



# Forest Sciences

Prince Rupert Forest Region

*Extension Note # 13*

*December 1995*

## Soil Biodiversity

### Research Issue Groups:

Forest Biology

Forest Growth

Soils

Wildlife Habitat

Silviculture

Ecosystem Inventory and  
Classification

Biodiversity

Ecosystem Management

Hydrology

Geomorphology

Extension



*Centipedes are one of the largest types of arthropods in the forest soil, important because they feed on other soil fauna in the litter layer. (mag. x 10)*

### Introduction

The forest soil holds an amazing variety of life: everything from microscopic mites to small mammals. The importance of this below-ground ecosystem is just beginning to be appreciated, but what we have learned so far has shown that forest soils are very much alive, dynamic and incredibly complex. Current research into soil ecology is exploring the workings of the forest

soil and the potential impacts from forest operations. This extension note will describe some of the more common groups of organisms in the forest soil and discuss ways in which we can help conserve soil biodiversity.

### Arthropods

Many people are familiar with the food chain concept of the forest, in which plants supply food for

**Forest Sciences, Prince Rupert Forest Region**

Bag 5000, Smithers, BC V0J 2N0 847-7500 (FAX 847-7217)

herbivores, such as leaf-eating insects, which then cycle through predators, such as birds. These same kinds of food chains exist on a microscopic scale in the soil, but with many times the diversity of species found aboveground. Our research into soil fauna diversity in the interior of British Columbia was initiated in 1992<sup>1</sup>. One year's sampling in mature forests found 18 types (families and orders) of arthropods (insects and insect-like creatures) and three types of worms. The population estimates of these fauna are staggering. In the North and Central Interior, for example, the number of arthropods ranged on average from **350,000** to almost **700,000 individuals per square metre**.

The diversity of species within this arthropod sample cannot be



*Spiders are common in the forest—on trees, shrubs, plants and throughout the soil and forest floor. (mag. x 10)*

determined yet because many species have not been adequately described. There are estimated to be 48,000 to 60,000 species of soil arthropods in North America (estimates of around 35,000 have been made for BC), of which maybe only 50% have been identified. Compare these numbers with other species in BC:

approximately 2500 species of vascular plants, 450 species of birds, 100 species of mammals, 20 species of reptiles and 20 species of amphibians have been recorded. In these groups, there are very few species that have not yet been identified.

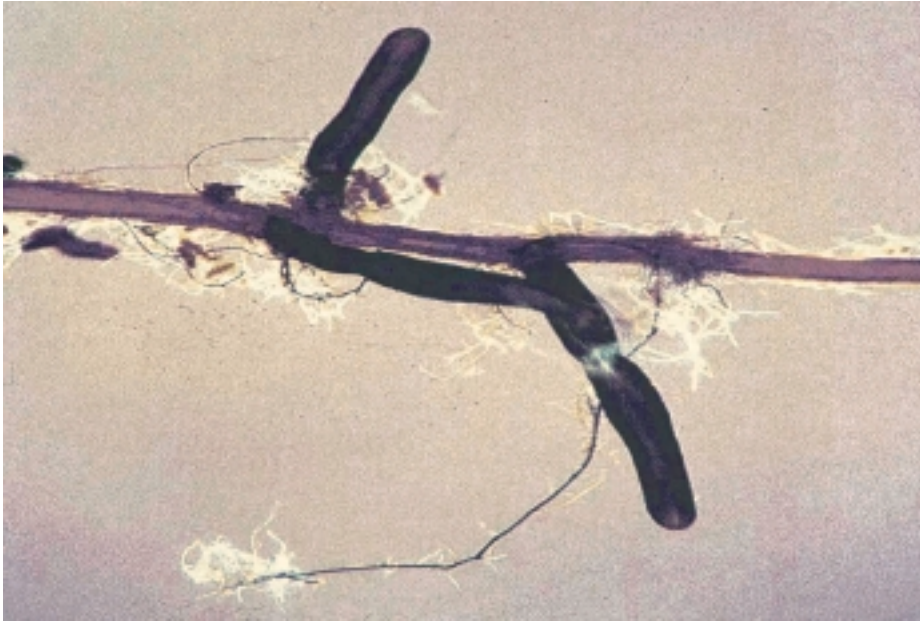
The forest soil ecosystem is comprised of several habitat types, each of which could have unique arthropod communities. The **mineral soil** and **forest floor** provide the most widespread habitats. Variations in site factors lead to the formation of **mor**, **moder** and **mull** type forest floors. Faunal species, populations and activity seem to increase along this gradient from mor to mull. **Coarse woody debris** in forest ecosystems provides a unique and ecologically important habitat for soil fauna. Another microhabitat is the **rhizosphere**, which is the soil surrounding feeder roots. This is a very microbially active zone, with large amounts of root exudates that create a unique environment for bacteria, fungi and the fauna that feed on them.

The life histories and ecology of the small proportion of identified arthropods have not been well studied. Many functional groups are represented: detritivores, wood

channelers, bacteriivores, fungivores, parasites and predators. Many soil species can act in more than one capacity. We can only speculate on some of the interactions among arthropod groups, interactions that regulate important processes of the soil, and ultimately, the forest.

One of the key soil processes in which arthropods participate is **nutrient cycling**. The field work conducted to date in northern interior B.C. shows that the most abundant fauna are fungivores, such as mites and collembola. These indirectly affect nutrient cycling by grazing on the fungal biomass. In doing so, nutrients are released from the microbial biomass and made more available for plant uptake. However, grazing on the bacteria and fungus can also reduce the rate of decomposition of organic matter in the forest. These interactions within the nutrient cycle could help balance the rate of nutrient release and conservation, ensuring stable forest productivity over the long-term.

The movement of soil fauna leads to the transport of organic matter and microbes through the soil. This could prove to be one of the most critical roles of soil arthropods. On a large scale, some of the macro-arthropods can move between soil horizons, the rhizosphere and coarse woody debris. On a small scale, arthropods can redistribute organic matter to and from the rhizosphere by moving between pores and aggregates. The effect of this movement on nutrient cycling could be especially important for otherwise immobile nutrients, such as phosphorus.



*A mantle of fungus covers this ectomycorrhizal hemlock root. The extending hyphae move nutrients and water from the soil to the root. (mag. 10x)*

## Fungi

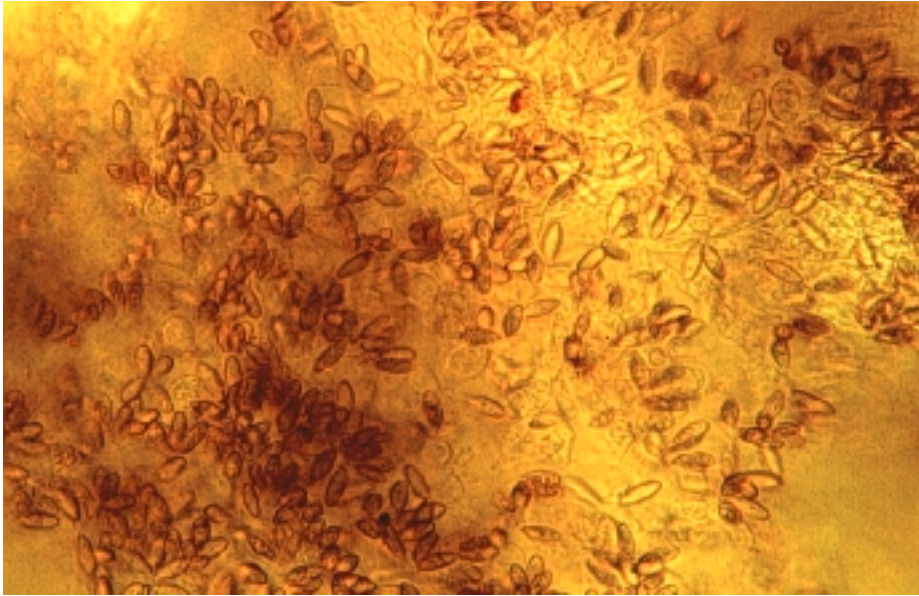
Approximately 69,000 species of fungi have been identified worldwide so far and it is estimated that there are about 1.6 million species in total. A typical ratio of number of fungi species to vascular plant species for a given ecosystem is about six to one. Many of the fungi live in the soil where they function as pathogens, parasites, saprophytes and **mycorrhizal** fungi. In temperate and boreal forests, fungi often constitute the largest biomass component of the forest floor. They play very important roles in organic matter decomposition, which contributes to nutrient cycling. As disease organisms, they have important functions, such as thinning of weak and suppressed trees in overstocked forests.

The health of the forest ecosystem is even more directly linked to

**ectomycorrhizal** fungi, which form a symbiosis with most of the trees and shrubs that grow in temperate and boreal forests. The few species without ectomycorrhizal fungi usually have other types of mycorrhizae. The feeder roots of ectomycorrhizal trees are the organ of the tree that is responsible for nutrient and moisture uptake. Essentially every feeder root of an ectomycorrhizal tree is completely covered by a dense covering of fungus called the mantle or sheath, and every cortical cell of the tree's feeder roots is also individually surrounded by a layer of fungus called the Hartig net. This combination of fungus and tree root is what constitutes a mycorrhiza (literally *fungus root*). It is estimated that up to about 50% of the energy that trees store goes directly to their mycorrhizal fungi, which indicates the significance of the mycorrhizal fungus in this symbiotic relationship.

There are currently estimated to be 5000 - 6000 species of ectomycorrhizal fungi. It is common to find 30 to 40 species of ectomycorrhizal fungi in a forest stand, but that may be an underestimate because of the difficulties in sampling for them. Each type of ectomycorrhiza may have different preferences for pH, temperature, moisture levels, season and substrate type. Some ectomycorrhizae exude **enzymes** which allow the tree to take up nutrients directly in organic forms, rather than mineralized forms that occur after decomposition. Some kinds of ectomycorrhizae exude **siderophores** which are organic molecules that can aid in the uptake of iron; others exude **antibiotics** into the rhizosphere that show specific antagonism towards various disease-causing organisms. Some kinds of mycorrhizal fungi form **fungus mats**, which are dense layers of fungus that physically, if not biologically or chemically, dominate some types of forest floors. Some kinds of mycorrhizal fungi connect overstory plants to understory plants and can transfer carbohydrates between trees of the same species or different species of plants.

Mycorrhizal fungi are dispersed by aerial spores, by spores transported in the guts of animals, and by root contact. Some species have no known spore dispersal mechanism and are dependent on mycelial contact from colonized roots to disperse unto new roots. Many small plants, such as kinnickinick (*Arctostaphylos uva-ursi*), are



*Truffle spores are dispersed when eaten by squirrels, voles and other animals so that the ectomycorrhizal fungus can spread throughout the forest. (mag. 1000x)*

ectomycorrhizal and can act as refugia for mycorrhizae after logging or other disturbances, though not all ectomycorrhizal fungi can colonize these species. Approximately 1000 species of ectomycorrhizal fungi form subterranean fruiting bodies (truffles or truffle-like mushrooms) that have evolved to be eaten so that spores can be dispersed in dung. Squirrels, voles, deer, bears and other animals eat these kinds of mushrooms.

Many fungi are very important food sources for humans as well. Several species of mushrooms are harvested in BC, including chanterelles, pine mushrooms, morels, brain mushrooms, king boletes and giant puffballs. Chanterelles, pine mushrooms and king boletes are ectomycorrhizal and require specific types of forests to produce mushrooms. Some types of

mushrooms, such as morels, fruit abundantly under specific conditions, as after a wildfire or broadcast burning. In Europe, dramatic declines (in the order of 50%) in the numbers of species of ectomycorrhizal fungi in forests have been reported. The reasons for this are unclear but factors that have been suggested include pollution, overharvesting of mushrooms, and fertilization of forests. Many of the forests of Europe are currently in a state of decline. It is not known if the decline in ectomycorrhizal species is contributing to the decline in the forest or if stress to the forest is causing the decline in some types of mycorrhizae. However, there is ample evidence now to suggest that complex populations of ectomycorrhizae are synonymous with a healthy and stable forest.

## Other Soil Organisms

There are many other types of organisms in the forest soil about which we know little. These include groups such as earthworms, potworms, nematodes, rotifers, protozoans, snails and slugs, algae, bacteria, actinomycetes and cyanobacteria. **Nematodes** are perhaps the largest (numerically) single group of animals in the soil and act as predators, pathogens and fungivores. All nematodes appear to feed on living tissue and there are at least 1000 species of soil nematodes.

**Protozoans** represent another immense population of soil animals. These single-celled organisms, such as the amoebae, could be one of the principal consumers of bacteria in the soil.

In many situations, **earthworms** make up the largest faunal biomass in the soil. Estimates of earthworm mass have been as high as 12,000 kg/ha for sites in the Cariboo Forest Region, but estimates of 3000 kg/ha are not uncommon. It was believed that earthworms were rare in conifer forests, but in many cases that now appears to have been incorrect. Earthworms are important for speeding up the decomposition of organic matter and improving the structure of mineral soil.

**Bacteria** have many roles as well, including disease causation, decomposition and nitrogen fixation. Bacteria can fix nitrogen in association with plants, but perhaps more important is nitrogen fixation by free-living bacteria in forests.

**Actinomycetes** are filamentous bacteria common in soils and responsible for giving soil its characteristic earthy smell.

Actinomycetes are a major source of antibiotics for human use and also are involved in nitrogen fixation in symbiosis with woody plants.

**Cyanobacteria** (blue-green "algae") are a special group of bacteria that can photosynthesize, and in many cases, also fix nitrogen. In some forest environments, it has been determined that cyanobacteria make a significant contribution to the nitrogen budget of the forest.

In short, there are many kinds of organisms living in the soil and contributing to the cycling of nutrients through the forest as well as to other functions. To really see the complexity of a forest ecosystem, one has to "look small."

### Managing Forest Soils for Biodiversity

The concerns about biodiversity from a soil's point of view reflect many of the same issues surrounding above-ground diversity. The relationships and workings of the soil ecosystem, as with other ecosystems, are too complex to fully understand the possible impacts of forest management. The creation of large-scale, uniform openings of only pioneer species will reduce the rich diversity of habitats and hosts that characterize the many communities of soil organisms. In contrast, after natural disturbances such as fire, the forest usually retains **island remnants** of living trees, undisturbed forest floor and coarse woody debris, all of which act as '**biological legacies**' for the succeeding forest. At this time all we can do to reduce

the risk of damaging the soil ecosystem is to manage such that patterns of disturbance resemble those caused by natural processes.

Island remnants left by approximating natural disturbance patterns will hopefully act as refuges from which species of mycorrhizae, fauna and other organisms can spread back into the disturbed forest. In the case of some organisms, dispersion may be slow, and thus the retention of habitat on the small scale is important. This requires the retention of some coarse woody debris and undisturbed forest floor and mineral soil (e.g., by avoiding intense burning or excessive mechanical site preparation). Some types of organisms, such as the underground mushrooms, need an intact community of mammals, particularly small mammals, to disperse spores from areas where colonies of the fungi remain to areas where they have been lost. This requires the conservation of larger islands of forest or habitat elements.

Some species of fungi show fairly large differences in strain characteristics with adaptations to specific environmental conditions. These strains are sometimes referred to as **ecotypes**. The ecological function of ecotypic variation is currently not well understood but it could be important for providing very site specific adaptation. As a measure to retain this genetic variability, as well as the specific complement of fungi and other organisms present in a stand, one



*Yellow-green and green algae grow on leaf litter in the forest floor, providing another type of food for soil fauna. (mag. 1000x)*

approach would be to preserve island remnants of each stand that is harvested. In other words, island remnants should not consist only of immature or riparian areas within a block but also representatives of the types being harvested. In some cases it could be desirable to at least leave one or more widely spaced windfirm dominant trees . Even this will contribute to preserving the soil biological legacy.

A second issue for management of soil biodiversity is the maintenance of ‘**soil integrity**’. Soil degradation, such as through the compaction of mineral soil, for example, reduces porosity and alters moisture

conditions, often to such an extent that this mineral soil habitat becomes lost to many species. Soil displacement exposes new and possibly poorer substrates from deeper in the soil profile, which take some time to be colonized and become stable productive environments. In addition, soils that are greatly disrupted become biologically frontier environments that may be susceptible to invasion by a variety of pioneering organisms that are alien to the intact ecosystem. These may be thought of as weed species, and in fact, weedy plant invasion can be one consequence of such disturbance. Other organisms, such as disease organisms, may also

use this opportunity to establish. Losses of soil from erosion and mass wasting also remove soil volume and reduce the biological legacy of the soil. Managing soils from a conservation point of view will, at the same time, help maintain biological diversity as well as biological integrity.

**Contact:**

This note prepared by **Bill Chapman** (Cariboo Region) and **Marty Kranabetter** (Prince Rupert Region)

**References and Suggested Reading**

<sup>1</sup>Battigelli, J.P. and S.M. Berch, 1994. Soil fauna abundance and diversity on the Long-term Soil Productivity Study (LTSPS) installations in the Sub-Boreal Spruce (SBS) Zone of the Prince Rupert, Prince George and Cariboo Forest Regions. Unpubl. BCMOF Progress Report, Prince Rupert (Smithers) Region, Forest Science Section.