McCully Creek Adaptive Management Plan for Monitoring Mature Forest Ectomychorrizal Mushrooms Including the Pine Mushroom

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EXECUTIVE SUMMARY

Mature-forest mushroom species were monitored in partial-cut stands from the Helen Lake, Date Creek, and McCully Creek areas and compared to mature, unharvested stands from a concurrent chronosequence study. Many of the mature-forest indicator species were found in the partial-cut plots, with a total of 11 of the 14 indicator species recorded. On average, 6 mature-forest indicator species were found per partial-cut site, compared to 9 species in each chronsequence plot. The percentage similarity of indicators was quite high at 73% for frequency, so the results suggest the partial-cut treatment was effective in maintaining a mature-forest mushroom community. Overall, average species richness decreased by about 45%, so partial-cutting did lead to some reduction in mushroom habitat. These results suggest that 1.8 ha partial-cut (20 to 30 m^2/ha, or 60% removal) would be equivalent to 1 ha undisturbed forest.

The results of this study would suggest these selectively harvested sites have not had a significant shift to mushroom communities represented in younger seral stages. However, partial-cutting appeared to reduce habitat proportional to the amount of basal area removal, and should therefore have an impact on mushroom biomass, including the pine mushroom.

1.0 BACKGROUND

The McCully Creek adaptive management plan for monitoring mature-forest mushroom species was initiated by the Kispiox Small Business Forest Enterprise Program (SBFEP). Its purpose is to evaluate the effects of harvesting on the presence or absence of ectomycorrhizal mushrooms, including the pine mushroom (*Tricholoma magnivalare*) in selectively harvested blocks of the Kispiox chart area. The results of this study will be used to adapt forest management strategies and silviculture prescriptions to better mitigate mushroom losses from timber harvesting (Bilodeau 2002).

The pine mushroom is a valuable botanical forest product that is found mainly in mature forests (age class 5 or greater, 80+ yrs.) in the Interior Cedar-Hemlock moist cool subzone of the Kispiox Forest District. The submesic conditions of the Western Hemlock – Step moss 01b site series (Banner et al. 1993) provide one of the most productive sites for the pine mushroom to grow (Kranabetter et al. 2002), and therefore will be a prime focus for site selection in this study.

An ongoing chronosequence study of ectomycorrhizal (ECM) mushroom communities across a range of forest ages has identified 14 indicator species, including the pine mushroom, that were found in only mature or old forest conditions. These mature-forest fungi spread slowly by spores from adjoining stands, and will only persist after enough stand development has occurred to maintain root and hyphal contact (Fleming 1984, Fox 1986, Kranabetter and Friesen 2002). The removal of host trees in a clear cut environment has been shown to cause an immediate reduction in ECM mushroom abundance (Wasterlund 1989; Durrall et al. 1999), and a shift in ectomycorrhizal community composition (Kranabetter and Wylie 1998). As an alternative, partial-cutting (up to 60% removal of basal area) was found to maintain mushroom richness and biomass comparable to unharvested stands (Kranabetter and Kroeger 2001). However, it was not clear in previous partial-cut studies whether any shift in mushroom community composition, such as the loss of mature-forest mushroom species, could have occurred.

Mature forest mushroom species were monitored in partial-cut stands from the Helen Lake, Date Creek, and McCully Creek areas and compared to mature and old forest communities from the chronosequence study mentioned above. Due to the intensity of pine mushroom harvesting in these study areas, the pine mushroom fruiting body may not be found during the sampling period. It is assumed however, that the other indicator species will react similarly to the partial-cut conditions, and their presence will indicate some maintenance of pine mushrooms as well.

2.0 OBJECTIVES

The purpose of this study is to:

1. develop a monitoring protocol with ECM mushrooms to test whether managed forests are effective habitat for mature-forest dependent species
2. use the protocol to test whether partial-cut stands in the Kispiox Forest District have maintained mature-forest attributes that favor the growth of late-stage EMC mushroom species, including the pine mushroom
3. make recommendations on monitoring methods for any future assessments of mature-forest habitat using ECM mushrooms.

3.0 METHODS

3.1 Site Description

Five selectively harvested blocks, ranging from 42 to 69% removal, were chosen as monitoring sites in the Date Creek and Helen Lake areas of the Kispiox Forest District. Transect lines were established in blocks where at least three years had elapsed since harvesting to ensure fungal associations had adjusted to the new stand conditions and the ECM communities were not remnant survivors from harvested trees.

These blocks were comprised in part by the 01b site series (Hemlock – Step moss submesic phase) or the 01a site series (Hemlock – Step moss mesic phase) in the Interior Cedar - Hemlock moist cool subzone Hazelton variant (ICHmc2). Transect sample lines were located primarily in the 01b or 01a sections of the block. These sites are primarily dominated by western hemlock (*Tsuga heterophylla*) with scattered western redcedar (*Thuja plicata*). The understory is characterized feathermosses, and a poorly developed shrub and herb layer consisting mainly of scattered blueberry (*Vaccinium* species), conifer regeneration, false azalea (*Menziesia ferruginea)*, bunchberry (*Cornus canadensis*) and twinflower (*Linnaea borealis*). Soils are Orthic Dystric Brunisols or Eluviated-Orthic Humo-ferric Podzols with sandy to silty loam textures and Hemimor humus forms. Surficial materials are morainal or glaciofluvial deposits of varying depths.

3.2 Sampling

Each of the five plots measured 100 x 30 m (3000 m^2 or 0.3 ha) in size. Transect lines down the plot centre and plot edges were marked using flagging tape and spray paint. Plot location maps were created detailing access and plot boundary markings (see Appendix 1).

A Ground Inspection Form was completed at each of the monitoring sites at the 50 m mark along the transect center line, using a standard 20 x 20 m BEC plot size. Site and vegetation information was collected including site series, crown closure (%), tree height, diameter at breast height, and age of the dominant tree species (see Appendix 2 for detailed plot card data).

Basal area was measured along each transect using a BAF 5 prism. Five measurements were taken along the transect line at 20 m intervals, and an average basal area (m^2/ha) was recorded for both western hemlock and western redcedar. Unlike western hemlock, western redcedar is not a host for ectomycorrhizal fungi (Carpenter and Trappe 1970), and was therefore recorded independently.

Mushroom data collection was carried out on September 30 and October 1, 2002. Total ECM mushroom species richness was recorded for each 3000 m^2 plot. Any unknown or questionable mushroom species were collected and later identified in the office. Due to the great variety of previously unidentified species in the *Cortinarius* genus, it was necessary to subdivide these species into the subgroups of Plegmacium, Telamonia, and Seriocybe. The undifferentiating macro-features of *Hebeloma mesophaeum* and *H. sacchariolens* made it necessary to combine these species together in the *Hebeloma crustuliniforme* group. A similar set of data was collected from an ongoing chronosequence study (5 sites in mature and oldgrowth forest in the ICHmc2) between September 24 and 27, 2002.

The abundance of mushroom species within a plot was determined by the presence of mushroom fruiting bodies along five 30 m transect lines measuring 1 m in width. These transects ran perpendicular to the center line at 20 m intervals. The occurrence of each mushroom species found along a transect line was given a value of 20. A species found on 2 of the 5 transects within a plot, for example, would have an abundance value of 40. A species found within the plot, but not on a transect, was given an abundance value of 5. Average mushroom abundance was then determined across the 5 monitoring plots and used to determine percentage similarity. The frequency of mushroom species was determined only by the presence/absence per 3000 m^2 plot, then summed over the 5 monitoring plots to then determine percentage similarity.

4.0 RESULTS AND DISCUSSION

4.1 Site Characteristics

Three of the five monitoring plots were predominantly the 01b site series. The remaining two plots were made up of the 01a site series and a complex of the 01a, 01b, and a minor component of the slightly richer and moister Western hemlock, Western redcedar – Oak fern (03) site series.

Slope and aspect measurements were variable, coinciding with mesoslope position. The soil moisture was between 3 to 4-, and nutrients regimes ranged from B to C-. Soil drainage was rapid to well on morainal blankets, morainal veneers, or thick glacial fluvial deposits. An average visual estimation of moss cover within the plot ranged from 30 to 90%.

Table 1: Site characteristics

Transect Plot	Helen 1	Helen 2	Helen 500	Date 19	Date 20
Site Series	01b	$01a^{6}01b^{2}03^{2}$	01b	$01b^{8}01a^{2}$	01a
Slope (%)	23	9	3	15	5
Aspect (°)	284	97	70	58	225
Mesoslope	UP	CR	CR	UP	LV
Soil Moisture	3	4-	3	3	4
Soil Nutrient	B	C-	B	B	C
Drainage	rapid	well	rapid	rapid	well
Terrain	Mbv	Mb	Mv	FGb	Mb
% Moss Cover	90	70	90	30	40

Coding (B.C. MoF 1998)	
Mesoslope	Terrain
Cr - crest	M – morainal
UP - Upper	FG - glaciofluvial
MD - middle	b – blanket
LW - lower	v – veneer
LV - level	

4.2 Stand Characteristics

Stands in the monitoring plots were predominately western hemlock, with a smaller amount of western redcedar (Table 2). Amabalis fir (*Abies amabalis*), trembling aspen (*Populus tremuloides)*, and paper birch (*Betula papirifera*) was found in the understory, and scattered within the transect plot boundaries. Crown closure percent was made as a visual estimate and ranges from 15 to 35%.

The average remaining basal area was 26 m^2/ha, ranging from 20 to 35 m^2/ha. The overall basal area removal was estimated to be 42-69%. Basal area retention (%) was determined using 60 m^2/ha as an average basal area for natural mature forest in the 01b site series and 73 m^2/ha in the 01a site series. The average basal area of ECM host species (western hemlock) was 23 m^2/ha. The basal area of the western redcedar, a non ECM host species, was generally low, accounting for an average of 13% of the stand composition within the 5 sample sites.

Tree ages of the dominant species in the plots ranged from 118-279 years. Tree ages in the Helen 1 and Helen 500 plots were approximately 120 years, which matches the lower age range of the chronosequence study. The remaining three plots had dominant tree measurements greater than 150 years old, which corresponds well to the higher age range of the chronosequence study.

Table 2: Stand characteristics

Transect Plot	Helen 1	Helen 2	Helen 500	Date 19	Date 20
Hw Basal Area (m^2/ha)	31	16	21	17	28
Cw Basal Area (m^2/ha)	4	7	3	3	0
Total Basal Area (m^2/ha)	35	23	24	20	28
Basal Area Retention %*	58	31	40	33	38
Age	129	150+	118	279	210
Average DBH	28	57	41.5	41	44
Average height	25.5	31.5	24.3	26.5	27.5
Spp. Comp.	Hw/Cw	Hw/Cw	Hw/Cw	Hw	Hw
Crown Closure %	25	30	25	15	35
% Basal Area Removal	42	69	60	67	62

* Basal area retention % was estimated using 60m^2/ha as an average basal area for an unharvested mature forest in the 01b site series; 73m^2/ha was used as the basal area for an unharvested mature forest in the 01a site series.

4.3 Mushroom Indicator Species and Total ECM Richness

Many of the mature-forest indicator species were found in the partial-cut plots (Table 3), with a total of 11 of the 14 indicator species recorded. *Albatrellus flettii* had also been observed at Helen 1 during a reconnaissance visit, but was not included in the final data. On average, 6 mature-forest indicator species were found per partial-cut site, compared to 9 species from each chronsequence plot. The pine mushroom (*Tricholoma magnivelare*), and *Tricholoma robustum* were not found on partial-cut sites during the sampling sessions. These species are most abundant on submesic sites, and so were less likely to occur across the 01a site series of the partial-cuts. The frequency and abundance of mature-forest mushroom indicators for unharvested sites are found in Appendix 4.

Table 3: Mature-forest mushroom indicator abundance† from partial-cut sites.

Species	42% removal Helen 1	69% removal Helen 2	60% removal Helen 500	67% removal Date 19	62% removal Date 20	Frequency Occurrence (%)	Average Abundance (%)
Albatrellus flettii						0	0
Amanita porphyria		5		20	5	60	6
Boletus mirabilis				5	5	40	2
Craterellus tubaeformus		40		20	20	60	16
Chroogomphus tomentosus		5		20		40	5
Cortinarius muscigenus	40	40	5	20		80	21
Cortinarius subscaurus	5			20		40	5
Hygrophorus camarophyllus	20		40			40	12
Hygrophorus saxatilis	20		20			40	8
Russula decolorans	40	20	5	20	5	100	18
Russula occidentalis	20		20	5		60	9
Sarcodon imbricatus*			5			20	1
Tricholoma magnivelare*						0	0
Tricholoma robustum*						0	0
Indicator spp. richness	6	5	6	8	4		
% Indicators present	43	36	43	57	29		

† The occurrence of each mushroom species found along a transect line was given a value of 20. A species found within the plot, but not on a transect, was given a value of 5.
* these species are found in primarily submesic conditions

Table 4: Community similarity between undisturbed and partial-cut forests by indicator species frequency and abundance

Indicator species	Undisturbed forest	Partial-cut	Undisturbed forest	Partial-cut
	by frequency		by abundance	
Albatrellus fletti	60	0	3	0
Amanita porphyria	80	60	10	6
Boletus mirabilis	20	40	4	2
Cantharellus infundibuliformis	60	60	9	16
Chroogomphus tomentosus	60	40	9	5
Cortinarius muscigenus	100	80	48	21
Cortinarius subscaurus	80	40	10	5
Hygrophorus camarophyllus	60	40	9	12
Hygrophorus saxatilis	60	40	6	8
Russula decolorans	80	100	14	18
Russula occidentalis	100	60	25	9
Sarcodon imbricatus	20	10	1	1
Tricholoma magnivelare	40	0	2	0
Tricholoma robustum	60	0	6	0
Percentage similarity	73		67	

The communities of mature-forest mushroom species were compared between partial-cut and undisturbed forests (Table 4). The percentage similarity of indicators was quite high at 73% for frequency, and 67% for abundance. Communities < 50% similarity are considered distinct, and rarely exceed 80% similarity because of natural variability (Pielou 1984), so the results suggest the partial-cut treatment was effective in maintaining a mature-forest mushroom community.

Total richness of the partial-cut plots ranged from 32 to 58 species, with an average of 43 species per 3000 m^2. A complete list of these ECM mushroom species, along with abundances, is found in Appendix 3. In comparison, the chronosequence study from September 24-27 had an average of 81 species per plot from five unharvested mature-forest sites. Based on these 10 sites, basal area retention was a significant but weak predictor of total species richness (Fig 1; $p = 0.05$, adj. r^2 0.32), likely due to site variability, stand structure or climatic variables affecting mushroom fruiting. A similar pattern was found for basal area and indicator frequency (Fig 2). Overall, average species richness decreased by about 45%, so partial-cutting likely lead to some reduction in mushroom habitat. These results suggest that 1.8 ha partial-cut (20 to 30 m^2/ha, or 60% removal) would be equivalent to 1 ha undisturbed forest.

Figure 1: Comparison of total species richness to ECM host basal area

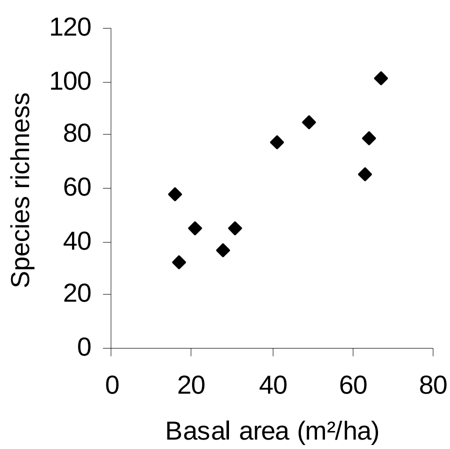
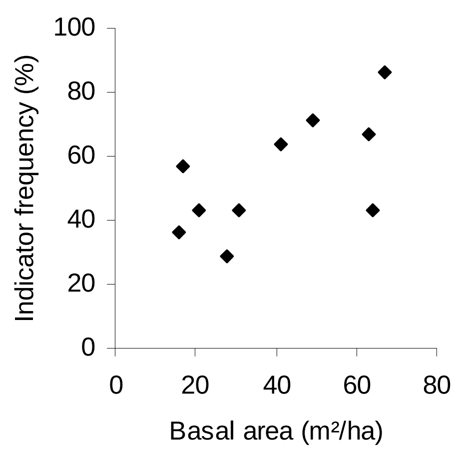


Figure 2: Comparison of indicator frequency to ECM host basal area



The results of this study would suggest these selectively harvested sites have not had a significant shift to mushroom communities represented in younger seral stages. However, partial-cutting appeared to reduce habitat proportional to the amount of basal area removal, and will therefore have an impact on mushroom biomass, including the pine mushroom.

4.4 Monitoring Protocol

Average abundance for each indicator species was generally low in both the partial-cut and natural stands. In the natural mature stands, only two species, *Cortinarius muscigenus* and *Russula occidentalis*, were found with an average abundance greater than 20%, while partial-cut sites had only *Cortinarius muscigenus* with abundances greater than 20%. It is difficult to assess the abundance of mushroom species within a plot, and the technique of 5 smaller transects is prone to over, or underestimate actual abundances. Since collecting data for average species abundance is rather time consuming it is suggested that this information need not be surveyed in future monitoring work.

A second consideration for monitoring is the number and timing of sampling. Some species of mushrooms tend to fruit earlier in the fall while others are more abundant later. A second, earlier sample period would have been effective in capturing the full ECM mushroom community in 2002, such as the missed indicator *Albatrellus flettii* mentioned earlier. Mushroom fruiting in 2002 was slow to start because of dry weather in August, and so it is unclear how representative these results would be in comparison to more typical years. Monitoring over 2 to 3 years would be desirable to account for these seasonal variations, and would further strengthen the correlation between basal area and total mushroom diversity.

A minimum of 5 plots for both partial-cut and unharvested sites would also be encouraged because of the large variability in mushroom crops that can occur naturally. The plot size used in the monitoring program (3000 m^2) was relatively large but was quite effective in capturing the full ECM community. A previous partial-cut study (Kranabetter and Kroeger 2000) used smaller plots that may have contributed to the poorer correlation between diversity and basal area.

The indicator list was determined from submesic sites in the ICHmc2. Not all species can be considered indicators on other site series, although it would be expected that many of them would occur on mesic and perhaps richer sites. In addition, this list may not completely apply to other variants, such as the ICHmc1 or other zones (CWHws2), and certainly not to other forest types without western hemlock, such as the SBS.

It was originally thought that it would be possible to set benchmarks for assessing mature-forest mushroom habitat based on species abundance comparisons; for example, "10 indicator species at a minimum of 20% abundance found in a 3000 m^2 plot" might indicate that mature forest attributes and mushroom habitat was maintained (Bilodeau 2002). However, there is not enough baseline data to set such benchmark criteria, and it is recommend that comparisons with unharvested stands continue. Sorenson's percentage similarity (Pielou 1984), was a simple and useful method to compare mushroom communities. Given that an 80% similarity is a likely maximum in natural species variability among ecologically equivalent communities (Pielou 1984), a 70% similarity to mature forests by species frequency is suggested as the threshold and preliminary benchmark for mature-forest mushroom communities in partial cut stands.

7.0 MANAGEMENT IMPLICATIONS

7.1 Partial-cut Harvesting in High Value Mushroom Habitat

Many of the mushrooms found on partial-cut sites were located around single or small groups of trees where the forest floor remained intact. Since the majority of fine root tips are found in the forest floor, it is likely that minimizing forest floor disturbance around remnant trees would best preserve mushroom habitat. However, some small amounts of light scarification or raking might only disturb the surface moss layer, leaving the fine roots intact, and have little impact on mushroom communities in the long term. There have not been thorough studies of how the varying degrees of forest floor disturbance will affect the persistency or recovery of mushroom colonies, but it is recommend to minimize excessive soil disturbance and forest floor displacement wherever mushroom crops are of a concern.

As mentioned previously in this report, western redcedar is not a host species for ectomycorrhizal fungi. It is therefore important to leave adequate distribution of host species (such as western hemlock and lodgepole pine) as remnant trees in partial-cut stands to maintain mushroom communities.

7.2 Pine Mushroom Habitat Mapping

Photo interpretation of the Date Creek, Helen Lake and McCully Creek chart areas has identified 1848 ha of potential high-value pine mushroom habitat (Friesen and McLennan 2000). GIS analysis has identified that approximately 215 ha (12%) has been impacted by harvesting, 87 ha (40%) is in retention patches or partial-cuts. An additional 339 ha (18%) pine mushroom habitat is either currently approved or proposed for harvesting, and of that total, 80% will be in retention areas or in partial-cuts (Bilodeau 2002).

Current methodology of pine mushroom habitat mapping identifies the target site series (01b) as either a pure unit; or a complex or marginal unit, where the 01b site series would consist of approximately 80 to 95 percent of the polygon area, or being slightly marginal to the 01a or 02 site series (Friesen and McLennan 1999). This original photo line work should be referred to when the decision is made to create a reserve zone or to partial-cut the area. Efforts should focus reserve zones around the larger continuous polygons of pure 01b in order to further mitigate losses of high value pine mushroom habitat.

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