Research Report

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Pine mushroom habitat characteristics and management strategies in the West Kootenay region of British Columbia

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Abstract

This study was initiated by BC Timber Sales (BCTS), in the B.C. Ministry of Forests and Range, to guide its forest management planning for popular pine mushroom (*Tricholoma magnivelare* [Peck] Redhead) harvesting areas near the town of Nakusp in the West Kootenay region of the southern Interior. Pine mushroom habitat was located and mapped in the study areas using information gathered from local harvesters and from ground surveys conducted over a 5-year period. Habitat characteristics were described for 25 plots centred on pine mushroom patches across the study areas. Recommendations were provided to BCTS to incorporate into their forest management plans for the study areas. The study demonstrated how new information on managing for non-timber resources can, when integrated into forest management plans, support pine mushroom harvesting opportunities in conjunction with timber harvesting.

KEYWORDS: *co-management, ecology, matsutake, non-timber forest products, pine mushroom,* Tricholoma magnivelare, *West Kootenay*

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Introduction

The pine mushroom (*Tricholoma magnivelare* [Peck] Redhead), also known as white matsutake or American matsutake (Arora 1991), is an important non-timber forest product in British Columbia. The annual pine mushroom harvest generates both local employment and, with the influx of working people, increased demand for goods and services, thereby contributing to local and regional economies (de Geus 1995; Amaranthus and Pilz 1996).

An ectomycorrhizal fungus, the pine mushroom fruits in association with mature conifers, especially western hemlock *(Tsuga heterophylla),* Douglas-fir *(Pseudotsuga menziesii),* and lodgepole pine *(Pinus contorta)* (Berch and Wiensczyk 2001). Because of the complexity of this relationship and of other growth requirements of this fungus, the pine mushroom has so far resisted artificial cultivation attempts (Hosford *et al.* 1997). World supply of the highly valued mushroom is therefore limited to wild harvests. Given this situation, forest managers are increasingly being challenged to include pine mushroom (as well as other non-timber forest products) in their planning considerations (Cocksedge 2006). In order to accomplish this, they need better information on inventory and management of pine mushrooms.

Little research has been done on designing silvicultural practices to maintain or enhance pine mushroom production. Most of what we know is either anecdotal or based on studies of the Japanese matsutake (Pilz *et al.* 1999). Since the pine mushroom is part of a community of mycorrhizal fungi dependent on late seral stands at least 85 years old (Kranabetter *et al.* 2005), clearcut harvesting renders a site unproductive for pine mushroom for several decades. A simple management strategy would be to reserve all identified pine mushroom producing areas from timber harvest indefinitely. However, given that pine mushrooms fruit in clusters (or "patches") throughout an area, there may be opportunities to harvest some timber without negatively impacting mushroom production. Anecdotal evidence suggests that, on some sites, selective logging can be beneficial to pine mushroom production. Some of the most productive pine mushroom habitats in the West Kootenay region of British Columbia are in stands that have a history of high-grade selective logging. This might be a result of removing non-host species and favouring host tree species or of opening the canopy and changing the environmental conditions of the forest floor. As one respondent to the Pine Mushroom Task Force (de Geus *et al.* 1992) stated, "Logging and mushroom harvesting can be cooperative. Some of the best pine mushroom patches are in areas where selective logging has taken place."

> *Forest managers are increasingly being challenged to include pine mushroom in their planning considerations.*

The first step in developing effective management strategies for pine mushroom is to inventory the resource and, in so doing, identify priority areas for management. Where timber and pine mushroom resources overlap, co-management strategies to maintain or improve pine mushroom production along with timber should then be explored.

Pine Mushroom Research to Date in British Columbia

De Geus (1995) provided a broad overview of pine mushroom harvesting areas in British Columbia, based on the local knowledge of mushroom harvesters and B.C. Ministry of Forests District staff at the time. Berch and Wiensczyk (2001) collected ecological data to classify ecosystem types in which productive pine mushroom patches are found throughout the province.

In northwestern British Columbia, detailed pine mushroom habitat mapping has been carried out based on ecosystem classification of pine mushroom habitat and aerial photographs (Trowbridge *et al.* 1999; Kranabetter *et al.* 2002). Some pine mushroom habitat modelling and mapping has also been done in the Chilliwack Forest District (Freeman 1997; Williams 2002), Port McNeill Forest District (Ehlers 2004), Squamish Forest District (Olivotto 1999), Kispiox Forest District (Rechnell 2001), Cariboo-Chilcotin (Bravi and Chapman 2006), and Nisga'a First Nations traditional territory (Nisga'a Lisims 2002).

In southeastern British Columbia, however, pine mushroom habitat has only been formally documented on a large scale map of the province. The map shows a broad area that encompasses the former Arrow Forest District, reaching from Revelstoke down along either side of the Columbia River Valley, expanding east to Trout Lake and south to Castlegar and Nelson (de Geus 1995). Some of the most popular areas for pine mushroom harvesting are near the town of Nakusp, along the

Upper Arrow reservoir. Several other edible and commercial mushroom species are also harvested in these areas, including white chanterelle *(Cantharellus subalbidus)* and lobster mushroom *(Hypomyces lactifluorum)*. This abundance and diversity of mushrooms, coupled with ease of access and proximity to markets, make these destinations attractive to mushroom harvesters. However, these are also important timber-producing areas, in a region where logging has a dominant influence on the landscape and on the socio-economic fabric. Thus, while the commercial wild mushroom industry adds value to the forested land base and diversity to local economies, forest management planning has not recognized it until recently. The result is that much of the best productive mushroom habitat has been logged.

Study Objectives and Scope

The objectives of this study were to locate, describe, and map productive pine mushroom habitat within forest lands managed by BC Timber Sales in the Arrow-Boundary Forest District; and to recommend co-management strategies for timber and pine mushrooms.

It was not in the scope of this study to quantify pine mushroom productivity or conduct long-term experiments to test the effectiveness of different management practices.

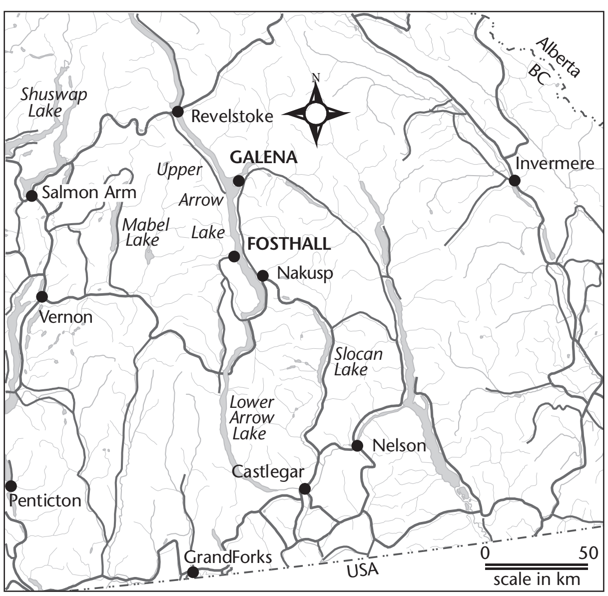

FIGURE 1. Map of the West Kootenay region of Southern British Columbia showing prominent towns and the two study sites, Galena and Fosthall, along Upper Arrow Lake.

Study Area

The study area consisted of two BC Timber Sales (BCTS) management units, Fosthall and Galena, which are near the town of Nakusp along the Upper Arrow reservoir (part of the Columbia River Valley) in the West Kootenay region of the southern Interior of British Columbia (Figure 1). The Fosthall BCTS area, approximately 600 ha in size, is very popular among both transient and resident mushroom pickers. The Galena BCTS area is approximately 200 ha. Topographic features of both management units include relatively flat benches or glaciofluvial terraces, moderate slopes, and some large escarpments.

Methods

Pine Mushroom Habitat Characterization and Inventory

Productive pine mushroom habitat was identified and mapped across the BCTS study areas through interviews with harvesters and ground surveys. Although mushroom harvesters are generally secretive about their foraging grounds, those we approached were cooperative and appreciative of the opportunity to participate in the study.

Ground Surveys

Ground surveys were conducted periodically during August, September, and October from 1998 to 2002. In 1998, we focused on the Fosthall BCTS area only. Galena was added in 1999. Previously marked timber reconnaissance lines that transected the study areas at 100- to 200-m intervals were used to systematically locate and reference pine mushroom patches. Two surveyors walked between two transects, ensuring complete coverage of the area. Pine mushroom patches were marked with flagging tape and a handheld global positioning system, referenced to the nearest station on a transect, and later located on maps. Sampling intensity was variable across each area and over the years as the study's priorities shifted from habitat characterization and mapping to development of specific management recommendations for individual timber harvest units.

We defined a pine mushroom patch as a cluster of pine mushrooms (or sometimes a single mushroom) separated from others by at least 20 m. This operational definition was intended to encompass the shiro, or zone, of underground mycelium of individual pine mushroom colonies. In similar mixed Douglas-fir and western hemlock forests of central Washington Hosford *et al.* (1997) described a shiro diameter of 6 m. By adopting a 20 m separation rule, we were attempting to ensure that the patches we identified were distinct shiros.

Habitat Description

Habitat characteristics associated with eight pine mushroom patches located in the Fosthall and 17 in the Galena BCTS areas were described in detail. The plot centre was established in the middle of a pine mushroom patch (Figure 2). Site, vegetation, and soil characteristics were described following procedures outlined in the *Field Manual for Describing Terrestrial Ecosystems* (B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Forests 1998). Biogeoclimatic site series was classified using the local field guide (Braumandl and Curran 1992).

For 12 plots, a soil pit was excavated next to a pine mushroom to a depth of 60 cm where possible, organic and mineral soil horizons were described, and soil was returned to the pit. Site indices were estimated for Douglas-fir and western hemlock based on height-age models (site index curves) using *Site Tools 3.1* (B.C. Ministry of Forests 1998).

Habitat Mapping in the Fosthall and Galena BCTS Areas

Using the combined anecdotal information (from harvester interviews) and observational information (from ground surveys and habitat descriptions), we delineated productive pine mushroom habitat on 1:10 000 scale maps of the study areas, which also showed existing and proposed roads and timber harvest blocks. We then stratified the entire area according to observed productive potential for pine mushrooms (high, moderate, low) based on the following criteria:

High productivity potential

- Many patches were found in relatively high density during ground surveys.
- Forest cover and ecological characteristics (understorey, soil and terrain features) were uniformly consistent with habitat characteristics described from pine mushroom patches.
- Harvesters we interviewed identified the area as highly productive.

Moderate productivity potential

- Fewer patches per hectare were found during ground surveys.
- Forest cover and ecological characteristics were not uniformly consistent with habitat characteristics described from pine mushroom patches.
- The area may or may not have been identified by harvesters as being productive.

Low productivity potential

- No patches were found during ground surveys.
- Habitat characteristics were inconsistent with data collected from pine mushroom patches.
- The area was not identified by harvesters as being productive.

We also tested the utility of Predictive Ecosystem Mapping (PEM) for predicting the occurrence of the specific pine mushroom habitat types on the BCTS map areas. PEM is a modeled approach to ecosystem mapping, in which knowledge of ecosystem attributes and relationships are used to predict ecosystem representation in the landscape *(http://www.env.gov.bc.ca/ecology/tem/)*.

FIGURE 2. Collecting data from a pine mushroom habitat description plot. Note pine mushroom at plot centre (beside the shovel) and reference tree marked with flagging tape.

Proposed Timber Harvest Impact Analysis

Timber harvesting activities on BCTS lands and other forest lands in British Columbia are detailed in forest development plans that project over five years and are updated annually. In the Fosthall and Galena BCTS areas, silviculture prescriptions and timber harvest planning had been completed prior to this study. We examined these plans to identify where proposed timber harvesting overlapped with the productive pine mushroom habitat that we had identified. Using information avail-

TABLE 1. Soil characteristics at 12 pine mushroom patches in the Galena and Fosthall BCTS planning areas in the West Kootenay region

	Study plots											
	Galena						Fosthall					
	1	2	3	4	5	6	1	2	3	4	5	6
Soil moisture regime	subxeric-submesic	submesic	submesic	submesic	submesic	submesic-mesic	submesic	submesic	submesic	subxeric-submesic	submesic	subxeric-submesic
Soil nutrient regime	poor	poor	poor	poor	poor		poor	poor	poor	poor	poor	poor
Drainage	rapid	rapid	rapid	very rapid-rapid	rapid	well	rapid	rapid	rapid	rapid	rapid	rapid
Soil texture (0–30 cm)	loamy sand-sandy loam	silt loam	loamy sand	loamy sand	silt loam-loamy sand	loam-silt loam	loamy sand	sandy loam	sandy loam-loamy sand	loamy sand	loamy sand-sand	sandy loam
Coarse fragment (%)	60	70	50	70	75	0	0	0	0	75	0	1
Mineral soil horizon depth (cm)[a]												
Ae	1.5	0–2	0–3	0–2	0–3	0–1.5	0–1	0–5	0–2	0–2	0–2	0–3
Bfj	1.5–7.0	n/a	3–60	2–60	3–12	1.5–8	1–110+	5–100+	2–20	2–45	2–24	3–45+
Bm	7–50	2–60	n/a	n/a	n/a	8–64	n/a	n/a	n/a	n/a	n/a	n/a
BC	50+	60–100	60+	60+	12–60+	65+	> 110	> 100	20–65+	45+	24–60+	> 45
Forest floor [a] thickness (cm)												
Ln	2	1.5	1.5	1	1	1.5	1	1.5	0.5	2	2	1
Fm	6	2	3	5	5	3.5	3	4.5	6	5	5	4
Hr	1	0.8	1	1	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total (LFH)	9	4.3	5.5	7	7	5.5	4.5	6.5	7	7.5	7.5	5.5

a For soil classification terms, please refer to B.C. Ministry of Environment Lands and Parks and B.C. Ministry of Forests. 1998. Field manual for describing terrestrial ecosystems. Victoria, BC. Land Management Handbook No. 25.

able in the literature and our field experience, we then made recommendations to BCTS for ways to minimize impacts in proposed timber harvest blocks on pine mushroom habitat.

Results and Discussion

Patch Locations

We recorded 161 pine mushroom patch locations within the Fosthall and Galena BCTS planning areas over the 5-year study period. In 1998, pine mushroom fruiting was poor throughout the West Kootenay region. Our inventory for that year therefore relied largely on information supplied by harvesters as only three patches were found during ground surveys. Better pine mushroom fruiting was observed in successive years and ground surveys generally confirmed the distribution of productive pine mushroom habitat reported by harvesters.

Site and Soil Characteristics

Slope and aspect were variable in the habitat description plots and coarse woody debris cover was low, but moss, needles, and small woody debris covered the forest floor in most plots. Soils were found to be eluviated dystric brunisols. Forest floors were hemimors, averaging 6.4 cm thick (Table 1), with a strongly matted F horizon containing fungal mycelia, often fragrant of pine mushrooms. Soil moisture regime ranged from subxeric to mesic, but was mostly submesic. Soil nutrient regime was consistently poor. Soils were well to rapidly drained and coarse-textured, with high sand content. These characteristics – submesic soil moisture regime and poor, well-drained soils – typify many pine mushroom habitats in much of British Columbia (Berch and Wiensczyk 2001; Kranabetter *et al.* 2002).

Vegetation Characteristics

The cover of dominant trees (> 10 m tall) averaged 73% across the sample plots (Table 2). Western hemlock and Douglas-fir were the predominant species in this layer (Table 3). Moss cover averaged 68%, but shrub and herb cover was low. The most common shrub species were red huckleberry *(Vaccinium parvifolium)* and falsebox *(Paxistima myrsinites)*. Prince's pine *(Chimaphila umbellata)* and rattlesnake plantain *(Goodyera oblongifolia)* had the highest constancy in the dwarf shrub and herb layer. Other species in the herb layer occurring in more than half the plots were queen's cup *(Clintonia uniflora)*, twinflower *(Linnae borealis)*, and bracken fern *(Pteridium aquilinum)*. Falsebox, twinflower, and prince's pine are common to all ecosystem types where pine mushroom habitat has been described in British Columbia (Berch and Wiensczyk 2001; Kranabetter *et al.* 2002). Step moss *(Hylocomium splendens)* and red-stemmed feather moss *(Pleurozium schreberi)* are associated with pine mushroom habitat across the province in all but the SBS and ESSF biogeoclimatic zones (Berch and Wiensczyk 2001).

Submesic soil moisture regime and poor, well-drained soils typify many pine mushroom habitats in much of British Columbia

TABLE 2. Average percent cover of vegetation layers across 25 sample plots (100 m^2) at productive pine mushroom sites

Vegetation layer	Average % cover
A (trees > 10 m)	73
B1 (trees < 10 m)	17
B2 (shrubs > 15 cm)	4
C (herbs, dwarf shrubs)	8
D (mosses, lichens)	68

Stand Characteristics

Stands were generally even-aged, although one plot was located in an old- growth stand (Table 4). Sample tree ages around pine mushroom patches ranged from 92 to 135 years. No patches were found in forests with a large component of paper birch or in stands younger than 90 years. Forest cover types were previously mapped as 80- to140-year-old mixed forests. Our data indicate that pine mushroom habitat in the study area, and in the West Kootenay in general, is largely associated with 100- to 140-year-old stands (age class 6–7) composed primarily of western hemlock and Douglas-fir and often with a component of western white pine *(Pinus monticola)*.

Stand characteristics were summarized as follows (Tables 4 and 5):

- Characteristics of the mature live trees were the most consistent. Density averaged 1125 stems/ha. Basal area (live trees > 4 cm DBH) averaged 61 (+/-5) m^2/ha. Basal area of dead trees averaged 5 (+/-2) m^2/ha.

TABLE 3. Constancy and average percent cover of vegetation species across 25 plots (100 m^2)

	Constancy[a]	Average % cover
A Layer: Tree species (> 10 m)		
Tsuga heterophylla	0.75	31.5
Pseudotsuga menziesii	0.67	24.2
Larix occidentalis	0.42	3.8
Thuja plicata	0.42	2.8
Pinus monticola	0.17	1.7
Betula papyrifera	0.08	1.3
B1 Layer: Tree species (< 10 m)[2]		
Thuja plicata	0.83	9.5
Tsuga heterophylla	0.58	9.2
Pinus monticola	0.25	3.0
Pseudotsuga menziesii	0.17	0.5
B2 Layer: Shrub species (> 15 cm)		
Vaccinium parvifolium	0.72	2.8
Paxistima myrsinites	0.44	2.9
Spiraea betulifolia	0.44	1.5
Vaccinium membranaceum	0.40	2.4
Lonicera utahensis	0.28	0.4
Rosa gymnocarpa	0.24	0.8
Mahonia aquifolium	0.16	0.7
Taxus brevifolia	0.12	2.2
Acer glabrum	0.12	1.3
Lonicera involucrata	0.08	0.6
Shepherdia canadensis	0.04	5.0
Vaccinium ovalifolium	0.04	0.5

	Constancy[a]	Average % cover
C Layer: Herb and low shrub species		
Chimaphila umbellata	0.96	2.6
Goodyera oblongifolia	0.92	0.6
Clintonia uniflora	0.88	0.6
Linnaea borealis	0.84	3.5
Pteridium aquilinum	0.56	1.3
Gaultheria ovatifolia	0.44	0.9
Cornus canadensis	0.32	2.1
Pyrola asarifolia	0.24	0.5
Listera convallarioides	0.12	0.1
Streptopus roseus	0.08	0.8
Tiarella trifoliata	0.08	0.5
Hieracium sp.	0.04	0.5
Equisetum arvense	0.04	0.5
Galium triflorum	0.04	0.5
Osmorhiza chilensis	0.04	0.5
Gymnocarpium dryopteris	0.04	0.1
D Layer: Moss and lichen species		
Pleurozium schreberi	0.96	23.9
Rhytidiopsis robusta	0.96	3.9
Hylocomium splendens	0.88	41.0
Rhytidiadelphus loreus	0.60	10.7
Peltigera aphthosa	0.36	1.8
Ptilium crista-castrensis	0.32	3.56
Dicranum sp.	0.28	1.21
Polytrichum juniperinum	0.04	1.00
Cladina sp.	0.04	0.30

a Constancy is the proportion of plots in which a species occurred.

TABLE 4. Stand characteristics observed in pine mushroom patches recorded from fixed-area plots (100 m^2, n=12)

	Galena	Fosthall	All plots	Range
A layer density (stems/ha)	950	1300	1125 (+/-19)	600–1700
B layer density (stems/ha)	2467	6550	4508 (+/-1710)	900–9500
Basal area (m^2/ha)	55.78	63.92	61 (+/-5)	31.5–89.0
A layer average DBH (cm)	24.5	17.0	20.2 (+/-1.8)	4.5–78.6
B layer average DBH (cm)	8.7	7.6	8.1 (+/-0.6)	4.0–20.7
Crown closure (%)	76	69	74 (+/-4)	54–88
Age	92–250+	100–120	115	92–250
Species composition (% of total stems by species)[a]				
A layer (trees > 10 m)	Hw67Fd33	Hw67Fd33	Hw67Fd33	
B1 layer (> 1.3 m < 10 m)	Cw83Hw17	Hw83Cw17	Hw50Cw50	
B2 layer (< 1.3 m)	Cw80Hw20	Cw50Hw33Pw17	Cw64Hw27Pw9	

a B.C. Ministry of Forests species codes: Hw=western hemlock; Fd=Douglas-fir; Lw=western larch; Cw=western redcedar; Pw=western white pine; Ep=paper birch.

TABLE 5. Constancy and percent of total basal area for both live and dead tree species averaged across 25 variable radius (prism) plots

	Species					
	Hw	Fd	Lw	Cw	Pw	Ep
	Constancy [a]					
Live	0.96	0.92	0.60	0.96	0.28	0.32
Dead	0.24	0.36	0.28	0	0.56	0
	Percent of total basal area					
Live	47.37	25.34	8.56	15.07	2.05	1.60
Dead	13.70	19.18	17.81	0	49.32	0

a Constancy is the proportion of plots in which a species occurred.

- Characteristics of the understorey pole/sapling and regeneration layers were variable (e.g., density of trees < 10 m ranged from 900 to 9500 stems/ha).
- Crown closure averaged 74%.
- Site productivity was low. Site index averaged 16.7 m and 16.5 m for western hemlock and Douglas-fir, respectively, compared with 19.3 m and 24.0 m expected for these species in this ecosystem type (B.C. Ministry of Forests 2003).
- White pine blister rust *(Cronartium ribicola)* and Armillaria root disease *(Armillaria ostoyae)* were common tree pathogens influencing stand structure in productive pine mushroom areas.

Ecological Classification

All sites were classified in the Interior Cedar–Hemlock Moist Warm Columbia-Shuswap (ICHmw2) biogeoclimatic subzone/variant (Braumandl and Curran 1992). Most sites were best classified as being in the 01 site series, although many had characteristics of the 04 and 03 site series. The field guide we used to classify biogeoclimatic units for the former Nelson Forest Region (Braumandl and Curran 1992) indicates that all three site series overlap in the submesic/poor position on the edatopic grid. The guide does not recognize a submesic phase of the ICHmw2-01 site series. The ecosystem classification system is currently being revised for the former Nelson Forest Region, which will help resolve the classification difficulties with these ecosystem types (Lloyd *et al.* 2004).

Pine Mushroom Habitat Mapping

The PEM information provided to us was of limited use in predicting pine mushroom habitat at the stand and site level. PEM maps indicated predicted site series and forest cover polygons within the ICHmw2 for the study areas. However, when we cross-referenced these maps with confirmed pine mushroom sites, as well as doing some field-checking, we found several discrepancies between confirmed and predicted site series classifications. At a scale of 1:20 000, the PEM maps lacked the resolution needed to accurately pinpoint pine mushroom habitat within the study area. Furthermore, some of the mapped site series were not described in the regional BEC guide.

Given these problems, we believe that PEM currently does not offer the accuracy required for pine mushroom habitat mapping at finer spatial scales in the West Kootenay. As noted above, this might be resolved if PEM could better distinguish a submesic phase of the ICHmw2-01 site series, particularly where it is associated with gentler slopes and drier ecosystem types. Terrestrial Ecosystem Mapping (TEM), which uses extensive ground-truthing of ecosystem types interpreted from aerial photographs, is more accurate. TEM was not available for this study, but may be useful for mapping pine mushroom habitat where it is available.

Co-management Strategies for Timber and Pine Mushroom

Using the new information we gathered from field observations and interviews with mushroom harvesters, we then assessed the potential impacts of proposed logging on pine mushroom habitat and made recommendations about how BCTS might adapt existing forest management plans.

In the ground surveys, we located 88 patches in the Galena area, 19 of which were in proposed cutblocks and 69 in areas reserved from timber harvest (Table 6). In the Fosthall area, 73 patches were located on the ground, 31 of which were in proposed cutblocks and 42 in reserve areas (Table 7). Overlaying the pine mushroom inventory information with proposed timber harvest blocks revealed that although the majority of the productive mushroom habitat area would not be affected by logging as planned, some of the most popular mushroom harvesting areas – those with a high concentration of patches – did fall within proposed cutblocks.

TABLE 6. Patch density and relative impact rating for selected timber harvest blocks in Galena

Block and unit number[a]	Silviculture treatment[b]	Year logged	Number of pine mushroom patches	Area (ha)[c]	Patches/ha	Impact rating[d]
1-10	PCP	2003	1	0.81	1.23	M
1-16	PCP	2003	8	0.81	9.88	H
1-17	PCP	2003	1	0.81	1.23	M
1-11	PCP	2003	1	0.81	1.23	M
2-11	PCP	2001	3	0.93	3.23	H
3-6	PCP	2001	3	0.70	4.29	H
3-8	PCP	2001	1	0.70	1.43	M
3-9	PCP	2001	1	0.70	1.43	M
Reserve areas	PCP	no logging	69	-	-	none

a Timber harvest was planned in a series of small units within three larger blocks.

b Silviculture treatment: PCP=partial cut patches.

c Approximate area only. The area is averaged for all units in each block.

d Impact rating (L=low, M=moderate, and H=high) is based on both the total number of patches per hectare and the observed habitat features associated with each block. Only those blocks that received a moderate or high impact rating are included.

TABLE 7. Patch density and relative impact rating for proposed timber harvest blocks in Fosthall

Block number	Silviculture treatment[a]	Year logged	Number of pine mushroom patches	Area: gross ha (net ha)[b]	Patches/ha	Impact rating[c]
1	PCS	2002	3	25.5 (12.0)	0.12	L
2	PCS	2002	0	19.4 (9.0)	0.00	L
3	PCS	2002	0	17.0 (8.1)	0.00	L
4	CCR	not logged	24	32.9 (29.0)	0.73	H
5	PCS	2003	0	16.4 (6.8)	0.00	L
6	PCS	2003	4	24.0 (11.5)	0.17	M
Reserve area	none	no logging	42	~465	0.09	none

a Silviculture treatment: CCR=clearcut with reserves; PCS=partial cut strips.

b Gross area is the total area of the cutblock; net area actually harvested in partial cuts is less.

c Impact rating (L=low, M=moderate and H=high) is based both on the total number of patches per hectare and the observed distribution of productive pine mushroom habitat within the block. The distribution of timber harvesting within blocks was not known at the time of assessment, therefore the gross block area was used to calculate the average number of patches per hectare. The number of patches actually affected by logging would likely be higher.

For those blocks, BCTS had planned three silviculture systems: clearcut with reserves, partial cut in strips, and partial cut in patches.

In Galena, a partial cutting system had been prescribed using a number of small (approximately 1 ha) timber harvest units distributed throughout each block. In Fosthall, all blocks had been prescribed as partial cuts oriented in long strips approximately 30 m wide, except for block 4, which was to be a clearcut with reserves. The gross area of that block was used to calculate patch density because the location of reserves within the block was not known. Only about half of the block was to be logged, but there was no certainty about how logging would impact mushroom patches.

After identifying contentious cutblocks, we made several recommendations to minimize the potential impacts of logging on pine mushroom habitat. Where it could, the BCTS adapted these recommendations to its forest management plans. Among the main recommendations we made:

- Some timber harvest block boundaries should be relocated to avoid identified pine mushroom habitat.
- Some pine mushroom habitat should be maintained in small reserves centred on pine mushroom fruiting locations.
- Wildlife tree patches should be located to encompass productive pine mushroom habitat.
- Single-tree or group selection partial cutting with reserves should be used for the largest site unit with the highest identified pine mushroom values in block 4 in Fosthall, rather than, as originally prescribed, clearcut with reserves. Based on the average basal area of 61 m^2/ha recorded from pine mushroom fruiting locations, as much as 30–40% of the total basal area of the block could be removed while sustaining pine mushroom production if non-host species such as western redcedar and western larch are targeted. Timber harvest should focus on more nutritionally rich and moist areas that are more productive tree-growing sites where fewer pine mushrooms were observed.
- The impact to pine mushroom habitat should be minimized during timber harvesting operations through:
  - manual falling and low-impact skidding;
  - strategic placement of skidding trails to avoid pine mushroom patches;
  - winter logging; and
  - whole-tree skidding to a landing to avoid residual slash loading.
- Logged openings should be regenerated soon after harvest with the appropriate mix of tree species suitable to the site and to mycorrhizal formation with pine mushroom. Suitable mycorrhizal species in the study area include Douglas-fir, western hemlock, and lodgepole pine. Western hemlock should be considered a preferred species in silviculture prescriptions.

These recommendations support compatible management of pine mushrooms and timber in general. Partial cutting that removes timber in small strips and patches is a preferred timber harvest method where pine mushroom habitat can easily be avoided through the strategic location of partial cuts. Harvesting timber in strips requires less road area than harvesting small patches of the same volume of timber, but patches are less visually intrusive. Patches are also easier to design so as to avoid affecting known productive pine mushroom sites. Small openings, such as strips or patches that maintain a high edge-to-area ratio reduce the distance between regenerating seedlings and mature trees. Mature trees reserved from harvest are a major source of fungal inoculum, including the pine mushroom, for regenerating openings (Wiensczyk *et al.* 2002). Many mushroom harvesters interviewed for this study also noted that stand edges are preferred foraging locations. This observation suggests that further investigation is needed into the potential for edge-effect to enhance mushroom fruiting.

Where timber harvesting cannot avoid overlapping with productive pine mushroom habitat, a single-tree selection system that retains some basal area of pine mushroom host trees with good vigour is a preferred option for co-management. This recommendation is supported by Kranabetter and Kroeger (2001), who found that some removal of trees, especially non-host trees, might be possible without affecting the community of ectomycorrhizal fungi. Some of the most popular commercially productive pine mushroom sites in the West Kootenay are in stands that have a history of selective logging.

We do not know how production on previously logged sites compares with that on unlogged sites, but this observation does suggest that some level of logging might be compatible with, and even beneficial for, pine mushroom production. Studies in the Cascade Range of southern Oregon have concluded that timber extracted through well-planned silvicultural prescriptions may provide revenues while maintaining pine mushrooms (Amaranthus *et al.* 1998; Pilz *et al.* 1999) if practices are adapted to site-specific conditions.

FIGURE 3. Pine mushrooms fruiting abundantly in old selectively logged area in Fosthall.

Where timber harvesting cannot avoid overlapping with productive pine mushroom habitat, a single-tree selection system that retains some basal area of pine mushroom host trees with good vigour is a preferred option for co-management.

Conclusions

Although pine mushrooms may occur in a range of forests and ecosystem types, the areas of most concern to mushroom harvesters and forest managers are those that are consistently the most productive and support large scale harvests. These are the areas we attempted to identify and describe in the West Kootenay.

Sustaining wild harvests of pine mushroom and other non-timber forest products in British Columbia depends on forest management planning recognizing the importance of suitable stands and habitat surviving from one growing season to the next. As this study showed, integrating new knowledge about pine mushroom habitat and distribution into forest management plans enables relatively small adjustments to silviculture prescriptions to support pine mushroom harvesting opportunities in conjunction with timber harvesting. Pine mushrooms have been found fruiting in all the reserve areas since logging was done. Even in a small 100 m^2 reserve, pine mushroom, white chanterelle, and several other species of edible mycorrhizal mushroom were found two years after the surrounding area was logged. This relatively simple management action of identifying and reserving some pine mushroom habitat, even at small scales, contributes to sustaining pine mushroom production by maintaining habitat attributes and providing an inoculum source for regenerating stands.

To truly evaluate, within an adaptive management framework, the effectiveness of current co-management strategies, mushroom productivity should be monitored over the long term. Studies that evaluate mushroom productivity in relation to different treatments require some measure of abundance (i.e., kg/ha per year) (Pilz and Molina 2001). If accurate estimates are to be derived, such studies must overcome the challenges of securing exclusive access to monitoring plots and long-term commitments to monitoring.

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Note

This article contains information on the ecology and management of non-timber forest products. In promoting implementation of this information, the user should recognize the equitable sharing of benefits derived from the management and use of this product (Article 8(j) of the United Nations Convention on the Conservation of Biological Diversity). Where possible, the reader should involve the keepers of this knowledge and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with the conservation and sustainable use requirements (Article 10(c)).

FIGURE 4. Close-up of a pine mushroom button emerging from the needle-bed.

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Test Your Knowledge . . .

Pine mushroom habitat characteristics and management strategies in the West Kootenay region of British Columbia

How well can you recall some of the main messages in the preceding Research Report? Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1) What two tree species does pine mushroom commonly associate with in the West Kootenay region of British Columbia?

2) What soil characteristics are typically associated with pine mushroom habitat in British Columbia?

3) What are some options for the co-management of timber and pine mushroom habitat?
   A) Establish pine mushroom habitat reserves
   B) Harvest timber in small patches or strips
   C) Use a single-tree or group selection timber harvest method
   D) All of the above

ANSWERS

3. D

2. Submesic, nutrient poor, well-drained soils

1. Western hemlock and Douglas-fir