Title: **Developing indicators of soil productivity, function and biodiversity through soil biotic communities**

FSP No.: Y08-2010

Project Description: Soil indicators of sustainability are currently limited to soil disturbance surveys and reductions in net areas to be reforested (Montréal Process 1995, Curran et al. 2005). More biologically-based indicators of soil function, productivity, and biodiversity would provide more sensitive criteria of management practices. Such indices would be similar to the Index of Biological Integrity (IBI) that is widely used in the United States to monitor water quality, and which is now being adopted in northwest B.C. for fisheries habitat and water quality (Ministry of Environment 2005). Soil indices could include soil fauna, ectomycorrhizal fungi, or terrestrial nonvascular plants (lichens/bryophytes/liverworts – 'cryptogams') (e.g. Pandolfini et al. 1997, van Straalen 1998, Kremsater 2003), both as indicator species or indirectly through community parameters such as functional diversity (Bengtsson 1998). For example, ectomycorrhiza communities are strongly affected by stand disturbance, and 12 mushroom species have been identified as late-seral dependent in the interior cedar-hemlock zone of northwest British Columbia (Kranabetter et al. 2005). These species provide an excellent cost-effective monitoring tool that will clearly demonstrate the recovery of fungal biodiversity in managed stands. Further development of similar indicators is needed to examine issues such as soil disturbance (e.g. compaction and organic matter loss), soil biodiversity (e.g. green tree retention), and soil sustainability (e.g. nutrient cycling under alternative silviculture systems).

A logical step in the development of soil indicators is a better characterization of biotic communities across sites representing full gradients in ecosystem productivity. Species that are limited in distribution to poor ecosystems, for example, could serve as biological indicators of site-degrading forest practices. Better information on species distribution and community composition is also essential in providing unambiguous indicators across spatial scales. For example, the 12 mushroom species limited to late-seral stands in the ICH were only tested on submesic ecosystems, and might not be valid for richer ecosystems in that landscape. We also have very little information on the natural range in variability for community measures in soils, such as total species richness or relative evenness in species distribution between sites. Targets or criteria extrapolated from studies limited to mesic sites could lead to poor assessments of management impacts on soils across variable landscapes. Ultimately, the goal of a forest manager is to maintain the historic, natural range of species within ecosystems of all kinds, so characterizing these biotic communities across the landscape gradient is an essential first step.

In British Columbia, forested landscapes have a range of common but distinct ecosystems that reflect differences in soil nutrient and moisture availability (from nutrient poor/dry to rich/wet across the edatopic grid). A network of replicated sites encompassing a full gradient in forest ecosystems (the 02 Pl – Cladonia; the 01 Sxw – Huckleberry; the 06 Sxw – Oak fern; and the 09 Sxw - Devil's club) was established in the SBSmc2 in mature stands with a mix of lodgepole pine, hybrid white spruce and subalpine fir. Three large and important biotic communities will be assessed (repeatedly where necessary): ectomycorrhizal species (mushrooms and fine root ECM fungal colonization); soil macro- and mesofauna; and plant (especially the terrestrial bryophyte/liverwort/lichen) species. Taxonomic expertise will be utilized to allow for as complete a species inventory as possible. Species distribution will be compared across site series and tested against site potential (asymptotic stand height) and measured soil parameters such as N availability and moisture content.

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Project Objective:

Objectives (long-term):
1. Establish the ecological relationships that are needed to develop a biological indicator system for soil health, including:
• Establish relationships between BEC site series and soil-related species: ectomycorrhiza, macro/mesofauna, and cryptogam plants. Community data will include species identification where possible, and indices such as functional diversity and evenness of species distribution.
• Test soil parameters such as N availability, pH, and soil moisture against soil biotic communities to examine processes influencing species distribution.
2. Develop indicator lists for species which are either generalists and widely distributed, or specialists and narrowly distributed to well-defined soil conditions. Also document species distribution as a function of mineral soil, forest floor and coarse woody debris habitat.
3. Recommend a potential indicators suite for soil productivity.

Objectives (2007-2008):
1. Complete second year of soil fauna and epigeous ectomycorrhizal sporocarp surveys and taxonomic resolution. We have found the soil fauna taxonomy work more intensive than originally considered, and so will be seeking some extra funds (perhaps $5000) to help complete this work.
2. Publish manuscript on plant communities and cryptogam diversity across site productivity gradients.
3. Complete root ectomycorrhiza assessment of understory subalpine fir and initiate manuscript on ECM communities across site productivity gradients.
4. Update Cortinarius workbook with further species descriptions and photographs.

Objectives (2008-2009):
1. Complete final year of soil fauna and epigeous ectomycorrhizal sporocarp surveys and taxonomic resolution (including molecular techniques).
2. Collect nutrition data to supplement biological relevance of patterns in species distribution across productivity gradients.
3. Prepare manuscripts on ectomycorrhizal fungal communities, soil faunal communities and plant guild relationships across site productivity gradients.

Experimental Design and Methods: Five replicates of four site series (the 02 Pl – Cladonia; the 01 Sxw – Huckleberry; the 06 Sxw – Oak fern; and the 09 Sxw - Devil's club) were located in the SBSmc2 along the McDonnell Forest Service Road, with the exception of the 4th transect where an 09 Sxw-Devil's club site could not be located. These are mature stands (age class 8), with a varying mix of lodgepole pine (Pinus contorta), hybrid white spruce (Picea glauca x engelmannii) and subalpine fir (Abies lasiocarpa), and have no mountain pine beetle attack at this time, which is one of the few areas in the northern interior where intact stands can be currently found. The sites were fully described using standard BEC protocol, with soil descriptions (including detailed humus form classification), plant community assessments, coarse woody debris surveys and stand measurements. More intensive investigations were initiated for ectomycorrhizal species, soil macro- and mesofauna, and cryptogam plant (bryophyte/liverwort/lichen) species. The biotic assessments were across 50 m x 30 m (0.15 ha) plots, usually contiguous but occasionally as subplots for less extensive site series. Soil properties across site series, especially nitrogen availability and moisture levels, have been characterized through an ongoing linked study funded through the Forest Science Program. Ectomycorrhizal fungal species have been assessed through morphotypes retrieved from feeder roots in 2007 and sporocarp surveys in 2006/2007. Both methods were necessary to fully describe the diversity and functional differences in ECM communities. A final mushroom survey will take place (week of August 22 and September 12) in 2008 with the continued assistance of taxonomic experts. A species list will generated by searching the entire plot during each of the sample periods, and total species richness per site will be based on the cumulative species list collected over the 3 year sample period. Species frequency will be determined from transect lines, measuring 1 m in width, randomly located perpendicular to the central axis of the plot. Taxonomic identification will be based on macro and microscopic features. Representative voucher specimens will be dried and deposited at the Smithers Forest Service herbarium. Approximately 75 of the more abundant species will undergo ITS analysis through the UBC Okanagan lab to link species names to morphotypes described from the subalpine fir saplings in 2007.

Soil macrofauna will be collected in the early summer using timed searches of 30 minutes per plot. This method will augment the previous data collections since the cardboard method for gastropods has been relatively ineffective, and there are other macrofauna such as centipedes which might be understampled using pitfall traps. Microsites such as leaf litter, loose bark on CWD, rocks or small CWD on the ground will be examined for gastropods, centipedes, beetles etc. Species identification for these organisms will be undertaken with the assistance of taxonomic experts where necessary. In addition to species identification and abundance (# of individuals), the fauna community will be characterized by diversity within trophic levels (fungivores, predators, detritivores etc.) for a comparison of functional differences in food webs across site series.

We have thus far found quite clear differences in the distribution of plant and ectomycorrhizal species related to site series and soil productivity. The utility of these species as indicators could be enhanced if we can demonstrate a relationship between their occurrence and functional differences in nitrogen forms (organic N, ammonia and nitrate; Kranabetter et al. 2007). We will collect understory plant foliar and sporocarp samples in the fall of 2008 for nutritional analysis to further explore these nitrogen relationships with these soil measures (Lilleskov et al. 2002, Taylor et al. 2003). Three broad guilds related to mycorrhizal habit will be compared – ectomycorrhiza, ericoid mycorrhiza and arbuscular mycorrhiza. Nitrogen concentrations, natural abundance of 15N and leaf morphology will be compared between the 3 guilds along the soil fertility gradient.

Statistical analysis will be undertaken with the assistance of biometricians at BC Forest Service. All community plant, ectomycorrhiza and fauna data will be compared using nonmetric multidimensional scaling to examine the relationships to site series. Species distributions will be correlated with edaphic characteristics using multilinear or curvilinear regressions and multivariate techniques such as principle component analysis.

Kranabetter et al. 2007. Indices of dissolved organic nitrogen, ammonium and nitrate across productivity gradients of boreal forests. Soil Biology & Biochemistry 39: 3147-3158.
Lilleskov et al. 2002. Ectomycorrhizal fungal taxa differing in response to nitrogen deposition also differ in pure culture organic nitrogen use and natural abundance of nitrogen isotopes. New Phytologist 154: 219-231.
Taylor et al. 2003. Species level patterns in 13C and 15N abundance of ectomycorrhizal and saprotrophic fungal sporocarps. New Phytologist 159: 757-774.