundant in upper 5 cm subsamples in FD. However, immatures occurred primarily in the lower 5 cm subsamples of FE. Abundance tended to be higher in the FD sites than in FE. They also occurred in most microhabitat samples and were consistently abundant in moss samples from live trees. These findings correspond to Aoki's (1971) description of this species as a 'wandering form' that occurs on live trees in addition to litter and soil.

***Tectocepheus* sp.**

Determined using Norton (1992b)

Taxonomic Notes: Probably a larger version of *Tectocepheus velatus*

Specimens occured in soil samples from all FE sites and most FD sites, primarily in the upper subsamples. Abundance was much higher in FE sites

***Cosmoppia ornata*** (Oudemans, 1900)

Determined using Norton (1992b) and Gilyarov (1975)

Distribution: Holarctic; new Newfoundland record

Specimens occurred in moderate numbers (0.1 to 9.9), primarily in upper 5 cm soil subsamples, in all FD and most FE sites. Abundance was much higher in FD than FE sites. It also occurred in most microhabitats, except lichen samples.

***Moritzoppia* sp.**

Determined using Subias and Balogh (1989)

Taxonomic Notes: Similar to *Moritzoppia clavigera* (Hammer, 1952), except the sensillus is slightly more fusiform and lamellar hairs are separated from the lamellae.

Distribution: New Newfoundland record

Individuals of *Moritzoppia* sp. were rare (0.01), and occurred primarily in the upper 5 cm soil subsamples from FDO and FD40. It did not occur in any microhabitat samples.

***Oppia nitens*** C.L. Koch, 1835

Determined using Norton (1992b) and Gilyarov (1975)

Distribution: Holarctic; new Newfoundland record

Specimens of *O. nitens* occurred rarely (0.02 to 2.62) in soil samples, predominantly the upper 5 cm subsamples, from regrowth sites. It was also collected in most microhabitats.

***Oppiella washburni*** (Hammer, 1952)

Determined using Hammer (1952)

Distribution: Nearctic; new Newfoundland record

*Oppiella washburni* was one of the most abundant (51.6 to 126.1) species in soil samples from all study sites and in all microhabitats. Abundance was highest in the upper 5 cm soil subsamples.

***Quadroppia* sp.**

Determined using Norton (1992b) and Balogh (1963)

Taxonomic Notes: Similar to *Quadroppia skookumchucki* (Jacot, 1939), however prodorsal lamellae differ slightly, notogasteral setae are longer and body is slightly smaller.

Distribution: New Newfoundland record

Individuals of *Quadroppia* sp. were moderately abundant (5.3 to 12.9), primarily in the upper 5 cm soil subsamples, in all sites, particularly FD. It was also collected in

most microhabitat samples except bark and lichen covered branches from the ground.

***Ramusella manifera*** (Hammer, 1955)

Determined using Norton (1992b) and Hammer (1955)

Distribution: Holarctic; new Newfoundland record

Two specimens of *R. manifera* were collected in the lower 5 cm soil subsamples from FD40.

***Subiasella* sp.**

Determined using Subias and Balogh (1989)

Distribution: New Newfoundland record

Individuals of *Subiasella* sp. were collected on two occasions in upper 5 cm soil subsamples from FD40.

***Allosuctobelba* sp.**

Determined using Gilyarov (1975)

Distribution: New Newfoundland record

One and two specimens of *Allosuctobelba* sp. were collected in upper 5 cm soil subsamples from FE60 and FDO, respectively. Specimens were also collected in dead tree moss microhabitat samples.

***Suctobelbella* spp.**

Determined using Gilyarov (1973)

Taxonomic Notes: Due to their small size and difficulty in identification and counting, all *Suctobelbella* species were placed together under *Suctobelbella* spp.. At least three species were present including a new Newfoundland species record, *Suctobelbella longicuspis* (Jacot, 1937).

Specimens of *Suctobelbella* spp. were among the most common (9.5 to 47.8) species, primarily in upper 5 cm soil subsamples, in all FD and FE sites. Specimens were more abundant in FD sites than in FE sites. They occurred in all microhabitat samples except lichen-covered branches from the ground.

***Autogneta longilamellata*** (Michael, 1885)

Determined using Gilyarov (1975)

Distribution: Holarctic

Specimens occurred rarely (0.01 to 0.07), primarily in upper 5 cm soil subsamples, in most FD and FE sites. It was also collected in rotten wood and bark from dead trees.

***Conchogneta traegardhi*** (Forsslund, 1947)

Determined using Gilyarov (1975)

Distribution: Holarctic; new Newfoundland record

Individuals of *C. traegardhi* occurred rarely (0.01 to 0.9), primarily in upper 5 cm

soil subsamples, in most FD and FE sites. It also occurred in tree holes, moss from dead tree and the upper layer of deciduous leaves.

***Eremobodes* sp.**

Determined using Balogh (1963)

Six specimens of *Eremobodes* sp. were collected in soil samples from FDO only.

***Banksinoma lanceolata canadensis*** Fujikawa, 1979

Determined using Norton (1992b) and Fujikawa (1979)

Distribution: Nearctic; new Newfoundland record

Specimens were moderately abundant (0.2 to 5.6), primarily in upper 5 cm soil subsamples, in all FD and FE sites, but more abundant in the former. Individuals occurred in most microhabitat samples except those from lichen and moss from live trees.

***Dometorina plantivaga*** (Berlese, 1895)

Determined using Willmann (1931)

Distribution: Nearctic, Neotropical; new Newfoundland record

Specimens of *D. plantivaga* were collected rarely (0.01 to 0.08) in upper 5 cm soil subsamples from most FD and FE sites. It was also collected from rotten wood, dead tree bark and moss from dead trees. Specimens also occurred in the upper layer of deciduous litter.

***Liebstadia similis*** (Michael, 1888)

Determined using Norton (1992b) and Gilyarov (1973)

Distribution: Cosmopolitan; new Newfoundland record

Specimens occurred rarely (0.01 to 0.6), primarily in upper 5 cm soil subsamples, in most FD and FE sites. It was most abundant in FE sites. Specimens also occurred in several microhabitat samples and were particularly abundant in rotten wood samples. Unlike the other *Liebstadia* species, *Liebstadia similis* occurred in the tree hole samples and was not collected from lichen-covered branches from trees.

***Liebstadia* sp. a**

Determined using Norton (1992b) and Willmann (1931)

Taxonomic Notes: Though specimens keyed to *Liebstadia* it is uncertain if they belong to this genus. Specimens are characterized by $ad_1$ setae thickened throughout their length, being longer and thicker than $ad_2$ and $ad_3$ and longer in males than in females. The male also has a circumventral porose area.

Individuals of *Liebstadia* sp. a occurred rarely (0.01 to 0.2), primarily in upper 5 cm soil subsamples, in all study sites but were most abundant in FD sites. Specimens occurred in several FDO microhabitat samples and unlike *Liebstadia* sp. b, specimens occurred in live tree bark samples.

***Liebstadia* sp. b**

Determined using Norton (1992b) and Willmann (1931)

Individuals occurred rarely (0.03 to 0.2), primarily in upper 5 cm soil subsamples, in all FD and some FE sites with the highest abundance occurring in the FD sites. It was also collected from a variety of tree-related microhabitats,but unlike *Liebstadia* sp. a, specimens occurred in dead tree bark and lichen covered branches from the ground.

***Paraleius* sp.**

Determined using Balogh (1963)

Distribution: New Newfoundland record

One specimen of *Paraleius* sp. was collected in upper 5 cm soil subsamples from FD60.

***Scheloribates* sp.**

Determined using Norton (1992b)

Specimens occurred in moderate numbers (1.1 to 8.5), primarily in upper 5 cm soil subsamples, in all study sites. It also occurred in most microhabitat samples except lichen and upper deciduous leaf samples.

***Phauloppia* sp.**

Determined using Balogh (1972)

Distribution: New Newfoundland record

Individuals occurred on one sampling occasion in each of FDO and FD60 sites in the upper 5 cm soil subsamples. A few specimens were collected in moss samples from dead and live trees.

***Zygoribatula bulanovae*** Kulijew, 1961

Determined using Norton (1992b) and Gilyarov (1973)

Distribution: Holarctic; new Newfoundland record

Specimens occurred rarely (0.02 to 0.1), primarily in upper 5 cm soil subsamples, in all FD and FE sites. It occurred in all microhabitat samples except lichen covered branches from the ground and the lower layer of deciduous leaves.

***Haplozetes* sp.**

Determined using Balogh (1963)

Distribution: New Canadian genus record

Four *Haplozetes* sp. specimens were collected in soil samples from FEO.

***Xylobates* sp.**

Determined using Norton (1992b) and Gilyarov (1975)

Distribution: New Newfoundland record

Specimens occurred in low numbers (0.04 to 3.3), primarily in upper 5 cm soil

subsamples, in all study sites. They were also collected in a variety of microhabitats including rotten wood, tree hole, moss from live and dead trees and lower deciduous leaves samples.

***Neoribates aurantiacus*** (Oudemans, 1914)

Determined using Willmann (1931)

Distribution: Holarctic

One specimen of *N. aurantiacus* was collected in an upper 5 cm soil subsamples from FE40.

***Chamobates cuspidatus*** (Michael, 1884)

Determined using Norton (1992b) and Gilyarov (1973)

Distribution: Holarctic; new Newfoundland record

Specimens occurred rarely (0.03 to 0.6), primarily in upper 5 cm soil subsamples, in most FD and FE sites. It also occurred in several microhabitat samples including dead bark and lichen covered branches collected from trees, supporting Luxton's (1981) description of the species as semi-arboreal.

***Ceratozetes cuspidatus*** Jacot, 1939

Determined using Norton (1992b) and Behan-Pelletier (1984)

Distribution: Nearctic

Specimens of *C. cuspidatus* occurred in low numbers (0.4 to 3.5) in soil samples from all FD and FE sites and were distributed evenly throughout the upper and lower 5 cm subsamples. It occurred in a variety of microhabitat samples except those from lichen and tree bark. These findings concur with habitat accounts by Behan-Pelletier (1984) who examined specimens from rotting wood, conifer litter, moss and mixed deciduous-fern litter.

***Ceratozetes gracilis*** (Michael, 1884)

Determined using Norton (1992b) and Behan-Pelletier (1984)

Distribution: Cosmopolitan

Specimens occurred in low numbers (0.1 to 3.1), primarily in upper 5 cm soil subsamples, only in FE sites. It was not found in any microhabitat samples. The restriction of *C. gracilis* to FE sites may indicate a preference for moister conditions.

***Ceratozetes thienemanni*** Willmann, 1943

Determined using Norton (1992b) and Behan-Pelletier (1984)

Distribution: Holarctic, Neotropical

Individuals of *C. thienemanni* occurred in low to moderate numbers (0.7 to 9.6), primarily in lower 5 cm soil subsamples, in FD and FE sites. It was also collected in various FDO and FD40 microhabitat samples. Unlike *C. cuspidatus*, specimens occurred in all lichen samples. According to Behan-Pelletier (1984), these mites prefer moist

conditions that may account for their predominance in the lower subsamples.

***Fuscozetes setosus*** (C.L. Koch, 1839)

Determined using Norton (1992b) and Gilyarov (1973)

Distribution: Holarctic; new Newfoundland record

Specimens occurred in very low numbers (0.02), primarily in upper 5 cm soil subsamples, in FD40. It also occurred in moss samples from live and dead trees.

***Neogymnobates luteus*** (Hammer, 1955)

Determined using Hammer (1955)

Distribution: Nearctic; new Newfoundland record

Specimens occurred in low numbers (0.01 to 2), primarily in upper 5 cm soil subsamples, in all study sites with the highest abundance occurring in FE sites. It was also collected in all microhabitat samples except lichen covered branches from the ground.

***Sphaerozetes arcticus*** Hammer, 1952

Determined using Hammer (1952)

Distribution: Holarctic; new Newfoundland record

Specimens of *S. arcticus* occurred rarely (0.01 to 0.4), primarily in upper 5 cm soil subsamples, in FE sites only.

***Trichoribates* spp.**

Determined using Gilyarov (1975)

Taxonomic Notes: Due to difficulty in separating individual species, *Trichoribates* species were combined under *Trichoribates* spp. and includes at least three different species.

Distribution: New Newfoundland record

Individuals occurred rarely (0.2 to 0.5), primarily in upper 5 cm soil subsamples, in FD and FE sites and in all microhabitat samples, except bark from live trees.

***Mycobates incurvatus*** Hammer, 1952

Determined using Norton (1992b) and Hammer (1952)

Distribution: Nearctic

Individuals of *M. incurvatus* occurred rarely (0.01 to 0.1) in upper 5 cm soil subsamples from FE. One specimen was recovered from a moss sample from dead wood in FD60.

***Eupelops* sp.**

Determined using Balogh (1963)

Taxonomic Notes: Specimens could not be associated with any of the species listed by Marshall, Reeves and Norton (1987).

Individuals occurred rarely (0.3 to 0.7), primarily in upper 5 cm soil subsamples, in FE sites only.

***Propelops canadensis*** (Hammer, 1952)

Determined using Norton (1992b) and Hammer (1952)

Distribution: Holarctic; new Newfoundland record

Specimens of *P. canadensis* occurred in low numbers (0.1 to 1.4), primarily in upper 5 cm soil subsamples, in only FE sites.

***Oribatella* spp.**

Determined using Norton (1992b) and Balogh (1963)

Taxonomic Notes: Two species differing significantly in size were combined under *Oribatella* spp..

Distribution: New Newfoundland record

Specimens occurred rarely (0.01 to 0.1), primarily in upper 5 cm soil subsamples, in FD and FE sites. They were also present in a variety of microhabitat samples including rotten wood, tree holes, bark and moss from live trees.

***Lepidozetes singularis*** Berlese, 1910

Determined using Norton (1992b) and Gilyarov (1973)

Distribution: Holarctic; new Newfoundland record

One specimen of *L. singularis* was collected from an upper 5 cm soil subsample from FE60.

***Anachipteria* sp.**

Determined using Balogh (1963)

Distribution: New Newfoundland record

Individuals of *Anachipteria* sp. occurred in low numbers (0.01 to 2.4), primarily in upper 5 cm soil subsamples, in FD regrowth and FE sites. Abundance was higher in FE sites. It was not collected in any microhabitat samples.

***Dentachipteria highlandensis*** Nevin, 1974

Determined using Norton (1992b) and Nevin (1974)

Distribution: Nearctic; new Newfoundland record

Specimens occurred rarely (0.04 to 0.4), primarily in upper 5 cm soil subsamples, in FD and FE regrowth sites. Abundance was higher in FD sites. It was also collected in a variety of microhabitat samples. Unlike *Dentachipteria* sp., specimens were collected from rotten wood and tree hole samples.

***Dentachipteria* sp.**

Determined using Norton (1992b) and Nevin (1974)

Taxonomic Notes: This is a much larger species than *Dentachipteria highlandensis* Nevin, 1974.

Individuals of *Dentachipteria* sp. occurred rarely (0.1) in soil samples and moss samples from live trees in FD regrowth sites.

***Parachipteria travei*** Nevin, 1977

Determined using Norton (1992b) and Nevin (1977)

Distribution: Nearctic

Specimens of *P. travei* were among the most abundant (7.2 to 81.7) mites collected. Both adults and immatures occurred in high numbers in soil samples from FD and FE but were most abundant in FD sites. Density was consistently high in lichen covered branches from ground, upper and lower layers of deciduous leaves and moss from live and dead trees. Individuals were also collected, in lower numbers, from several other microhabitat samples.

In all three FD age classes, numbers of immatures were high in June 1993, decreased in July 1993 and increased in August 1993 (Figure 53); adult populations did not show similar fluctuations. Both adults and immatures were concentrated in the upper 5 cm soil subsamples.

***Pilogalumna* sp.**

Determined using Norton (1992b) and Balogh (1963)

Distribution: New Newfoundland record

Specimens occurred rarely (0.01 to 0.4), primarily in upper 5 cm soil subsamples, in FD40, FEO and FE40 sites and were more abundant in the FE sites. They did not occur in any microhabitat samples.

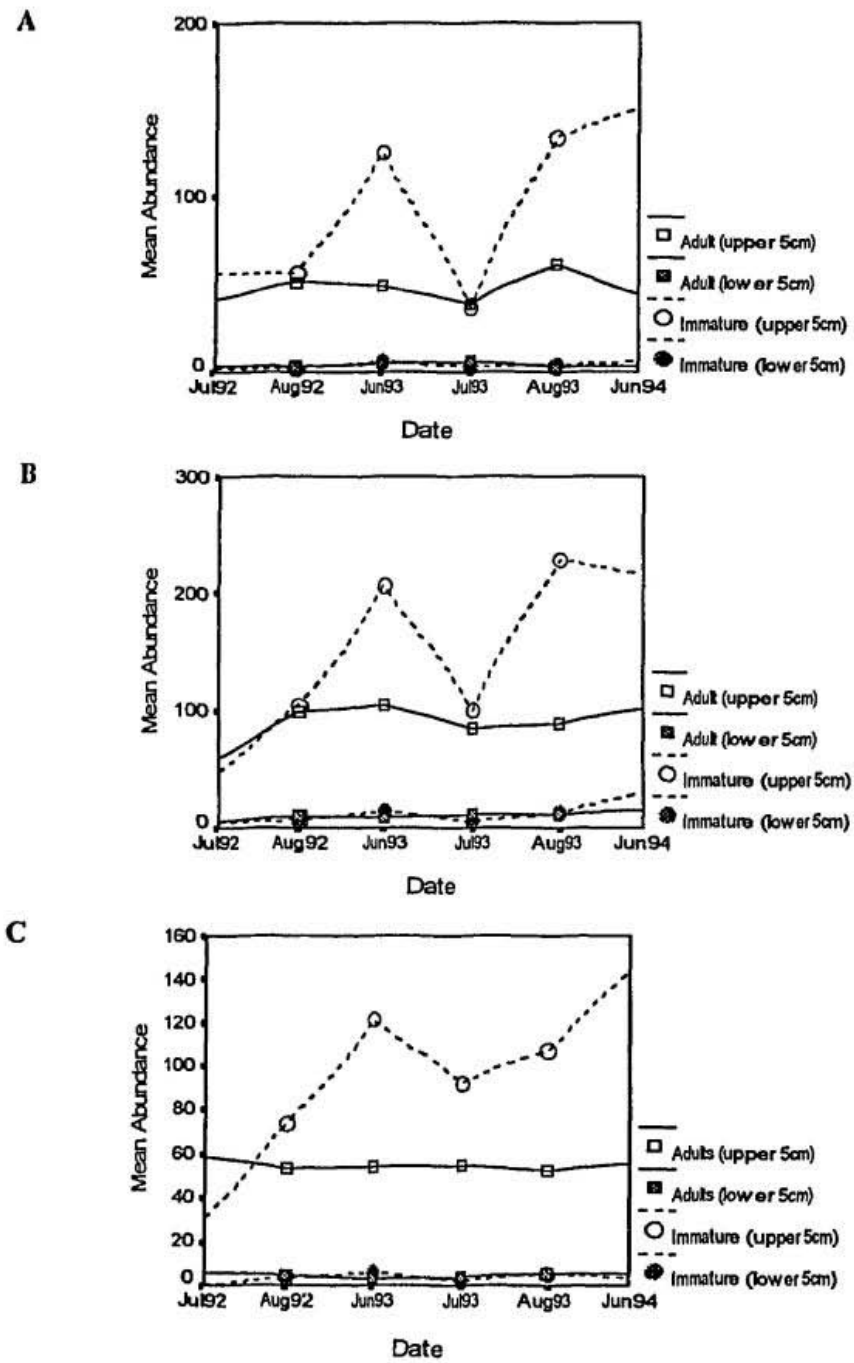



**Figure 53: Seasonal and vertical distribution of *Parachipteria travei* in upper and lower 5 cm soil subsamples from FDO (A), FD60 (B) and FD40 (C).**

# 4.0 DISCUSSION

## 4.1 Soil Description

The two forest types examined in the study were characterized by different soil groups, podzol (balsam fir-*Dryopteris*) and gleysol (balsam fir-*Equisetum*), defined by differing moisture and soil horizon parameters. Podzolic soils are usually found under forest vegetation in humid areas and are strongly acidic. Balsam fir - *Dryopteris* sites were classified as orthic humo-ferric or orthic ferro-humic, where the latter contains more organic matter and subsequently higher carbon values in the B horizon (ACECSS, 1987). The FDO sites were classified as orthic ferro-humic because of the relatively high carbon values, likely due to a longer time period allowing organic matter build up.

Based on Pearsall (1968), the soil of the FD sites is considered *mor* having a low pH generally below 4.0 and reduced nitrification due to lower bacteria numbers. The microflora of *mor* tends to be dominated by fungi which are more tolerant of acidic conditions than bacteria (Pritchett and Fisher 1987, Pearsall 1968).

The PCA analysis of the FD soil data grouped the old sites with one site of each of the sixty and forty year old areas, indicating similarity between the three age classes with respect to soil parameters such as relatively high nitrogen, carbon, potassium, magnesium, phosphorous, calcium and organic matter. The old sites showed the most similarity to one another, supporting their use as site replicates within the old forest stand. However, dissimilarity was evident between the replicate sites in each of the sixty and forty year old regrowth areas. These intersite differences may reflect the range of soil parameters in an

age class due to variation between sites in factors such as decomposition rates, nutrient release and accumulation, slope and drainage. Drainage differences are most likely as both the sixty and forty year old areas contained an upperslope and a lowerslope site. However, of the two sites that did not group on factor one, one was an upperslope site (FD40-3), the other a lowerslope site (FD60-6) and both were associated with high aluminum and iron levels, indicating occasional waterlogging and oxidation at the sites (Pearsall 1968).

Although soil parameter values differed between the three age classes of FD forest, no differences were significant. However, the pattern of differences are similar to some nutrient trends reported by Page (1974) in balsam fir and spruce stands of differing regeneration ages. These trends included increasing thickness of L, F and H soil layers as forest matured; higher pH in younger sites; decreased phosphorous after clearcutting followed by a gradual return to original levels; and decreased sodium levels after clearcut which increased in the new stand then subsequently decreased.

Variation in soil parameters in different aged forest stands can be partially explained in terms of forest stand succession and its effects on the soil environment. As a forest matures, there is a gradual build up of organic matter resulting in consistently higher percent organic matter and carbon values of the older FD forest stands. Gholz and Fisher (1982) reported that reaccumulation of the forest floor in other conifer stands after clearcutting took up to 35 years.

Balsam fir - *Equisetum* gleysol soil, which is continuously or intermittently

saturated with water, differs from FD podzol in terms of soil composition and nutrient levels. Unfortunately, due to time constraints, soil analysis for the FE sites was not available. However, Bhure and Page (1971) noted that gleysols of central Newfoundland contained higher levels of phosphorous and calcium and had a lower acidity than the podzols. According to Pearsall (1968), the FE soil could be similar to *mull*, a soil type typically associated with fertile forests. This fertility was reflected in the large diversity of plant species at the FE sites. Typically, *mull* soil is less acidic than *mor*, consequently containing a higher number of bacteria and supporting nitrification (Pritchett and Fisher 1987).

### 4.2 Vegetation Description

Variations in vegetation features (Thompson, 1994) between study areas were probably related to differences in age and succession. Early stages of natural forest regeneration are characterized by high tree density that gradually decreases as the stand matures, opening up the canopy and allowing more light to penetrate to the forest floor promoting ground vegetation (Page 1974). This process was reflected in the FD site data as FDO sites had the lowest stand density and highest number of fallen logs with significantly greater diameters than the other areas. Herbaceous plants were at lowest density in the sixty year old forest stand, possibly in response toighter canopy, and higher density in the mature, open canopied FDO sites. The old sites were further characterized by significantly higher feathermoss and sphagnum cover and a smaller deciduous component, all of which may affect soil communities.

The PCA showed only slight grouping of the replicate sites of each forest age which suggests that the regrowth sites possessed a range of conditions, some similar to those of a mature forest stand. Discriminant function analysis, however, clearly separated the FDO sites from the two regrowth stands based on forest age related characters such as fallen logs, log diameter, herbaceous plants and shrub diversity. The greatest similarity occurred between the replicate sites of the forty year old forest stand whereas the sixty year old sites showed the highest dissimilarity. Overall, the consistent proximity of old sites on both soil and vegetation graphs may relate to similar slope and drainage at the sites or to the possibility that both have reached a similar climax level of development.

Differences between the two FD60 and the two FD40 sites may reflect different slope and drainage effects as the replicate sites of both regrowth areas included an upper slope and a lower slope site. Regeneration of sites within each of FD60 and FD40 areas may also be progressing at different successional rates for some site specific reasons.

### 4.3 Sampling and Extraction Efficiency

The cumulative number of species in a series of samples from both the FD and FE sites tended to reach an asymtope at about ten soil samples indicating the number of samples was generally adequate to recover the majority of the soil oribatid species. It is important to note, however, that soil samples were standardized in that the surface vegetation was restricted to feathermoss. Some habitat-specific species may have been missed as a result. This number may be small, however, as most of the species occurring in the microhabitat samples also occurred in the soil samples and only one species was

unique to the microhabitat samples.

The actual efficiency of the Berlese extraction apparatus is unknown, though it is assumed to be similar to that of other studies since oribatid species diversity and abundance values are comparable to those of other studies (Table 27). It is possible, that loss of species and abundance may have occurred due to behavioural responses in which some species may aestivate in response to drying conditions, thereby decreasing the efficiency of passive extraction. Other species may have been susceptible to dry conditions and died before reaching the funnel. However, the same apparatus was used for all sample extractions of the study, therefore any inefficiencies of the apparatus and/or techniques were consistent for all samples and should not affect between site comparisons.

The deterrent effects of various collection fluids was minimal as no significant differences were detected between total oribatid abundance and diversity collected in water, 70% ethanol and 50:50 Kahle's solution and 70% ethanol.

### 4.3 Study Design

. This study attempted to assess the recovery of oribatid mite populations in forty and sixty year old post-harvest balsam fir forests. Due to time restrictions, comparisons could not be made on the same site over a forty or sixty year time span. Thus, different aged forest stands with similar soil and vegetation were chosen from the same general locality in western Newfoundland. Variation in these characters among the sites is attributed to individual site differences and effects of forest succession in the regenerating forest sites. This may explain some of the variation in oribatid mite population structure

**Table 27: Comparison of oribatid mite density and diversity collected from balsam fir (*Abies balsamea*) - fern (*Dryopteris*) and balsam fir - horsetail (*Equisetum*) forest with those of other studies.**

| Habitat | Oribatid Density | | Species Number | Author |
|---|---|---|---|---|
| | per $m^2$ | per $cm^3$ | | |
| Pine litter<br>Oak Ridge Area, Tennessee | 22, 050 | NA | 60 | Crossley, D. and K. Bohnsack 1960 |
| Spruce mor | 517, 000 | 7 | 40 | Behan, V. (Unpub.) 1971 |
| Hardwood (Oak, Hickory) - Pine/Hardwood watershed North Carolina | 53,800 - 82,600 | NA | 52 | Abbott, D.T. et al 1980<br>Seastedt, T. and Crossley, 1981 |
| Mixed deciduous forest<br>Switzerland | 1135 - 34,679 | NA | 65 | Schenker, R. 1984 |
| Mixed coniferous - hardwood forest<br>Ontario, Canada | ~60,000 | .6 | NA | Bird and Chatarpaul 1986 |
| Pine forest (*Pinus* var *austriaca* (A. Et G.))<br>Netherlands | 48,950<br>(70 years old)<br>42,380<br>(35 years old) | NA | NA | Teuben, T. and Smidt, G.R.B. 1992 |
| Scots Pine (*Pinus sylvestus*)<br>Netherlands | 3000 - 100,000 | NA | NA | Hogervorst, R.F. et al 1993 |
| Balsam fir (*Abies balsamea*) - fern (*Dryopteris*) - mor | 34,390 - 107,000 (1992)<br>79,140 - 168,100 (1993)<br>85,000 - 189,400 (1994) | .3 - 1.1<br>.8 - 1.7<br>.9 - 1.9 | 43 - 53<br>49 - 55<br>40 - 53 | Dwyer, E. (present study) |
| Balsam fir (*Abies balsamea*) - horsetail (*Equisetum*) - mull-like | 50,120 - 88,610 (1994) | .5 - .9 | 52 - 60 | Dwyer, E. (present study) |

among the sites. It is assumed that conditions, including faunal composition, were similar among the three forest age classes in the FD and FE forest types prior to harvesting.

### 4.5 Oribatid Fauna

#### 4.5.1 Distribution Among Habitats

Oribatid mite distribution is a function of the abiotic and biotic suitability of the surrounding habitat and includes such factors as moisture conditions and plant cover (Anderson 1977). Species differ in their ability to tolerate variations in environmental factors including moisture, pH and organic content and this will undoubtedly determine their horizontal distribution (Wallwork 1970). Distribution may also be a function of geological history as emergence of land in response to the retreat of the Wisconsin glaciers from Newfoundland and Labrador provided land surface for colonization by both plants and animals (Macpherson, 1981).

#### 4.5.2 Oribatid Diversity

A relatively diverse oribatid mite population occurred in the balsam fir forests of western Newfoundland with a total of 91 species recovered from soil and microhabitat samples. This number is comparable to other studies that reported species numbers of 94 for moder beech wood in southwest Germany (Beck and Woas 1991), 65 in mixed deciduous mull and moder of Switzerland (Schenker 1986), 52 in a pine/hardwood watershed of North Carolina (Abbott et al. 1980), 40 in a spruce mor (Behan 1972) and 60 in pine litter of the Oak Ridge area of Tennessee (Crossley and Bohnsack 1960).

Of the 91 species from this study, 17 genera and 35 species were new

Newfoundland records and one genus was a new record for Canada. The microhabitat samples contained 64 species, of which 63 species also occurred in the soil samples, with one species unique to the tree related microhabitat samples. Cluster analysis of species presence/absence data from FD soil and microhabitat samples and FE soil samples showed clear separation of the two forest types and of the soil and microhabitat samples.

#### 4.5.2.1 Microhabitat Samples

The majority of the species from the microhabitat samples were primarily associated with samples taken in proximity to the forest floor, particularly deciduous leaves, tree moss and tree holes. Of the rarer soil species, a few were either of higher abundance or more regular occurrence in certain microhabitats suggesting some habitat specificity due possibly to moisture or feeding preferences. *Camisia biuris* was present in all moss samples from dead and live trees whereas *Palaeacarus hystricinus* and *Podopterotegaeus velatus* occurred in all tree hole samples. The panphytophagous *Platynothrus* species occurred in high numbers in the deciduous leaves samples corresponding with previous feeding accounts of Wallwork (1970). Since the distribution of these species was likely affected by the amount and placement of deciduous litter in the forest sites, standardization of the soil samples (i.e. collection from areas of feathermoss cover free from deciduous litter) may have biased the *Platynothrus* species counts.

Due to the habitat specificity of some oribatid species, several were undoubtedly missed in the soil samples. This was clear in the collection of *Eueremaeus marshalli* which occurred only in the tree-associated microhabitat samples. This habitat preference

agreed with previous habitat accounts for this species (Behan-Pelletier 1993). Since one additional species occurred only in the microhabitat samples, it is assumed that most of the species diversity was covered in the soil samples.

#### 4.5.2.2 Soil Samples

Species abundances curves for the soil samples from FD and FE indicated that for all three forest age classes, the oribatid population was composed primarily of a few common species with the majority of species occurring in small numbers. Anderson (1977, 1978) suggested that high species diversity may be maintained by microhabitat specialization such that potentially competitive species are separated. Thus, the more complex the soil structure, the higher the species diversity. The number of species recovered from any one site ranged from 55-65 in balsam fir - *Dryopteris* and from 51-59 in balsam fir - *Equisetum* sites. The lower species numbers in FE may be due to the more homogeneous soil profile of FE (Figure 12) and the heavier, more compacted soil layers as indicated by the generally higher soil dry weights (Table 9). This would result in fewer air spaces for the non-burrowing oribatids to move through the soil profile and in less microhabitat diversity both of which affect oribatid diversity and abundance.

The majority of the oribatid mite species occurred in both balsam fir - *Dryopteris* and balsam fir - *Equisetum* forest types suggesting that most of the species were eurytypic. However, a small percentage of the species showed preference for one or the other of the two forest types with 14 species (*Euphthiracarus* sp., *Epidamaeus* sp., *Epidamaeus longitarsalis*, *Eupterotegaeus* sp., *Dorycranosus* sp., *Moritzoppia* sp., *Ramusella*

*manifera*, *Subiasella* sp., *Eremobodes* sp., *Paraleius* sp., *Phauloppia* sp., *Peloribates* sp., *Fuscozetes setosus* and *Dentachipteria* sp.) restricted to the balsam fir - *Dryopteris* forest and 11 (*Gozmanyina majestus*, *Gymnodamaeus* sp., *Haplozetes* sp., *Neoribates aurantiacus*, *Ceratozetes gracilis*, *Sphaerozetes arcticus*, *Mycobates incurvatus* *Eupelops* sp., *Propelops canadensis* and *Lepidozetes singularis*) restricted to the balsam fir - *Equisetum* forest.

These species are particularly interesting and may be used to characterize different forest types as they may indicate differences in environmental factors such as litter and soil types, moisture, vegetation and availability of certain food resources. The FD and FE forest types differed in terms of pH and moisture with FD having the lowest values of both. The FE sites apparently experience periodic water saturation which affects the habitat of the mites by altering pH, soil mixing and stratification and the distribution and availability of nutrients in the soil profile. This is reflected in the restriction of *Nothrus palustris*, a species known to prefer habitats with high humidity (Dalenius, 1960), to the moist FE sites. The soil profile of the FE sites lacked a F horizon while L and particularly H layers were relatively deep suggesting a rapid transfer of material from L to H horizons and a fast decomposition rate. A high abundance of easily decomposable, herbaceous plants thriving in the FE sites combined with high moisture levels in the soil may account for this fast decomposition rate.

Availability and type of food resources probably vary between the two forest types in response to differing soil parameters subsequently affecting oribatid population

structure. Acidic conditions in the FD sites may support a more diverse fungi population than the less acidic FE sites. Fungal diversity and abundance are also regulated by moisture conditions which affect the availability of suitable substrates and the ability of a fungus to use it (Dick 1992). In laboratory tests, some mycophagous oribatids will feed voraciously on certain fungi and ignore others even when starved (Hartenstein 1962). Gut content analysis of field-collected specimens has confirmed some of these preferences (Hartenstein, 1962). Laboratory feeding experiments by Mitchell and Parkinson (1976) showed different fungi differed in food suitability between oribatid species although clear correspondence between feeding amount and reproductive success was not evident. They attributed this to the nutritional quality of fungi and/or oribatid mortality due to the enveloping of early developmental stages by certain fungi. Species unique to either the FD or FE forests may rely on certain fungal species supported only in their respective forest type. Also, the wide variety of plant species in the FE sites supply a broad food resource for macrophytophagus mite species such as *Eupelops* sp. and *Nothrus palustris*. *Eupelops* sp was reported by Wallwork (1967) as feeding on green plant material and plant detritus while *Nothrus palustris* has been observed feeding on microbially conditioned leaves (Harding and Stuttard 1974). The restriction of these species to the FE habitat, suggests some feeding preference for a particular plant species as FD and FE habitats differed in several of their plant species.

The differing faunal composition of the FE and FD forest types were clearly reflected in both binary cluster analysis and TWINSPAN. In both, the primary division

separated FD from FE sites. *Ceratozetes gracilis* was one of the indicator species whose presence was unique to the FE sites. Other species, *Adoristes* sp. and *Anachipteria* sp., also served as indicator species due to differing abundance levels in the two forest types. A difference in relative species abundance was also noted in the higher relative abundances of *Platynothrus peltifer, Platynothrus* sp. and *Platynothrus* spp. immatures in the FE habitat. High herbaceous plant diversity and abundance may again explain this observation as some members of the genus *Platynothrus* feed on plant fragments and debris (Wallwork 1967).

Some of the rarer species from FD and FE sites, namely *Euphthiracarus, Eupterotegaeus* sp. and *Ceratoppia bipilis,* were represented by only one specimen. These may have been naturally rare due to some feeding or habitat specificity or perhaps the particular habitat in which they flourish was not sampled. Anderson (1977) suggested that rare species may be competitively excluded by abundant generalist species.

Differences in the species composition of the three FD age classes were reflected in their clear separation in the cluster analysis of species presence and absence data and TWINSPAN. In the FD forest type, most oribatid species were common to all sites but some were restricted to either old or regrowth stands. These included *Epidamaeus longitarsalis, Allosuctobelba* sp. and *Eremobodes* sp. which were restricted to the old forest and *Ceratoppia bipilis, Ramusella manifera, Subiasella* sp., *Paraleius* sp., *Peloribates* sp., *Dentachipteria* sp. and *Pilogalumna* sp. which occurred only in the regrowth stands. The highest number of species occurred in FD40 followed by FDO and

finally FD60. Diversity indices for the upper 5 cm soil samples were highest for the FD40 sites. Indices for the FDO and FD60 sites were similar though those of FD60 were generally lower. Species richness was also lower in FD60 as indicated in the rarefaction graphs. Soil samples from FD60 had a significantly higher dry weight than those of FDO and FD40 and were similar to those of the FE sites. This combined with a consistently large Bf horizon and lack of a Bhf layer suggests a heavier, more compact soil. As in the FE soils, FD60 soils may have had fewer air spaces for oribatid movement and less microhabitat diversity resulting in fewer oribatid species. More abundant herbaceous plants and fallen logs in the forty year old and old forest stands, adding to microhabitat and food diversity, may partially explain these species diversity differences.

Forest age classes of FE did not show as clear a separation in the cluster analysis or TWINSPAN as in FD. In the cluster analysis, the FEO and FE40 sites were clearly separated whereas the FE60 sites were evenly grouped with either FEO or FE40. Thus suggesting that FE60 may be a transitional forest stage between the old and forty year old forests. Higher similarity among the FE age classes as compared to that among FD ages may be due the more similar soil profiles, dry weight and percent moistures among the FE age classes. As in the FD forest, the three FE age classes differed slightly in species composition. Species unique to the old forest included *Gymnodamaeus* sp., *Ceratoppia quadridentata* and *Haplozetes* sp. whereas *Hafenferrefia nitidula*, *Pyroppia* sp. b, *Oppia nitens*, *Allosuctobelba* sp., *Dometorina plantivaga*, *Neoribates aurantiacus* and *Lepidozetes singularis* were unique to the regrowth sites. With the exception of *Oppia*

*nitens*, all of the species unique to the old or regrowth sites were fairly rare. *Oppia nitens* occurred only in the forty year old site with a mean of 3.4 per sample. In the FD forest type, this species was also absent from the old forest stands and had a significantly higher abundance in the forty year old than in the sixty year old stand. This may represent a transitional species that gradually disappears as the forest matures, possibly in response to higher tree density and subsequently closer canopy in the sixty year old sites..

### 4.5.3 Oribatid Density

Oribatid mites are usually the numerically dominant arthropod of forest soils with reported densities ranging up to 425, 000 per $m^2$ (Wallwork 1983). Densities for this study ranged from 34, 390 to 189, 400 mites per $m^2$ in FD and from 50, 120 to 88, 610 in FE which were comparable with other studies (Table 27). According to Seastedt and Crossley (1981) oribatid densities appear to be positively correlated with the amount of undecomposed organic material on the forest floor. A significant correlation between total oribatid distribution and organic matter content was also noted by Schenker (1984). This is further reflected in the tendency toward increased oribatid densities with latitude (Harding and Stuttard 1974). Boreal systems, such as the present study area, have high standing crops of dead organic matter and subsequently high oribatid numbers (Table 27). Also, this correlation may explain the significantly lower oribatid numbers that occurred in FE sites where decomposition was faster, resulting in less standing organic matter than in the FD sites.

With the exception of some of the 1992 FD data, mean oribatid densities were

consistently lower in FE. The overall lower abundances in the moist FE forest type may be due to oribatid preference for environmental condition between wet and dry (Wallwork 1967) and the higher habitat diversity provided by the more stratified litter layers of the FD mor humus (Teuben and Smidt 1992).

**4.5.3.2 FD Sites**

Mites were significantly less abundant in the 1992 samples than those from 1993 and 1994. This may be a result of sampling and extraction techniques as this was the first collection season. The 1992 samples were extracted in a confined room and were subject to more rapid drying than subsequent samples, which may have resulted in higher oribatid mortality within the funnels. On the other hand, lower numbers in 1992 may reflect differences in precipitation levels which were low in June and July 1992 and higher in August. The k-selected nature of the oribatids, reflected in the creation of a stable community, particularly in forest soils (Mitchell 1977), may explain the relatively consistent numbers over 1993 and 1994.

In the FD sites, oribatid mite density varied over a broad range in the sixty and forty year old sites. Densities in the old sites remained fairly constant, although FDO-2 was consistently higher. This may indicate a more stable population in the old stand or it may reflect greater habitat heterogeneity in the regrowth sites. Between the forest age classes, total abundance was similar on all sampling dates indicating that the long term effect of clearcutting on total abundance was minimal.

Though similar oribatid species occurred in sites of all three forest age classes, the

relative abundances of some common species differed between sites possibly reflecting differences in soil, vegetation and moisture in forest stands of different maturity. Vegetation is of particular importance as it affects the amount of light reaching the forest floor, moisture content of soil and food resource availability for specialist oribatid species.

Most of the common species had a similar relative abundance in FDO and FD60, possibly indicating a return to precut oribatid population structure in the sixty year old regeneration sites. However, *Synchthonius cremulatus* was less abundant in FD60 and *Liochthonius lapponicus* occurred only in the old sites. Both of these small mites, belonging to the same family, may have been affected by lower moisture content and higher soil dry weights in FD60.

**4.5.3.2 FE Sites**

Total oribatid abundance was similar among the FE sites with the highest and lowest densities consistently occurring in FE60 and FEO, respectively. The higher numbers in the sixty year old sites may reflect moisture effects on oribatid distribution as the soils of FE60 were less water- logged than the other FE sites. Though oribatid mites prefer moist habitats, too much moisture may be a deterrent.

As in the FD forest, oribatid abundances did not differ significantly among the three age classes of FE forest. Thus , long term recovery of species abundances from clearcutting was similar in the two forest types.

Differences in relative abundances of common species were less pronounced than in the FD forest. In the FE forest, two species, *Eniochthonius minutissimus* and

*Tectocepheus velatus*, were significantly more abundant in the old stand whereas *Parachipteria travei* was significantly more abundant in the sixty year old stand. The remaining common species, *Steganacarus thoreaui*, *Synchthonius crenulatus*, *Nanhermannia bryophila*, *Oppiella washburni* and *Suctobelbella* spp, did not differ significantly in density among the age classes. The mixing of FE sites in the TWINSPAN analysis and PCA graph showed that there was less separation of FE sites in terms of both species diversity and abundance than of the FD sites. This suggests either a faster recovery rate after clearcutting, higher similarity among FE sites in soil and habitat characters or less initial disturbance in the balsam fir - *Equisetum* forest.

**4.5.4 Seasonal Distribution**

Oribatid populations generally peak during autumn, winter or early spring and decline in midsummer (Wallwork 1970, Anderson 1977). This pattern cannot be verified in this study as samples were taken only in late spring to late summer and it is unknown if winter abundances differed. Also, Haarlov (1960) suggested that the life cycle of most soil microarthropods is noncyclic with reproduction occurring under suitable environmental conditions. With this in mind, the general trends seen in this study are described. In the FD forest, 1992, the oribatid population in the old forest a declined from July to August while populations in both regrowth forests increased. All three aged forests had lower oribatid abundances in July 1993 followed by an increase in August 1993. This pattern also appeared in the old and forty year old FE forest stands in July and August 1994. Conversely, the sixty year old FE stand had a decrease in oribatid numbers

in August 1994. Generally, there appeared to be a decrease in total abundance from June to July followed by an increase in August.

This pattern was shown in varying degrees in the immatures of individual species including *Hypochthonius rufulus*, *Eniochthonius minutissimus*, *Nanhermannia bryophila* and *Parachipteria travei*. A similar pattern occurred in *Camisia lapponica* though the number of immatures continued to decline in August 1993 instead of increasing. The seasonal density pattern of *Nothrus anauniensis* immatures differed among the FD age classes indicating a site related effect on reproduction possibly due to differing moisture levels and soil profiles.

### 4.5.5 Vertical Distribution

A majority of the oribatid population (~80 %) of both the FD and FE forest types occurred in the upper 5 cm soil subsamples. Species abundance and diversity decreased with soil depth probably due to a size related ability to penetrate deeper soil layers. A similar decline in oribatid species diversity and abundance with increasing soil depth and the occurrence of larger species almost exclusively in the upper 5 cm of soil was observed by Schenker (1984). Wallwork (1970) also noted that species composition and relative abundance varies with soil depth . Larger mites such as *Platynothrus peltifer* and *Parachipteria travei* are more common in surface litter whereas smaller species, including *Oppiella washburni*, *Suctobelbella* spp and *Tectocepheus velatus*, are generally distributed throughout the humus layers. In both the FD and FE forest types, the relative abundance of the smaller species, *Oppiella washburni* and *Suctobelbella* spp, was high in

the upper 5 cm soil subsamples and increased in the lower 5 cm soil subsample. This increase was probably a reflection of their smaller body size allowing these mites to move in the tiny spaces of the deep soil. The same ability to move throughout the soil profile was indicated in the immatures of *Nothrus anauniensis*, *Camisia lapponica* and *Nanhermannia bryophila* which tended to have a higher abundance than the adults in both upper and lower soil subsamples. Distribution of these species throughout the soil profile may indicate vertical migration in response to alterations of the temperature or moisture conditions in the litter (Wallwork 1970). However, Schenker (1984) reported no seasonal shifts in vertical distribution patterns, suggesting that seasonal migration to deeper soil layers did not occur. Vertical distribution of litter types or microorganisms preferred by adult or immature stages of certain oribatid species may also affect their distribution (Harding and Stuttard 1974).

### 4.6 Effects of Clearcutting

Various effects of clearcutting on the forest floor have been reported by numerous authors. The immediate effects of clearcutting on abiotic and biotic characters include increased solar radiation on the forest floor due to canopy removal which, combined with more drying air movement, results in variable soil temperature and moisture conditions. More direct precipitation also reaches the surface and rapid downward movement of moisture occurs due to the lack of root uptake and retention by the upper organic layers thus resulting in increased nutrient leaching (Pritchett 1987, Page 1974). Energy and nutrient inputs are further altered by initially high organic matter input from cutting wastes

and dying roots and animals followed by a decreased input in subsequent years (Bird and Chatarpaul 1986). Biological activity also tends to increase following a clearcut and is beneficial in cold regions as it increases decomposition and prevents accumulation of undecayed material. Pritchett (1987) suggested that although forest manipulation may increase nutrient cycling and availability through increased organic matter oxidation and biological activity, increased nutrient losses occur simultaneously and are not beneficial to the long-term growth and productivity of a site. However, as a vegetation canopy redevelops, soil temperature, moisture and nutrient levels may approach precut conditions within 4 years (Covington 1981). Sundman et al. (1978) suggested that changes in the biological state of the forest soil following clearcutting may return to clearcut conditions within 10-13 years. These changes in physical parameters of the forest floor undoubtably affect metabolism and behaviour of microarthropods (Mitchell and Parkinson 1976).

On the other hand clearcutting may slow litter decomposition rates for up to 8 years, contributing to the build up of organic surface matter (Blair and Crossley 1988). This reduction in decomposition rates may be a result of microclimate changes and litter quality. Blair and Crossley (1988) recorded altered litter nitrogen dynamics, particularly lower net nitrogen immobilization after clearcutting. This may partially be a result of lower oribatid numbers since they influence microbial activity and affect nitrogen storage and release in litter (Seastedt 1984).

Clearcutting may affect oribatid mite diversity and abundance in a number of ways. Disturbance to the forest floor during cutting and the deposition of cutting wastes may

destroy a majority of the soil flora and potential food sources thereby decreasing species diversity and abundance in the mite population. Conversely, the initial addition of organic matter in the form of cutting debris may promote growth of fungi and bacteria species required by certain oribatid mite species (Wallwork 1967).

Damage incurred by the forest floor of the study sites due to initial forest harvesting is unclear. Richardson (1975), in a study of forest regeneration in Newfoundland, noted that the most severe forest floor disturbance occurred in poorly drained sites, as muck developed in response to the repeated passage of machinery over wet soils. This combined with the abundance of easily damaged herbaceous plants in the wetter FE sites suggests that they may have incurred more initial forest floor damage due to clearcutting than the FD sites. However, there is no evidence to support this contention.

Variable results have been presented by researchers on the immediate effects of clearcutting on oribatid mite populations. Huhta et al (1967, 1969, 1976) noted an initial increase in oribatid numbers, followed by a long term decline. This was attributed to increased food resources in the form of organic material which eventually declined in clearcut areas. However, Abbott et al. (1980) and Bird and Chatarpaul (1986) reported an immediate decrease in oribatid densities which they attributed to decreased food supply and the effects of lethal temperatures on soil and litter. Seastedt and Crossley (1981) suggest that the removal of the canopy and subsequently higher temperatures at the litter-soil interface may affect oribatid mite reproductive success as Woodring and Cook (1962)

demonstrated that exposure to 35°C for several hours was enough to kill oribatid mite gametes. When these levels were not exceeded, Seastedt and Crossley (1981) reported increased oribatid numbers in response to the presence of increased organic matter.

The results of this study suggest that, though total oribatid abundance varied little between the age classes, clearcutting does have a long term effect on oribatid species composition, diversity and individual relative abundances through alteration of habitat conditions and forest vegetation. The severity of the effect may vary between forest types as the age classes of FE were more similar to one another than the FD ages. Differences in species composition among the three FD ages may reflect the effects of succession of forest vegetation on oribatid populations. The forest canopy tightens as the forest progresses from forty to sixty years old and opens up again in the old forest due to tree mortality (Thompson 1994) thereby altering light and moisture conditions of the soil. These variations directly effect the oribatid habitats, thereby affecting species composition, diversity and relative abundances.

Differences in species diversity may also reflect successional changes in the fungi that serve as food resources for many oribatid species. Different fungal species are present at different levels of decomposition and flourish on particular plants and litter components such as leaves or needles (Cooke and Rayner 1984). Several species of fungi, producing conidiophores upon which many oribatid species feed, grow in needle litter and subsequently die after the needles have decayed (Burges and Raw 1967). These changes in composition of the oribatid's food base may result in either the restriction or

predominance of an oribatid species to one age class or another. Several fungivorous oribatid species that varied in abundance between the FD and FE age classes were collected including *Liochthonius lapponicus*, *Ceratozetes gracilis*, *Eniochthonius minutissimus*, *Oppia nova* and *Scheloribates* sp..

## 5.0 CONCLUSIONS

The different age classes of the FD forest were clearly separated in the cluster analysis due to differences in species composition. The forty year old and uncut FE forests were also clearly separated whereas FD60 sites were grouped equally with FDO and FD40 indicating variation in oribatid species diversity within a transitional forest stage.

Several species were either unique to or showed different abundance levels in one age class of the FD and/or FE forest types and may be important components in the classification of age classes in different forest types. Among the species restricted to one age class or another, those that showed regular occurrence in one of the ages are of particular interest including *Epidamaeus longitarsalis* (FDO), *Ceratoppia quadridentata* (FEO) and *Oppia nitens* (FE40).

Other oribatid species occurred in noticeably higher abundances in one age class of FD and/or FE indicating differences in habitat suitability among the age classes. One such species, *Oppia nitens*, was predominant in the forty year old forest stand of FD though it appeared rarely in FD60. Both *Fuscozetes setosus* and *Dentachipteria* sp occurred primarily in soil samples from FD40 however, they were also collected in very low numbers in microhabitat samples from FDO and FD60. Also, the relative abundance of all of the common FD species were significantly different among FDO, FD60 and FD40. In the FE forest, three common species differed significantly among the ages.

Species richness and diversity also varied among the age classes. In FD, richness,

diversity and evenness tended to be higher in FD40 followed by FDO and FD60, respectively. In FE, species richness was again lowest in the sixty year old forest however, diversity tended to be higher in FEO. Again, these differences may reflect successional variations in vegetation and habitat characteristics among the ages.

Overall, this study suggests that clearcutting has a long-term effect, varying with different forest types, on oribatid species diversity and relative abundance. The return of oribatid populations to precut conditions is a long process possibly linked to the slow recovery of the forest vegetation and ground cover. Some rarer species may require an even longer recovery period if in fact they do recover. The severity of this effect and its implications in future forest management practices require further examination. This is particularly important as quantitative and qualitative changes in functional groups of soil organisms may affect nutrient availability to trees and the functioning of root systems (Hogervorst et al. 1993).

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