Prince George, Prince Rupert and Cariboo Forest Regions

LTSPS RESEARCH NOTE

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Note #LTSPS-05

Soil Fauna in the Sub-Boreal Spruce (SBS) Installations of the Long-Term Soil Productivity (LTSP) Study of Central British Columbia: One-Year Results for Soil Mesofauna and Macrofauna

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Introduction

The diversity of animal species in forest soil rivals that of a coral reef, with hundreds of species represented by thousands or millions of individuals occupying a single square meter of soil. Soil fauna come in a variety of shapes and sizes and play a variety of roles in soil development and the maintenance of soil fertility.

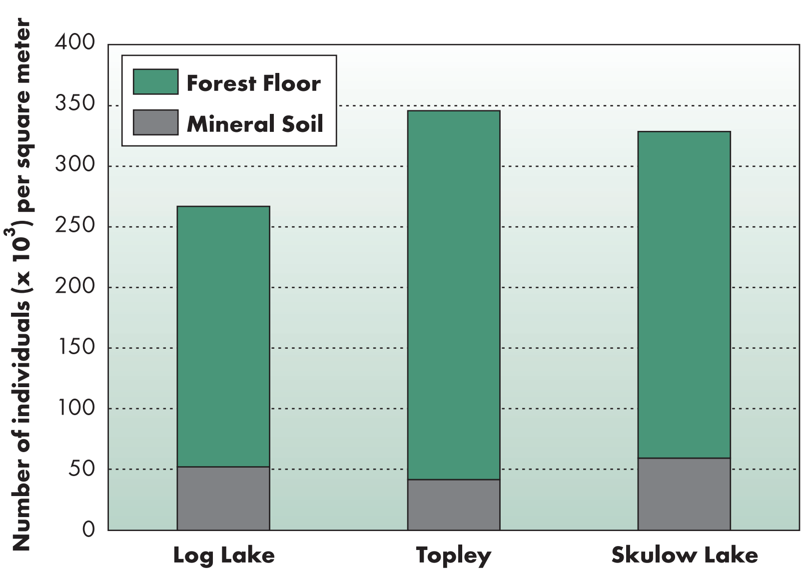
Soil macrofauna are defined as organisms bigger than 2 mm in body width and are the most conspicuous animals within the soil ecosystem. Included in this group are ants, beetles, spiders, centipedes, millipedes, and earthworms. Although generally less numerous than soil mesofauna, macrofauna can represent a significant proportion of the animal biomass in the soil and play an important role in soil ecosystem function. For example, millipedes and earthworms break up organic matter, increasing its surface area and thereby enhancing microbial activity and nutrient cycling. Soil macrofauna mix and redistribute mineral and organic material and microorganisms within the soil profile.

Soil mesofauna range from 0.1 to 2 mm wide and include mites, springtails, Protura, Diplura, Symphyla, and Enchytraeidae, as well as smaller forms of spiders, pseudoscorpions, and insect larvae. Via grazing, they control bacterial and fungal biomass, thus liberating immobilized nutrients and stimulating further fungal and bacterial activity, as well as enhancing plant growth. Furthermore, soil mesofauna transport microbial propagules and spores into new substrates and contribute to the development of soil structure and humus formation through the deposition of fecal pellets.

Timber harvesting and site preparation can modify physical and chemical properties of the soil, consequently affecting soil porosity, composition, and organic matter content; forest floor and mineral soil temperatures; and soil moisture. Organic matter supplies nutrients in soil, influences soil structure, and provides living space for more than 80% of soil fauna and microbes in the forest soil ecosystem. Soil porosity, determined by soil structure and texture, directly influences soil physical properties such as aeration, and water storage, infiltration, and flow. The alteration of soil porosity through compaction and the loss of organic matter through removal or displacement can directly influence biological activity, reducing the diversity and density of soil fauna and altering the structure and function of the soil fauna community.

In 1990, in conjunction with a similar research program in the United States, the B.C. Ministry of Forests established the Long-Term Soil Productivity (LTSP) study to determine the effects of three levels of organic matter removal and soil compaction on soil

FIGURE 1. Mean density of mesofauna (mostly mites and springtails) in the uncut forest control of the SBS LTSP sites.



productivity over a full timber rotation period (Holcomb 1996). We studied the soil fauna communities on the Sub-Boreal Spruce installations of the LTSP in central British Columbia.

Objectives

This study had two main objectives. First, we needed to establish baseline data on the density and structure of the soil mesofauna and macrofauna communities at the Sub-Boreal Spruce LTSP installations. Second, we described the short-term changes in density and structure of the soil fauna community in response to timber harvesting, organic matter removal, and soil compaction. This study establishes the baseline for monitoring long-term changes of the soil fauna community throughout a full timber rotation period on these sites.

Methods

Site Description

The LTSP sites that we studied are located in the Sub-Boreal Spruce (SBS) biogeoclimatic zone in the central interior of British Columbia. Three sites, each located in a different subzone to cover the range of climatic conditions within the SBS, had been established as follows:

1. Log Lake: near Prince George, B.C. (54°2', 122°37'); in the SBSwk subzone.
2. Topley: near Topley, B.C. (54°37', 126°18'); in the SBSmc subzone.
3. Skulow Lake: near Williams Lake, B.C. (52°20', 121°55'); in the SBSdw subzone.

Detailed site descriptions can be found in Sanborn (1996) and Holcomb (1996).

TABLE 1. Mean density of selected soil macrofauna per square meter in the uncut forest at the three SBS LTSP sites

Soil macrofauna		LTSP sites					
Scientific taxon	**Common name**	**Log Lk**	*	**Topley**	*	**Skulow Lk**	*
Aranaea	Spiders	10	c	181	a	96	b
Pseudoscorpionida	Pseudoscorpions	81	a	20	b	21	b
Chilopoda	Centipedes	64	a	10	b	2	b
Coleoptera adults	Beetle adults	25	a	35	a	0	b
Coleoptera larvae	Beetle larvae	42		121		30	
Diplopoda	Millipedes	19	a	17	a	0	b
Diptera larvae	Fly larvae	331		185		127	
Gastropoda	Snails and slugs	1		1		1	
Hemiptera	True bugs	60		535		610	
Hymenoptera	Wasps	4	c	10	b	36	a
Formicidae	Ants	47		1		0	
Lumbricidae	Earthworms	185		19		32	
Total macrofauna		**925**		**1180**		**1026**	

Different letters within row indicate statistically significant difference.

Sampling

Sites were sampled in the same phenological windows 1 year before and 1 year after treatment application. Timing of sample collection was based on bud burst on trembling aspen (spring); soil temperature of 10°C at a 10-cm depth (summer); and leaf colour change in trembling aspen (fall). In addition to standardizing sampling times among sites, these indicators relate to biological activity in the soil and span the range of seasonal variation in distribution and life stages for soil fauna at these sites.

Because of time and financial constraints, sampling was limited to the treatment extremes. Samples for soil mesofauna were collected from six plots at each installation — the uncut forest (control) (OM0C0) and five treatment combinations: (1) stem-only harvesting, no compaction (OM1C0); (2) whole-tree harvesting and forest floor removal, no compaction (OM3C0); (3) whole-tree harvesting, light compaction (OM2C1); (4) stem-only harvesting, heavy compaction (OM1C2); and (5) whole-tree harvesting and forest floor removal, heavy compaction (OM3C2). Macrofauna samples were collected only from those plots that retained the forest floor (four in total), as most soil macrofauna are found in this organic horizon.

In the uncut forest control, three 3.0 x 3.0 m plots greater than 10 m apart were created at each site and subdivided into 36 subplots (0.5 x 0.5 m). For each sampling date, two subplots were selected at random in each plot at each site. In each treatment plot, six 2.5 x 2.5 m subplots were randomly selected for sampling. Each subplot was sampled only once during the study so that the impact of soil removal and habitat alteration would not affect the samples being taken. One subplot was sampled using a metal soil corer (4.5 cm in diameter) and a 3 cm long sample was removed from both organic and mineral soil horizons to collect mesofauna. From the second subplot, a 0.3 x 0.3 m sample of forest floor was removed to collect macrofauna. Samples were packed into coolers and transported to the laboratory for extraction and sorting. Extractions were begun within 48 hours of sampling.

Extraction

Soil core samples were placed in a high-gradient extractor for 1 week. Mesofauna were collected into a 0.6% (weight per volume) picric acid solution, then transferred into vials with 70% ethanol for counting and identification. Macrofauna samples were either hand-sorted in a white enamel tray or placed in modified Berlese funnels for 1 week. Macrofauna were also stored in 70% alcohol.

Meso- and macrofauna samples were identified, sorted, and counted under a dissecting microscope. Taxa can be selected for further intensive study at the species level for the duration of the study, provided interest and financial support are available. All samples are stored with the B.C. Ministry of Forests Research Branch.

Density (number of individuals per square meter) and percentage relative abundance ([number of individuals per taxon/total individuals collected in the sample] x 100) were used in analyses. Density is useful for estimating population size and determining changes in absolute abundance, whereas relative abundance is useful to compare the structure of soil fauna assemblage and the structural similarity among sites, seasons, or treatments.

Analysis

Analysis of variance (ANOVA) was used to analyze density and relative abundance data. A non-parametric test of ranked scores was used for those taxa that did not have normally distributed data. Statistical significance was judged using the Type III *F*-test for both procedures. If significant differences were found, then Tukey's Studentized range test was used to specify significant comparisons. A Tukey-type multiple comparison test was used with the non-parametric test results.

Results and Discussion

Macrofauna Baseline

Densities of macrofauna in the forest floor ranged from about 900 to 1200 individuals per square meter and did not differ significantly among the three sites (Table 1). Although the true bugs seem to dominate the soil macrofauna at two of the three sites, some of these bugs may have originated in the foliage and dropped to the forest floor during sampling, which means that they are not true soil-dwelling fauna. At Log Lake, the two most abundant groups of soil macrofauna were fly larvae and earthworms. At Topley and Skulow Lake, after true bugs, fly larvae and spiders were most abundant. Larval stages of flies and beetles are important agents of physical breakdown of dead plant and animal parts in the forest floor. Earthworms were relatively abundant at all three sites although the species we found are not thought to be native to North America. All Lumbricid earthworms are believed to have been introduced to Canada since the arrival of European settlers.

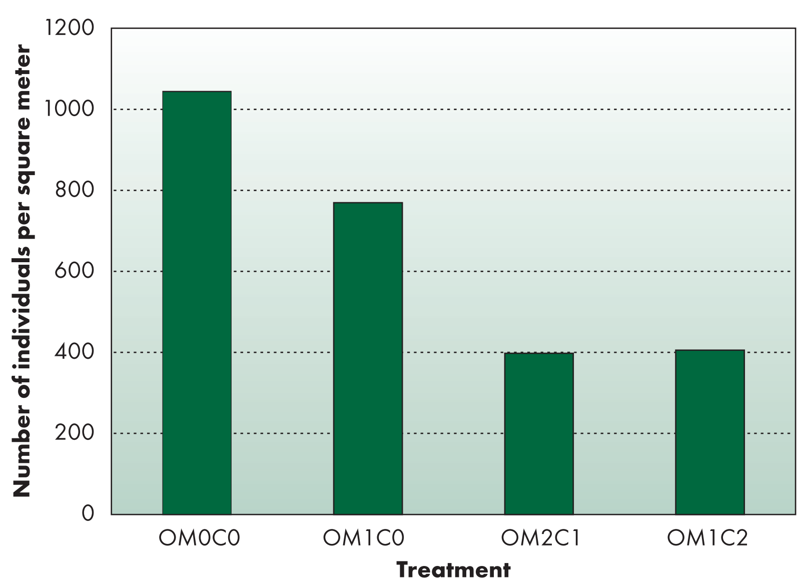
Although it appeared at the three SBS sites of the LTSP that soil macrofauna were most abundant in the fall, the difference was not statistically significant be-

TABLE 2. Mean density of selected soil macrofauna per square meter in the uncut forest at the three SBS LTSP sites for spring, summer, and fall

Soil macrofauna		Season				
Scientific taxon	**Common name**	**Spring** *		**Summer** *		**Fall** *
Aranaea	Spiders	75		94		119
Pseudoscorpionida	Pseudoscorpions	5	b	60	a	57
Chilopoda	Centipedes	15		52		10
Coleoptera adults	Beetle adults	16		21		22
Coleoptera larvae	Beetle larvae	58		94		41
Diplopoda	Millipedes	6		12		17
Diptera larvae	Fly larvae	141		264		238
Gastropoda	Snails and slugs	1		0		2
Hemiptera	True bugs	217		86		901
Hymenoptera	Wasps	14		9		27
Formicidae	Ants	47		0		1
Lumbricidae	Earthworms	11		78		147
Total macrofauna		**625**		**826**		**1680**

*Different letters within row indicate statistically significant difference.

FIGURE 2. Mean density of soil macrofauna in forest floor 1 year after treatment application.



cause of high variability (Table 2). However, in temperate and boreal coniferous forests, fall is often a time of high abundance of soil fauna (Battigelli et al. 1994). Therefore, we can infer that our observation was probably biologically significant.

Mesofauna Baseline

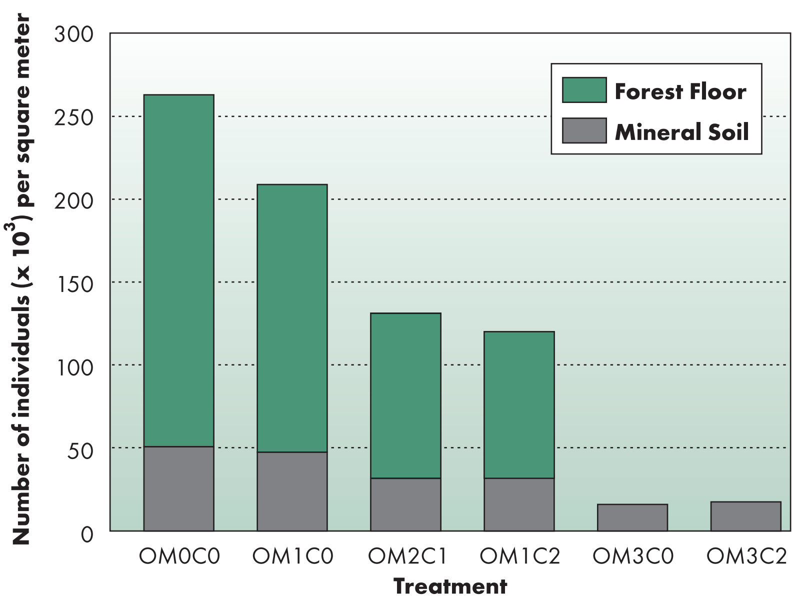
The mean density of soil mesofauna ranged from about 250 000 to 350 000 individuals per square meter and did not differ significantly among sites (Table 3). However, more mesofauna were in the organic horizon than in the mineral soil at all three sites (Figure 1). Greater abundance of mesofauna in the forest floor than in the upper mineral soil is often reported for temperate and boreal forest soils (Battigelli et al. 1994).

The structure of the mesofauna community, based on the relative abundance of the various groups, was similar across all sites, seasons, and horizons. Mites (Acari) accounted for approximately 75—80% of the mesofauna collected, while springtails (Collembola) made up 15—20%, and other mesofauna contributed 0—5%. Prostigmata and Oribatida were the dominant mite taxa, and Isotomidae, Hypogastruridae, and Onychiuridae were the dominant springtail taxa. Similar proportions for these broad mesofaunal groups have been observed in other forest soil ecosystems (Battigelli et al. 1994; Marshall 1998).

TABLE 3. Mean density of soil mesofauna per square meter in the forest floor (FF) and mineral soil (MS) from the uncut forest at the three SBS LTSP sites

Soil mesofauna		Sites and soil horizons					
		Log Lk		Topley		Skulow Lk	
Scientific name	**Common name**	**FF**	**MS**	**FF**	**MS**	**FF**	**MS**
Acari	Mites	179,734	44,514	232,669	32,495	202,376	48,777
Collembola	Springtails	29,909	6,953	65,129	8,421	61,950	8,910
	Others	4,857	769	5,940	908	4,542	1,782
	Total	214,500	52,236	303,738	41,824	268,868	59,469

FIGURE 3. Mean density of soil mesofauna 1 year after treatment application.



LTSP Treatment Impact on Macrofauna

The reduction in density of soil macrofauna (Figure 2) 1 year after stem-only timber harvesting without soil compaction (OM1C0) was not statistically significant when compared with the uncut forest control (OM0C0). However, the density of soil macrofauna was significantly reduced by whole-tree harvesting with light compaction (OM2C1) and by stem-only harvesting with heavy compaction (OM1C2) when compared with the uncut forest control (OM0C0). From this result, we see that soil compaction or slash removal combined with tree harvesting had a greater influence on the density and structure of the soil macrofauna community than did tree harvesting alone.

LTSP Treatment Impact on Mesofauna

The densities of soil mesofauna in the combined forest floor and mineral soil were significantly lower on plots with whole-tree harvesting and forest floor removal (OM3) than on plots with stem-only harvesting (OM1). The removal of the forest floor in the OM3 treatment removed most of the soil mesofauna and their habitat. Density of soil mesofauna was also significantly lower with heavy soil compaction (C2) than with no compaction (C0). Compaction of the soil kills some existing soil mesofauna and alters soil spaces in which mesofauna live. This change probably accounts for their reduction in compacted soil.

Stem-only harvesting plots without compaction (OM1C0) had substantially more mesofauna than the other four treatments (stem-only harvesting combined with heavy soil compaction [OM1C2]; whole-tree harvesting with light compaction [OM2C1]; whole-tree harvesting and forest floor removal with no compaction [OM3C0]; and whole-tree harvesting and forest floor removal with heavy soil compaction [OM3C2]).

Forest floor removal had a greater influence on soil mesofauna than did soil compaction, accounting for al-most 60% of the variation in mesofauna density. One year after treatment application, the density of total soil mesofauna was higher in plots that retained the forest floor, even with heavy soil compaction (OM1C2), than in plots where the forest floor had been removed (OM3) (Figure 3). The forest floor is the soil layer where most soil mesofauna live; therefore, removing this layer results in a dramatic decrease in habitat and therefore numbers of soil mesofauna.

As density of soil mesofauna 1 year after treatment application decreased with increasing soil disturbance, the structure of the mesofauna community also changed. In the forest floor, the relative abundance of oribatid mites remained relatively unchanged among the treatments and comprised about 25—30% of the mesofauna community (Figure 4). However, in the mineral soil, the relative abundance of oribatid mites was lower (15—17%) in the whole-tree harvesting and forest floor removal (OM3) plots than in the stem-only harvesting (OM1) plots (25—26%) (Figure 5). At the same time in the mineral soil, the relative abundance of prostigmatid mites was higher (50—52%) in the whole-tree harvesting and forest floor removal (OM3) plots than in the stem-only harvesting (OM1) plots (38—40%). This finding indicates, as others have suggested (Behan-Pelletier 1999), that oribatid mites decline rapidly in disturbed habitats and may therefore be useful biological indicators.

Our results differed slightly from those of some studies. For example, 2 years after timber harvest in a temperate mixed conifer—hardwood stand, both stem-only and whole-tree harvesting reduced mesofauna densities by 56—68% (Bird and Chatarpaul 1986). In a Finnish study, the density of springtails was higher in harvested stands of Norway spruce than in uncut control stands immediately after timber harvesting, but mite densities in harvested stands were about half that of the control areas (Huhta et al. 1967). In our study, in the first year after timber harvesting, the density of soil mesofauna, including springtails and mites, in stem-only harvesting plots was not significantly different from mesofauna density in the uncut forest control plots.

Our results also agreed with those of some studies. For instance, we found that stem-only harvesting combined with heavy soil compaction (OM1C2) decreased densities of most soil mesofauna taxa by 50% or more relative to the uncut forest control. This finding was similar to reductions observed by Bird and Chatarpaul (1986) and Huhta et al. (1967).

Conclusions

Overall, the reduction in density of soil fauna increased with the severity of the disturbance, with combined heavy compaction and extensive removal of organic matter resulting in the lowest density of soil fauna. Any measures taken to minimize soil compaction and loss or displacement of organic matter, particularly the forest floor, will help mitigate the short-term effects of disturbance on the soil fauna community.

Although lowered densities of soil fauna may not be permanent, changes to the overall community structure may be long lasting (Marshall 1998). It is necessary, therefore, to establish baseline data on the density, diversity, and structure of the soil fauna assemblage against which to compare changes in the soil fauna after disturbance (Behan-Pelletier 1999). The long-term nature of the LTSP study offers an opportunity to monitor the recovery of the soil fauna community in the SBS over a full timber rotation of 80—120 years. These biological data can be integrated with other monitored soil properties, both physical and chemical, to measure the overall response of the forest soil ecosystem to disturbance.

FIGURE 4. Comparison of mean relative abundance of mesofauna in forest floor among treatments.

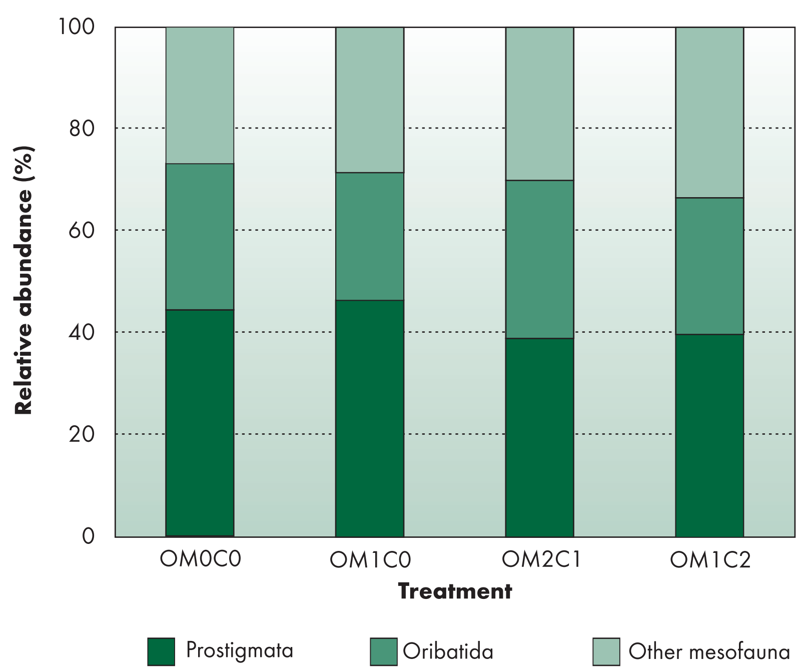
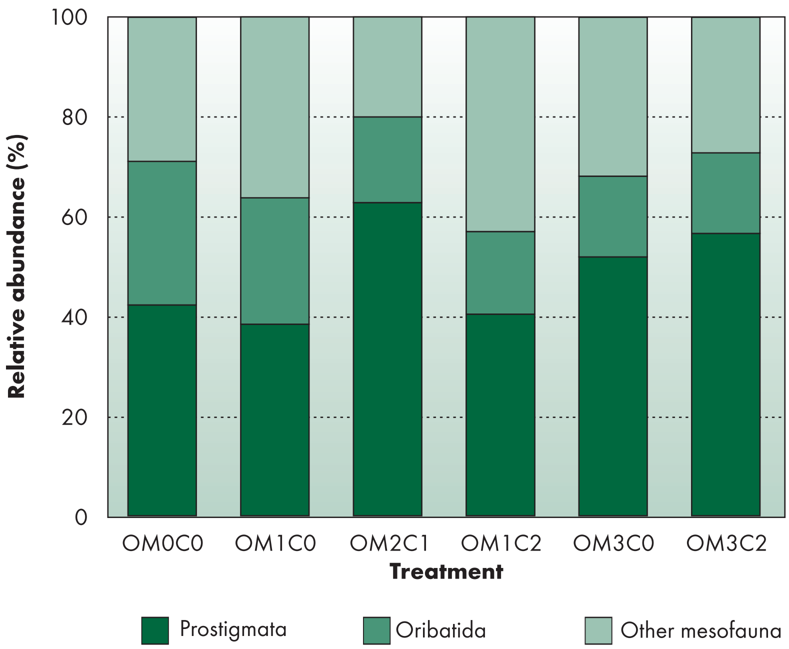


FIGURE 5. Comparison of mean relative abundance of mesofauna in forest floor among treatments.



Literature Cited and Suggested Reading

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