An Overview of Pine Mushrooms in the Skeena-Bulkley Region

prepared for

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The pine mushroom (*Tricholoma magnivelare)*

Photo courtesy of Agriculture and Agri-Food Canada

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Abstract

In British Columbia, commercially important wild mushroom species include the morels, chanterelles and the pine mushroom (also known by its scientific name *Tricholoma magnivelare,* and as the American Matsutake, White Matsutake, or an older name*, Armillaria ponderosa)*. It is estimated that the British Columbia wild mushroom industry is valued at about $40 - 45 million dollars with an estimated 1.2 million kilograms harvested annually. The pine mushroom harvest ranges from about 250,000 - 400,000 kilograms per year (Wills et al. 1998). About sixty percent of the provincial pine mushroom harvest originates in the northwest region of the province. The pine mushroom business is largely cash based, attracting many transitional pickers that follow the harvest from Alaska to California. Like many areas in the Pacific Northwest of North America, the Nass-Skeena transition in the Prince Rupert Forest Region is the setting for a modern-day gold rush.

To set the scene we provide historical information on pine mushroom interest and activity in British Columbia from the 1930's on and then move into current information on the ecology of the pine mushroom. We review community issues and concerns around the sustainability of the resource within current land use planning in the Skeena-Bulkley Region, and consider the economic and social impact of the annual pine mushroom harvest on local communities, including First Nations' peoples. We include a list of relevant British Columbia researchers, their areas of research focus or interest, plus a selected list of relevant external researchers. Contact information is given. We also review research that is of significance to the Skeena-Bulkley Region, and give five priorities for future research in this geographic area. The final section reviews strategies to maintain the pine mushroom and other forest fungi. Appended to the report is a listing of research possibilities for pine mushroom inventory, biology and ecology, forest productivity, forest practices, mushroom harvest and socio-economic needs.

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Scope of the Report

Given the short time frame it was necessary to focus on a single mushroom so the logical choice was the pine mushroom. However, we do recognize the importance of the other wild mushrooms such as the boletes, chanterelles and truffles (ectomychorrizal, like the pine mushroom), and the morel, cauliflower and lobster mushrooms (saprophytic). As well, there have been preliminary economic evaluations of mushrooms for nutraceutical and industrial usage (Wills 1998). All could play a role in the development of a local, sustainable, alternative economy. Because of this, we believe there is a role for FRBC in supporting the whole wild mushroom industry in the Skeena-Bulkley Region. Our hope is that this study is just the beginning.

The main objectives of this report are to identify biological research related to the pine mushroom; to identify socio-economic research pertaining to the pine mushroom harvest and the various stakeholders; to identify BC researchers who focus on the pine mushroom or related ectomycorrizal mushrooms; and to identify priorities for further research.

For the purpose of this paper, the term Skeena-Bulkley Region is synonymous with the Prince Rupert Forest Region.

Background

Forest fungi are unable to make their own food, so they are forced to obtain sugars and carbohydrates from other sources. They do so by invading live trees and other plants, by decomposing dead materials such as needles, leaves and woody debris, and by forming intimate relationships with plants where both the fungus and plant benefit from the relationship. One such symbiotic relationship is the mycorrhizal one, where a fungus becomes intimately established inside and around the plant roots. In this relationship the fungus exchanges soil nutrients and water for sugars and carbohydrates produced by the plant. The fungus acts as an extended root system for the plant, providing access to water and soil nutrients that would not otherwise be available. Forest trees in British Columbia (BC) generally require a mycorrhizal association for growth and development. The fungal growth on this subterranean association is the vegetative or non-sexual stage in the development of the fungus. At a certain point, the fungus develops a sexual stage during which sexual spores are formed. This point is characterized by the production of complex and varied fruiting bodies. Mushrooms, conks, and truffles are the fruiting bodies of a variety of different fungi.

Managing forests for mushrooms is increasingly becoming a concern for many resource managers. Management decisions should always be based on the type of fungus. There are three main types of fungi — saprophytic, pathogenic and mycorrhizal. Each group has its own management issues. The major commercial species of mushrooms are either mycorrhizal or saprophytic. Pine mushrooms, chanterelles and boletes form mycorrhizae with many different host trees, while morels are saprophytic.

Mushrooms and other fungi have been a part of many cultures throughout history. They have been used for food, medicines and even tinder. In BC, mushrooms have been a traditional food for many native people (Turner et al. 1987). People with links to continental Europe prefer mushrooms like boletes, chanterelles and morels, while people with links to Asia often prefer the matsutake or pine mushroom.

History of the Pine Mushroom

The matsutake mushroom has been a part of the Japanese culture for centuries (Ohara 1994). Until the 17th and 18th century, matsutake consumption was strictly limited to the nobility class. Today, a gift of a matsutake mushroom is revered by many as it symbolizes fertility, good fortune and happiness.

There are two types of matsutake mushrooms in Japan: *Tricholoma matsutake* and *T. bakamatsutake*. Both mushrooms are similar in appearance and have strong odours and tastes. Since World War II, the Japanese matsutake mushroom has declined despite many efforts to increase its production (Kawai and Ogawa 1981, Futai 1980). The decline has been attributed to a nematode that attacks the matustake host roots and to a build up of woody debris that causes shading at the forest floor. As a result, the Japanese have been forced to look elsewhere for their supply of matsutake mushrooms.

In BC and the Pacific Northwest United States the counterpart to *T. matsutake* and *T. bakamatsutake* is *T. magnivelare*. *T. magnivelare* (referred to as pine mushrooms in this paper to distinguish it from *T. matsutake*, the matsutake mushroom of Asia) is similar in texture, odour and taste to the Asian species. Canadians and Americans with Asian roots began picking pine mushrooms in BC, Washington and Oregon in the 1930s and 1940s (Zeller and Togashi 1934). In the 1970s, large numbers of pine mushrooms were harvested and shipped to Japan from the Pemberton area of BC. Pickers were paid cash and it was reported that on a good day a picker could earn $1,000 (*The Vancouver Sun:* Oct. 17 1978, p.p. A1, 2 and 16, Giant Mushroom Causes Boom). By the early 1980s, pine mushrooms were harvested throughout the province, and the Pacific lumber market and Japanese matsutake production were in serious decline. With the lucrative prices being paid for pine mushrooms and the industry developing on a strictly cash basis, a gold rush mentality set in among the pickers and buyers. The price was so high that it became lucrative to fly pickers by helicopters into inaccessible sites. This has led to conflicts between transient pickers (who follow the mushroom harvest along the Pacific coast) and local pickers.

Local pickers and residents throughout the Pacific Northwest and BC became concerned about the impact of numerous pickers on the long-term productivity of the pine mushrooms. These concerns led to a number workshops and conferences dealing with the sustainability of wild mushrooms. Later on, the Pine Mushroom Task Force was established in BC to identify issues and concerns relating to the pine mushroom harvest (Anonymous 1994). The Task Force recommended a number of options for the management of the pine mushroom industry but to date none have been adopted. One recommendation was the undertaking of scientific research on the ecology of pine mushrooms. This paper comes with recommendations and priorities regarding the scientific research for the pine mushroom industry the Skeena-Bulkey Region.

Ecology of the Pine Mushroom

Host Species and Age

Like many other ectomycorrhizal fungi, the pine mushroom appears to be highly influenced by its host plant. In Asia, the matsutake forms mycorrhizal associations with a variety of pines *(Pinus densiflora, P. karaiensis, P. thunbergii, P. taiwanensis, P. pumila)*, spruce (*Picea glehnii),* fir *(Abies mariesii),* hemlock *(Tsuga dumosa),* and oaks *(Quercus aquifolius* and *Q. pannosa)* (Hosford et al. 1997). On the Pacific coast of North America, pine mushrooms are found predominantly under mixed stands of lodgepole pines (*Pinus contorta*), western hemlock (*Tsuga heterophylla*) and Douglas-fir (*Pseudotsuga menziesii*). They are found to a lesser extent with Pacific silver fir (*Abies amabilis*), western white pine (*P. monticola*), ponderosa pine (*P. ponderosa*) and mountain hemlock (*Tsuga mertensiana*) (Redhead 1997).

Preliminary indications show good pine mushroom sites from the Nass and Shumal Rivers in the Interior Cedar Hemlock Zone (ICH). Western hemlock and lodgepole pine are always present in both the tree canopy (stratum A) and understory (stratum B) layers (Trowbridge and Macadam 1996).

In Japan and the Pacific Northwest, good pine and matsutake mushroom sites are found in both conifer and hardwood forests ranging in age from 35 - 120 years (Hosford et al. 1997, Redhead 1997). Visser (1995) examined a number of different aged stands recovering from fire (6, 41, 65 and 122 years) for ectomycorrhizal fungi and found that pine mushrooms were present only in 122 year-old Jack pine sites in Alberta.

In the Skeena-Bulkley Region, pickers report that prime mushroom sites are always located in stands younger than 200 years. One report indicates that pine mushrooms were collected on the edge of a 15 year-old conifer stand adjacent to a prime pine mushroom forest. Trowbridge and Macadam (1996), indicate that the presence of lodgepole pine on all pine mushroom sites, reflect a maturing seral stage rather than an old-growth or juvenile stage.

Vegetation and Soils

All prime pine mushroom and matsutake forests have an open canopy that permits light to penetrate to the forest floor. Pine mushroom forests in the Pacific Northwest typically have a sparse understory that is dominated by Ericaceous shrubs such as salal (*Gaultheria shallon*), black huckleberry (*Vaccinium membranaceum*) and rhododendron *(Rhododendron albiflorum*). The candy stick plant (*Allotropa virgata*) is often reported to be present, and lichens and feather mosses may also be present on some sites.

On pine mushroom sites in the Nass and Shumal Rivers area, black huckleberry and red huckleberry (*V. parvifolium*), pince's pine (*Chimaphila umbellata*), rattlesnake plantain *(Goodyera ablongifolia),* and some mosses are present (Trowbridge and Macadam 1996). False azalea (*Menziesia ferruginea*), *Hypopitys monotropa, Pterospora andromedea, Corallorrhiza* spp. and ground lichen are also present on good pine mushroom sites in these areas.

Pine mushrooms are not found on bogs or poorly drained soils but are abundant on well-drained soils. Soils at these sites are typically podzols and originate from glacial deposits (Hosford et al. 1997). Podzols are rich in iron and aluminum, indicating nutrient leaching due to high rainfall. A distinctive and well-developed grey coloured A_e horizon indicating nutrient leaching is usually present. Both mycorrhizae and mushroom development occurs in the A soil horizon (Hosford et al. 1997). However, fungal mats of white and grey mycelium are sometimes present at the forest floor-mineral soil interface (Trowbridge and Macadam 1996).

Shiro Development and Ecology

The word shiro is used to describe the underground vegetative structure of a pine mushroom. It comes from the Japanese word meaning castle or domain, and when used as an adjective means white in colour. Japanese mycologists use the word shiro to describe a "subterranean biotic community where mycorrhizal development plays a leading part over the soil constituents, especially soil microbes" (Ohara (1994) cited in Hosford et al. 1997). Our understanding of shiro development and its ecology comes from research done by Japanese mycologists. Fortunately much of this information can be extrapolated to shiro development of the North American pine mushroom.

The growth of the shiro is directly related to mycorrhizal development (Ohara 1981). A number of zones are recognized in shiro development. Refer to Figure 1. Zone 0 contains no roots or mycelia and is the zone in which the advancing mycorrhizae are directed. Zone I contains mycelia and roots but no mycorrhizae. Zone II contains young active mycorrhizae but no mushrooms. This zone will produce next year's mushroom crop. Zone III contains active mycorrhizae that produce this year's mushrooms directly above. After the mushrooms fruit, the soils dry and the mycorrhizae degenerate. Zones IV and V contain decayed mycorrhizae from the previous 2 years of fruiting. Zones VI and VII are the zones in which the old decayed mycorrhizae have been completely sloughed off and the soil has recovered from the effects of mycorrhizae. Shiros are about 25-30 cm deep, and over 60 cm wide in the ring. Each shiro will reach several meters in diameter. Berch, (1996), examining pine mushroom shiros near the Shumal Creek area, reports that there were more blackened and 'carbonized' fine roots directly under and at some distance from the fruiting bodies.

Figure 1—Soil profile of the shiro of *Tricholoma matsutake* (Ohara 1981).

O = zone of roots free from mycorrhizal infection
I = zone of mycellium
II = zone of physiologically active mycorrhizae (next season's AMZ or "active mycorrhizal zone")
III = zone of mycorrhizae for fruiting (AMZ)
IV = zone of decaying mycorrhizae
V = zone of decayed mycorrhizae
VI = zone of sloughed mycorrhizae
VII = zone of soil recovered from mycorrhizal effect

Basidiospores (the initial stage of fungal growth) germinate to produce hyphae and mycelium that eventually colonize roots to produce shiros. Basidiospores are not able to withstand low temperatures and desiccation. Under laboratory conditions matsutake basidiospores remain viable for only 24 hours in low moisture conditions. Their germination is reduced by 50% after 4 days in moist conditions. In controlled experiments, spore germination is stimulated by organic acids and pine needle extracts (Ohta 1986). Pine mushroom mycelium growth on artificial nutrient media is slow, averaging about 1 - 2 cm per month (Berch 1996).

In winter, matsutake mycelia (and presumably pine mushroom mycelia) grow beyond dormant pine rootlets, but in spring, pine rootlets grow faster than mycelia and will grow into the mycelial zone. By summer and fall mycorrhizae have formed and with

the onset of fall rains, mushrooms form above the active mycorrhizae.
Optimal shiro growth occurs in soils that are warm, dry, and low in organic matter and woody debris. In 30-year-old Japanese red pine forests, matsutake management includes weeding, tree trimming and removing excess shrubs and litter. If soils are too dry and warm they are mulched to increase soil moisture and lower the temperatures to levels that are more conducive to shiro growth (Hosford et al. 1997).

Fruiting Body Development

The initial stage of fruiting body development is the production of primordia or small protomushrooms that have the ability to grow larger. In August, well before the onset of the pine mushroom harvest, there are many visible primordia present (Berch 1996). Primordia production and growth are dependent on soil moisture and temperature. In Japan, matsutake primordia will form when the soil is cooled to 20°C or less for 4 to5 days. Tominaga (1975) and other Japanese mycologists use a Hiroshima tunnel made of a wire frame and fine-mesh netting. It is placed over Zone III of the shiro to increase fruiting body development. Artificial watering, additions of ice and air-conditioning were used to control soil temperature. Note that there are two different soil temperatures and moisture requirements for matsutake production. Soils must be warm and dry to enhance shiro production, but cool and moist to enhance fruiting production.

Human Impacts on the Pine Mushroom and Other Fungi

Timber Harvesting and Management

Timber harvesting may affect the pine mushroom by:

- removing the host species;
- removing the tree cover and so changing the amounts of heat, light and moisture available to the fungus;
- scalping or removing the forest floor by mechanical means through the use of skidder or cat blades, and by the dragging of logs;
- accelerating the decomposition of the forest floor through increased heat and light which causes increased decomposer activity;
- compacting the soil which affects the density, permeability, moisture content, and oxygen supply in the soil, and also affects the ability of seedlings to force roots through the soil;
- adding litter and slash that will change the nutrient supply and chemical composition of the soil in a much faster way than would normally happen in an uncut forest;
- reducing the inoculum source for future mycorrhizal associations;
- reducing tree and mycelial health by negatively impacting mycorrhizal association;
- preventing spore dispersal by animals that use mushrooms in their diet;
- burning (with varying intensities and with or without timber harvesting) will change the soil temperature, moisture and nutrient evels impacting pine mushrooms.

Timber harvesting has a negative effect on ectomycorrhizal abundance. Reduction in mycorrhizal fungi has led to reduced tree seedling survival and growth on replanted cutblocks (Amaranthus and Perry 1989, Amaranthus et al. 1990). There is no information specifically on the role of pine mushrooms in tree survival or on the impact of different timber harvesting techniques on pine mushroom survival.

Durall and Jones (1995) released first and second year progress reports on the effects of gap size on the fungal community in the Date Creek area, Prince Rupert Forest Region. They identified mycorrhizal mushrooms in mature stands and gaps ranging in size from $28m^2$ to $4526\ m^2$. As the gap area increased the species richness of mycorrhizal mushrooms decreased. At gap sizes great than approximately $600m^2$ (a 20m x 30m gap) the production of mushrooms was reduced to a few species fruiting very infrequently. Only the fruiting part of the fungus was identified, so they are uncertain yet what effect the gaps have on the subterranean mycorrhizal community.

In the Pacific Northwest, Pilz et al. (1994) are studying the effects of 2 logging treatments (124 residual trees per hectare, and 297 residual trees per hectare) plus one unthinned control on chanterelle fruiting. There is no data yet from this study.

In Japan stands are *thinned* regularly to increase pine mushroom productivity. Penetrating light warms and dries the soil resulting in increased shiro production (Ogawa 1982). *Mild burns* will also reduce the understory layer and allow light penetration to the soil.

Soil compaction reduces the growth of soil mycelia (Bowen 1980). Management practices that involve the use of heavy machinery and soil trampling may reduce pine mushroom growth and productivity.

Mushroom Harvesting

In some similar ways, mushroom harvesting may also affect the sustainability of the pine mushroom.

- Foot traffic may cause soil compaction and the crushing of fruiting bodies and mycelia.
- Over harvesting for sale or personal use may cause a lower rate of pine mushroom reproduction through decreased spore dispersal.
- Over harvesting may cause a decline in the genetic diversity of future pine mushroom populations.
- Removing mushrooms may negatively impact animal populations and the dispersal of spores by animals. The role of mushrooms in the diet of animals is poorly understood.
- Tree health may be compromised due to lagging mycorrhizal associations.
- Removing 'flag' mushrooms, a common practice for competitive pickers, may also contribute to over harvesting. Flag mushrooms are the non-saleable mature mushrooms that are indicators of a good mushroom patch. These are picked and tossed elsewhere to maintain the secrecy of the mushroom site.

- And finally, raking the forest floor to expose the button mushrooms is perhaps the most detrimental picking practice. Raking destroys forest floor habitat and may also destroy pine mushroom mycelia and fruiting body production.

Hosford et al. (1997) report that disturbing slow growing soil mosses by either trampling or searching for pine mushrooms has a negative impact on pine mushrooms.

There are a number of current research projects in the Pacific Northwest involving the effects of fruiting body removal on long-term productivity of edible wild mushrooms (e.g., on chanterelles, Norvell 1995, Largent and Sime 1995).

Pine mushroom research is somewhat behind that of the chanterelles. Hosford et al. (1997) in Washington State and Pilz et al. (1994) in Oregon are looking at the long-term effects of the pine mushroom harvest on its production and commercial value. At both sites there are five treatments. Control sites, where no mushrooms are harvested, are being compared to four different harvest techniques as follows. Mushrooms are harvested with a gentle twist and pull, and the duff layer is not disturbed. Litter and duff layers are removed to the surface of the mycelial layer and not replaced. The litter and duff layers are removed to the surface of the mycelial layer and then replaced. Raking occurs into the mycelial layer and the litter and duff layers are removed and not replaced. And finally, raking occurs into the mycelial layer and the litter and duff layers are removed and then replaced.

Community Issues and Concerns.

The Skeena-Bulkley Region is breathtaking with its vast expanse of stunning mountains, valleys and blue sky. For years it has been known as a prime outdoor recreation area, and more recently, has achieved fame and at times notoriety for the pine mushroom harvest that is taken each fall from private lands, Crown lands, First Nations' territorial lands, and illegally from Provincial Park lands.

Stakeholders

Surrounding the scientific research issues are the sociological and economic issues raised by stakeholders. The stakeholder groups include, but are not limited to First Nations and non-native residents; local and transient pickers; buyers and exporters; the forestry companies that operate in the Skeena-Bulkley Region; the scientific community; the Province of British Columbia through the regulatory, research and extension activities of the Ministry of Forests, the Ministry of Environment, Lands and Parks (Conservation Office Service and Fish and Wildlife), and the Ministry of Agriculture, Fisheries and Food; the Province of British Columbia, Ministry of Attorney General (Provincial Emergency Program); Forest Renewal BC; Aboriginal Affairs; Revenue Canada Taxation; local Civic Governments and Regional Districts; and the Royal Canadian Mounted Police.

The Prince Rupert Forest Region bisects the northern half of the province and includes somewhat less than one quarter of the landmass of British Columbia, Refer to the Appendix B, Forest Region and District Boundaries Map. The six Forest Districts within the Region are the North Coast (Prince Rupert); Kalum (Terrace); Morice (Houston); Lakes (Burns Lake); Bulkley/Cassiar (Smithers); and Kispiox (Hazelton). Each District has known pine mushroom harvesting sites but by far the largest concentrations are in the Nass River Valley, Kalum District and the Hazeltons-Kispiox Valley, Kispiox District. Refer to Appendix B, Known Commercial Pine Mushroom Harvesting Areas in British Columbia.

As well, there are known pine mushroom sites within the Provincial Parks in the Skeena-Bulkley Region. This has its own implication as the harvesting of botanicals, including pine mushrooms, is illegal in Provincial Parks.

Background

For the past 10 years there have been ongoing discussions and public controversy over the pine mushroom harvest in BC. The issues are complex and the concerns are many. The following is a chronology of attempts to define the industry and/or to address stakeholder and public concerns.

Recognition of the potential for the growing pine mushroom industry came with the publication of a brochure called *A New Opportunity … Pine Mushrooms in BC* (Anonymous 1979). The brochure included information on identification and harvesting techniques for the pine mushroom and also set the stage for future attempts by government at qualifying and directing the BC industry.

In January 1989, a Province of British Columbia interdepartmental Wild Mushroom Committee was formed to outline the options for dealing with the growing public concern around the industry, and to make recommendations for regulating a controlled, environmentally sustained pine mushroom harvest. About the same time, commercial mushroom buyers and exporters were encouraged by the Federal Department of Regional Industrial Expansion to form the Canadian Wild Mushroom Association. The stated objective of the Association was to promote the interests and welfare of the industry through marketing programs, research and development, and through knowledge and statistics about the industry. At that time, Association members' estimate of monies paid to pickers for the 1988 season was $12,000,000 at an average rate of $12 per pound (Eligh 1989). Since then, Canadian Wild Mushroom Association activity has declined.

In September 1989, the Integrated Resources Branch of the BC Forest Service received a commissioned report called *The Harvesting of Edible Wild Mushrooms in British Columbia* (Eligh 1989). The concerns raised were the protection of both the mushroom resource and the associated trees; the prevention of forest fires; a lack of training for pickers; picker safety; the contravention of the Park Act (that prohibits the harvest and removal of mushrooms from Provincial Parks); a lack of accurate information about harvesting sites and volumes taken; the ecology of the pine mushroom and the effects of a sustained annual harvest on forest fungi; public safety in the forests; and conflicts by forest users. The report also gave extensive options for the management or regulation of the pine mushroom industry.

In October 1990, at New Aiyansh BC, the Gitlakdamix Council, the National Research Council Canada, and Western Biologicals sponsored a *Pine Mushroom Ecology Workshop,* (Falsetta 1990). The focus of the workshop was to raise awareness of pine mushroom ecology and biology, and to educate pickers about appropriate picking practices. There is no indication in the report if there was a follow-up to look at the effectiveness of the workshop.

In March 1992, intergovernmental discussions with researchers and representatives from the mushroom industry culminated in a report titled *Wild Mushroom Harvesting Discussion Session Minutes* (de Geus et al. 1992). The report focused on the regulatory structures in California, Oregon and Washington State; the increased public concern with over harvesting, destructive collecting, collecting in parks, and civil disturbances; the fear of lost income in small communities should the government decide to regulate the industry; and conflicts over land management practices between timber harvesting and mushroom harvesting proponents.

In September of 1993, the Pine Mushroom Task Force came together to look at a management approach by which government could achieve and maintain a sustainable pine mushroom industry. Chaired by the Ministry of Forests, the group contained 11 representatives from British Columbia Ministries—Forests; Environment, Lands and Parks; Small Business, Tourism and Culture; Aboriginal Affairs; and Agriculture, Fisheries and Foods as well as Agriculture Canada. After extensive discussions with stakeholders around the province the group met in Mesachie Lake in January 1994 to summarize their findings. A first report, *Pine Mushroom Task Force, Workshop Results* (Pine Mushroom Task Force 1994), was released for public discussion. The report called for the licensing of buyers; an increase in the enforcement of existing legislation; the development and distribution of educational materials related to the harvest; the undertaking of scientific research on the ecology of the pine mushroom; and the facilitation of a pine mushroom industry association. A second report added public response to the previous recommendations (Pine Mushroom Task Force 1995). Two most notable items in the latter report are the emphasis on protecting and conserving the pine mushroom resource and its habitat, and the need to include all stakeholders in the management of the mushroom resource.

In February 1995, *A Preliminary Analysis of the Economic Importance of the 1994 Pine Mushroom Industry of the Nass Valley Area, British Columbia* (Meyer 1995) was completed. The results showed an estimated 330,000 pounds of pine mushrooms taken from the Nass Valley study area with estimated harvest revenues of $3,755,400. Shipping and processing added another $2,296,800 to the BC economy. The author noted that these numbers were indicative of a "good mushroom year" and should not be generalized for all years.

The number of person days of picking was estimated at 28,800. An estimated 54% of the harvesters were residents of the Nass Valley area and a further 17.4% were residents of the Terrace/Kitimat area. Twenty-four percent resided in other parts of BC and 3% came from other parts of Canada. An estimated 1% were foreign residents.

Notable in this study was the difficulty of completing the research even with the help of Steve Azak, Chief of the Gitwinksihlkw who exercised overall control of the field work. The sampling protocol initially focused on three areas. Due to unacceptable levels of risk for survey field personnel, the collection protocol was adjusted to exclude the Cranberry Junction. The majority of buyers and brokers cooperated in the study, as did hundreds of mushroom pickers. An estimated 25% of the pickers did not cooperate. Air BC, Canadian Air and Central Mountain Air, operating out of Terrace, were forthcoming with freight information. External Affairs and International Trade Canada both in Ottawa and Japan assisted, as did BC Ministry of Forests personnel Nelly de Geus and Dr. Shannon Berch. This study gives some indication of the problems and complexity of regulation and enforcement around the pine mushroom harvest.

Local Issues and Concerns

First Nations and Conflicts Over Forest Resource Use

First Nations bring to the discussion a history of living with and on the land. They bring a vision of preserving the natural carrying capacity of the land and of enhancing their people and their culture.

With increasing populations, the First Nations are seeking new and challenging employment opportunities for their people. Some are researching valued added and new marketing strategies for the pine mushroom as ways to become less dependent on the mushroom buyers and the fluctuating prices. Others are looking for economic opportunity in alternative forest products such as huckleberries. Certainly, sustainable work that is close to the land, such as timber harvesting, mushroom picking and berry picking, will help them achieve their goals.

Some First Nations are doing work to identify areas of resource conflict with pine mushrooms. The Gitxsan Strategic Watershed Analysis Team (S.W.A.T.) in Old Hazelton have, with the help of external consultants Herb Hammond, Tom Bradley and Fred Philpot, mapped the Fiddler Creek area to identify zones most suited for timber harvest, cultural tourism, wildlife habitat, pine mushroom conservation and more. They have also identified sensitive zones where slopes of greater than 60%, or critical wildlife habitat, should preclude timber harvesting. To honor and preserve their culture, they have mapped the same area (pre-European contact) showing old trails, camps, village sites, hidden villages, medicinal areas, edible food areas and the trade or 'grease' trails as they are called. S.W.A.T. has acquired the necessary skills to repeat these studies in other drainages and the ability to map using current GIS technology. Examples of these maps are appended to the document.

To date, there has been no real dialogue over land use planning between any First Nation in the Skeena-Bulkley Region and the Ministry of Forests. The consultation process might more reasonably be called an information session(s). All the plans and engineering work for the cutblocks are simply presented. First Nations give input but generally find it ignored.

Prime pine mushroom harvesting sites are being lost to clearcuts on an ongoing basis. Unless the pine mushroom resource is protected and managed in a sustainable way, along with other biological forest resources, local First Nations and non-native people will lose these resources and also the long-term economic benefits that the resources provide. Amendments to the current land tenure system and the allowable annual cut need to be seriously considered to balance the rights of all stakeholders. Many First Nations are suggesting the co-management of the pine mushroom resource on territorial lands.

Environmental Damage
Garbage such as plastics, tent frames, cars and other debris are left in camps when the pickers leave. Human waste pits are left unburied. Several of the people interviewed have described the scene as a horrendous mess, one that can harm wildlife and pollute local streams and water bodies. The threat of campers starting forest fires is also a concern.

Currently the Ministry of Forests and the Ministry of Environment, Lands and Parks incur the costs of clean-up and fire fighting. The management of campsites and who bears the costs of clean-up and fire fighting need to be addressed in a management plan.

Safety Issues and Economics of the Harvest
The mainly peaceful year round existence of local residents is interrupted each year from August through October while picking proceeds. Hundreds of pickers arrive by train, plane or private vehicle, including large recreation vehicles and camper vans. With them, comes a criminal element.

The industry runs on cash with buyers holding significant amounts daily. These monies are transferred in cash to pickers who then return to their campsites in the forest or at the roadside. The abundance of cash in the picking community is a ready opportunity for illicit trade in alcohol and drugs, and for thefts and robberies.

"A few years ago we never heard of a seller coming in with bags of pot or cocaine—[it's] within the last three years probably," says Art Loring, Wing Chief, Eagle Clan, Gitx̲san (Loring pers. comm.). "Buyers are being held up in the Cranberry. RCMP [are] involved with the robberies. Vehicles get windows smashed. Tires [are] slashed. A group of Vietnamese [came in] with machine guns. This will continue if camp areas are not enforced."

Price fluctuation is a concern raised by some in the picking community. Much of the trouble between pickers, and also between pickers and buyers is thought to be related to the rapid daily change in the buying price. Pickers anticipate a certain income based on yesterday or last week's rates and become angry, and sometimes hungry, when the price drops quickly.

Both Loring (Loring pers. comm.) and Art Mercer (Mercer pers. comm.), Manager of Nisga'a Economic Enterprises, alluded to price fixing between buyers and brokers. They both observed that most evenings between 7:00 and 9:00 PM the buyers' phones ring steadily between one another. This situation will likely get worse without a concerted effort by all stakeholders to address the many economic and safety issues around the cash based pine mushroom industry.

Regulations

Legislation currently exits to control the harvest of non-botanical forest products. In 1994 the Pine Mushroom Task Force recommended that pine mushroom buyers be licensed. To date, no licensing or regulation exists at the provincial level.

The Royal Canadian Mounted Police Detachments at Smithers, New Hazelton and Terrace currently provide services throughout the main pine mushroom harvesting areas. Smithers has not had an incident in the last three years that could be related to the pine mushroom harvest (Roy pers. comm.). Terrace reports approximately one lost picker per week during the pine mushroom season plus pickers who require provincial or community social services for food and financial aid (Burke pers. comm.). This aid is usually to get the picker home or to the next picking area. New Hazelton reports up to 5000 transient new comers within their jurisdiction during pine mushroom season. Armed robbery, alcohol and drug incidents rise annually (Cheliak pers. comm.). With just thirteen members in their Detachment and 45,000 km^2 to cover, the New Hazelton Detachment are stretched to the limit. They would welcome some form of regulation for the pine mushroom buyers and some way to identify the individuals within the picking community.

A number of First Nations are looking at or involved in monitoring activities on their territories. The Haisla Nation are training watchmen. The Nisga'a Nation have developed a brochure to inform and educate pickers (Mercer pers. comm.). This brochure provides information on access to mushroom picking sites; the harvesting of wild mushrooms; campsite hygiene; campsite monitoring by Provincial authorities and by the Nisga'a Resource Officer; picker safety; the authority and philosophy of the Nisga'a people; and contact information for all with jurisdiction in the Nass Valley forests.

During 1996 and 1997, the Gitxsan Nation administered a picker permitting system on the West Bank of the Skeena (Loring pers. comm.). After some initial actions, seventy-five percent of the pickers now voluntarily sign the picking permits. The picking permits track who is where, and what volumes of mushrooms are being taken. Picking permits are filed anonymously. The Gitxsan Nation also has twenty-four Rangers for conservation, fisheries and peacekeeping.

In 1997 the City of Terrace required all pine mushroom buyers within city limits to comply with existing zoning by-laws (Miller pers. comm.). Pine mushroom buyers were required to obtain a business license and locate in commercial areas with washroom facilities. No temporary structures were allowed. Signage was monitored for safety and clutter. Miller reported 5 to 6 buyers within city limits and several more outside city limits in the Thornhill area. The City of Terrace was pleased with the results of the enforcement.

As shown above, local people are willing and able to work cooperatively with government on regulation and enforcement issues related to the pine mushroom harvest. It is recommended that these regulatory models be encouraged and expanded throughout the Region.

The Parks Act prohibits the picking of pine mushrooms and other biologicals making it illegal to pick mushrooms in all Provincial Parks. It is recommended that local communities assist the Parks Rangers in monitoring for mushroom pickers.

Many people believe that buyers should be licensed. One suggestion was to expand the zoning by-law/business license model used by the City of Terrace. In return for obtaining a license a buyer would provide information on the amounts, grades, origin and price of mushrooms. Revenues could be channeled into enforcement and pine mushroom research projects. Towns, municipalities and Regional Districts could be asked to consider this model. Some people also believe that brokers in Vancouver and other mushroom export centers should declare the types, origin, quantities and value of mushrooms exported from BC.

Many people also believe that pickers should register at designated stations and stay in designated campsites. Designated campsites would help ensure picker safety and campsite sanitation, and also provide opportunities for picker education such as pine mushroom ecology. A nominal fee at the time of picker arrival or departure may offset the cost of managing picker camps.

Research

This section includes two lists:

1) British Columbia researchers actively working on mushroom biology, ecology, or taxonomy.
2) Research from Canada, United States, and Mexico on ectomycorrhizal fungi that is relevant tot the pine mushroom issue in the Skeena-Bulkley region.

British Columbia Researchers

Cariboo Forest Region

Ministry of Forests
200 640 Borland Street, Williams Lake, BC V2G 4T1
Dr. Bill (William) Chapman
Focus: Ecology and impact of soil fungi on long-term site productivity.

Kamloops Forest Region

Ministry of Forests
500 Columbia Street, Kamloops, BC V2C 2T7
Dr. Suzanne Simard
Focus: Carbon transfer and linkages between mycorrhizal fungi and host trees.

Okanagan University College, Biology Department
3333 College Way, Kelowna, BC V1V 1V7
Dr. Dan Durrall
Focus: Mycorrhizal typing, identification and linkage to fruiting body production using Polymerase Chain Reaction (PCR which is a DNA methodology).

Dr. Melanie Jones
Focus: Mycorrhizal typing and nutrient transfer between mycorrhizae and host.

Prince George Forest Region

University of Northern BC, College of Science and Management, Forestry Program
Prince George, BC V2N 4Z9
Dr. Hugues Massicotte
Focus: Mycorrhizal typing and linkage to fruiting body production using PCR.

University of Northern BC, Natural Resources and Environmental Studies
Prince George, BC V2N 4Z9
Dr. Keith Egger
Focus: Mycorrhizal typing using PCR, and interactions with soil bacteria.
Graduate students: Quentin Baldwin, Karen Mah, Keith Williams, Aniko Varga. All are working on aspects of ectomycorrhiza typing. Their work is not specific to pine mushrooms.

Prince Rupert Forest Region

Ministry of Forests
Smithers, BC
Marty Kranabetter
Focus: Mushroom and ectomycorrhizae community structure.

Vancouver Forest Region

Ministry of Forests
Dr. Shannon Berch
1320 Glyn Road, Victoria, BC V8W 3E7
Focus: Ectomycorrhizal and pine mushroom inventory and ecology. Pine mushroom site inventory, ecology and description.
Graduate Students: Fidel Fogarty and Renata Outerbridge

Natural Resources Canada, Canadian Forest Service
Victoria, BC V82 1M5
Dr. Doug Goodman
Focus: Ectomycorrhizal typing and descriptions.

University of British Columbia, Department of Soil Science
Rm 139, 2357 Main Mall, Vancouver, BC V6T 1Z4
Dr. Guoping Xiou
Focus: Application of soil fungi and bacteria to forestry.

University of Victoria, Botany Department
Victoria, BC
Dr. Nancy Turner
Focus: Ethnobotany and ethnomycology for the Pacific Northwest.

Fidel Fogarty, Private Consultant (Forest Pathology/Mycology)
S-12 C-27 RR#2, Gibsons, BC V0N 1V0
Focus: Mushroom diversity and pine mushroom ecology.

Sharmin Gamiet, Private Consultant (Ecology)
Mycology Resources
PO Box 2603, Clearbrook Station, Abbotsford, BC V2T 6R4
Focus: Mushroom diversity, taxonomy and ecology.

Paul Kroeger, Private Consultant (Mushroom Identification)
395 E 40th Avenue, Vancouver, BC V5W 1M1
Focus: Mushroom identification and ecology.

Research Relevant to the Skeena-Bulkley Region

British Columbia

A–D Communications
Box 416, Hazelton, BC V0J 1Y0
Doug and Ann Donaldson
Title: *Action 2000: A journey into the human and economic potential of the Upper Skeena.*
Action 2000 was prepared for the Village of Hazelton and the Gitxsan and Wet'suwet'en Marketing Corporation, funded by Forest Renewal BC. It was a unique planning project – a partnership between a Western model of government and an organization based on a First Nation traditional government. These two partners want to increase local decision-making over the forest land base and create more equal distribution of the wealth generated from the resources harvested in the Kispiox Timber Supply Area. The plan is intended to move communities in the TSA out of passive thinking and into action. It addresses power and wealth. The plan includes strategies to gain some control and influence over decisions affecting the Kispiox TSA's resources. The plan includes observations, conclusions and recommendations. All of the recommendations are currently being implemented.

The plan had a research component and a public consultation component. Appendices include socioeconomic data with information on pine mushroom harvesting in the TSA. One of the recommendations is about marketing in the Upper Skeena. Botanical forest products are also discussed.

Fidel Fogarty, Private Consultant (Forest Pathology/Mycology)
S-12 C-27 RR#2, Gibsons, BC V0N 1V0
PhD Thesis Title: *North American Pine Mushroom (Tricholoma magnivelare Peck, Redhead) In Vitro Mycelia Culture, Ectomycorrhizal Synthesis Trials and Preliminary Shiro Analysis.*
Thesis work includes: the isolation, culture, maintenance and growth of pine mushroom mycelia under lab conditions (in vitro); the testing of isolates for cellulose, lignin and pectin decomposing ability in vitro; ectomycorrhizal synthesis trials with lodgepole pine, western hemlock and Douglas-fir in vitro; and preliminary field investigations of pine mushroom production and shiro in the

Nass Valley.
Current Focus: examining over 100 species of mushrooms, including the commercially valuable macrofungi, under alternative silvicultural systems including clearcut, shelterwood, extended rotation and unlogged control (Sunshine Coast Forest District); analysis for enhanced mushroom production and mapping of shiros; laboratory cultivation of pine mushroom mycelium and field inoculation trials into first and second growth stands; initiation and establishment of a culture bank of isolates of potentially sensitive macrofungi including *T. magnivelare* for conserving genetic material from throughout British Columbia.

Lax-Skiik Landscape Research, Gitxsan Nation
Box 106, Kitwanga, BC V0J 2A0
Art Loring, Eagle Tribe
Focus: *Co-management of pine mushrooms and forestry.*
This research includes the wholistic zoning of lands for timber use, cultural tourism, mushroom harvesting, critical wildlife habitat, and more. The most productive pine mushroom areas were identified and mapped, (see the appended maps by S.W.A.T.) and protection was provided for some sites. Selective harvest systems (single species logging, small patch cuts and overstory cuts) and their effects on pine mushroom fruiting are also being studied. This study is in its fifth year.

Meyer Resources, Inc.
3811 Duke Rd., Metchosin, BC V9C 4B2
Philip Meyer
Title: *A Preliminary Analysis of the Economic Importance of the 1994 Pine Mushroom Industry of the Nass Valley Area, British Columbia.* (Prepared for the Province of BC and the Nisga'a Tribal Council).
This report is reviewed in the section on Community Issues and Concerns, under Background.

Ministry of Forests, Smithers
Bag 5000, Smithers, BC V0J 2N0
Marty Kranabetter
Titles: *Effect of Timber Harvesting on Mushroom and Mycorrhizae in Date Creek Research Forests.*
The Effect of Gap Size on the Fungal Community at Date Creek: Ectomycorrhizae and sporocarps (Parts I and II). First and Second Year Progress Reports (Durall, D. and M. Jones. 1995).
Date Creek has a tremendous community of mycorrhizal fungi. During one period in September, mushroom surveys revealed 80 mycorrhizal species, plus others that could not be identified or were fruiting at different times of the year. Mycorrhizal mushrooms were identified in mature stands and in gaps ranging in size from 28m^2 to 4526 m^2. As the gap area increased the species richness of mycorrhizal mushrooms decreased. At gap sizes greater than approximately 600m^2 (a 20m x 30m gap) the production of mushrooms was reduced to a few species fruiting very infrequently. Only the fruiting part of the fungus was identified, so it is uncertain

yet what effect the gaps have on the subterranean mycorrhizal community.

Title: *Ectomycorrhizal Community Structure Across Forest Openings on Naturally Regenerated Western Hemlock Seedlings (Kranabetter, J.M. and T. Wylie 1997).*
Across large gaps of 50–75 m, western hemlock seedlings were examined to determine fungal richness and distribution. Seedlings under the canopy had the most mycorrhizae (38 fungal mophotypes), while seedlings near the edge had 21% less (30 fungal types). Seedlings furthest into the gap openings had 25 ectomycorrhizal types, 34% less than the seedlings in the mature forest. This research suggests that not all mycorrhizal fungi persist in soils after harvesting. Instead, some mycorrhizae re-enter the harvested area by slowly spreading from roots of mature trees to roots of seedlings in the openings. It is thought that this decline in fungal richness across the gaps is likely temporary.

Title: *Mushroom production under a range of forest basal areas. Plots ranging in basal area (20m^2 per ha to 75m^2 per ha) were selected at Date Creek to monitor the production of ectomycorrhizal mushrooms.*
The study examines the ability of single tree harvesting systems to maintain mushroom production.

Ministry of Forests, Victoria
1320 Glyn Road, Victoria, BC V8W 3E7
Dr. Shannon Berch
Title: *Ecological Description and Classification of Pine Mushroom Sites in Different Regions of the Province (Berch, S. 1998) ed.*
This report is still in the draft stage. Research plots were established in six areas of the province known to support commercial pine mushroom crops. In each area experienced local mushroom pickers assisted in the location of three 25 x 25-m plots in ecosystems typical of highly productive mushroom habitat. Characteristics of site, soil and vegetation were recorded and soil samples were collected for chemical analysis. Plots were established in a range of biogeoclimatic settings spanning seven different subzones.

Title: *Nisga'a Pine Mushroom Pilot Project: Preliminary Investigation of the Ecology and Productivity of Tricholoma magnivelare in the Field and the Lab (Berch, S. 1996).*
In the field, the involvement of local pickers was the best way to generally outline the productive pine mushroom stands on the map and to locate them in the woods. Transects were useful for confirming where in the landscape the pine mushrooms were found. The difficult to access sites (chosen for that specific reason) proved problematic for the researchers. Solutions could include increasing the budget or moving the sites so they are more easily accessed. Intrusion on the study sites by people not involved in the research could be overcome to some extent by talking with the people and explaining the research. In the lab, the pine mushroom failed to form ectomycorrhizae with lodgepole pine, Douglas-fir or western hemlock seedlings and also failed to use cellulose or lignin as a sole carbon source.

Title: *Ecological Description and Classification of the Pine Mushroom Study*

Plots Near the Nass and Shumal Rivers in Northwestern British Columbia (Trowbridge, R. and A. Macadam 1996, for BC Min Forests)
Three pine mushroom plots near the Nass and Shumal rivers were classified into the Submesic phase of the Hw – Step moss site series. Tree, shrub and herb strata were described. Soil moisture and nutrient regimes were designated and the soil layers classified. It was noted that fire was the likely agent of disturbance.

Ministry of Forests, Integrated Resources Branch
Victoria, BC V8W 3E7
Nelly de Geus
Title: *Botanical Forest Products in British Columbia. An Overview (de Geus 1995).*
This report covers industry profiles and harvesting for botanical forest products in British Columbia. It includes wild edible mushrooms; floral and greenery products; medicinal and pharmaceutical products; wild berries and fruit; herb and vegetable products; native landscaping plants; craft products; honey and by-products; syrup; and smoke woods. Resource issues are discussed and recommendations are made.

Titles: *Summary of Public Response: Pine Mushroom Task Force recommendations (Annonymous 1995).*
Pine Mushroom Task Force, Workshop Results (Anonymous 1994).
Wild Mushroom Harvesting Discussion Session Minutes (de Geus 1992).
These three reports are reviewed in the section on Community Issues and Concerns, under Background.

Nlaka'pamux Nation
P.O. Box 430, Lytton, BC V0K 1Z0
Shawn Freeman
Title: *The Identification of Pine Mushroom Producing Habitat in the Nahatlach River Watershed.*

Philpot Forestry Services (1977) Ltd.
4813 Graham Avenue, Terrace, BC V8G 1A9
Fred Philpot, RPF
Focus: *The design and implementation of partial cutting systems in Coastal Western Hemlock (CWH) and Interior Cedar Hemlock (ICH) Biogeoclimatic zones.*

Ontario

Agriculture and Agri-Food Canada
Eastern Cereal and Oilseed Research Centre (ECORC)
960 Carling Avenue, Ottawa, Ont K1A 0C6
Dr. Scott Redhead, Curator of the National Mycological Herbarium (DAOM)
Title: *The pine mushroom industry in Canada and the United States (Redhead, S.A. 1997).*

Monitoring of commercial developments on the pine mushroom industry in Canada and the United States.

Title: *A biogeographical overview of the Canadian mushroom flora (Redhead, S.A. 1989).*
Biogeographical studies on the Canadian mushrooms at the national level, including commercially harvested species such as pine mushrooms, chanterelles, boletes, etc.

Washington State

U.S. Department of the Interior, National Biological Service
Seattle WA 98115
Dr. Rusty Rodriguez
Focus: *Genetic diversity of chanterelles. Impact of harvesting fruiting bodies on genetic structure.*

Central Washington University, Department of Biological Sciences
Ellensburg, WA 98926
Dr. Dave Hosford
Title: *Ecology and management of the commercially harvested American matsutake. Gen. Tech. Rep. PNW-GTR-412. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 68p (Hosford, D. et al. 1997).*
The summary paper begins by reviewing the historical importance of the Japanese matsutake, its declining production and harvest in Japan, the taxonomy of matsutake species worldwide, ecological research pioneered by the Japanese, and how Japanese forests are managed for matsutake production. The discussion of the American matsutake includes descriptions of its distribution, tree hosts, and commercially important habitats, plus a case study of its ecology in central Washington. The authors also examine the social and economic context of its harvest in North America, as well as the biological, ecological and forest management issues that land managers must address to sustain its harvest. They conclude by discussing current matsutake research and monitoring activities in the Pacific Northwest and by explaining the relevance of these activities for integrating the harvest of the American matsutake into forest ecosystem management plans.
Focus: *Soil ecology of pine mushroom shiro production, seasonal variation of pine mushroom fruiting.*

Oregon

Oregon Mycological Society
c/o 13716 SE Oatfield Rd, Milwaukie, OR 97222
Judy Roger
Focus: *Effects of long-term chanterelle harvest on subsequent fruiting. Correlation of weather patterns and chanterelle productivity.*

Oregon State University, Department of Forest Science
Corvallis, OR 97331

Dr. Dan Luoma
Focus: *Response of chanterelle to post harvest green tree retention. Spatial and temporal pine mushroom production.*
This researcher is looking at the response of the chanterelle to logging, while leaving a few living trees. Using sample plots, he is also trying to establish the effects of different harvesting techniques over time and land area.

Dr. Nancy Weber
Focus: *Morel productivity, genetic variability, possible mycorrhizal association.*

Pacific Northwest Mycology Service
6720 NW Skyline Blvd
Portland, OR 97229-1309
Dr. Lorelei Norvell
Title: *The Chanterelle (Cantharellus cibarius): A Peek at Productivity (Norvell, L. with F. Kopecky, J. Lindgren, and J. Roger 1994).*
The Oregon Cantharellus Study Project team has been engaged in long-term research of the chanterelle. In 1986, 10 research plots were established in 100-year old hemlock-Douglas-fir stand in the buffer zone of Mt. Hood's Bull Run watershed to study whether the harvesting of chanterelles adversely affects later fruitings. Data reveal wide fluctuation of overall productivity – indicated by biomass as well as numbers of fruiting bodies – from year to year, harvesting data fail to show that picking chanterelles has an impact on subsequent productivity over the short term.

Focus: *Long-term effects of chanterelle harvesting, chanterelle taxonomy, fungal biodiversity assessment (Forest Ecosystem Management Assessment Team or EMAT).*
Dr. Norvell has published extensively on these topics.

Portland State University, Biology Department
Portland, OR 97207
Dr. Carter
Focus: *Morel productivity, ecology and genetics. Effects of prescribed burns on morel productivity.*

U.S. Department of Agriculture, Forest Service, Corvallis
Pacific Northwest Research Station, Corvallis, OR 9733
Dr. David Pilz
Title: *Managing forest ecosystems to conserve fungus diversity and sustain wild mushroom harvests (Pilz, D.; Molina, R. eds. 1996).*
The publication describes the forest management context of fungus inventory and monitoring issues, summarizes the mycological studies presented at the conference (Ecosystem Management of Forest Fungi, May 1994, Corvallis, Oregon) and provides a synopsis of audience discussion.

Title: *American matsutake mushroom harvesting in the United States: social aspects and opportunities for sustainable development (Pilz D. and R. Molina 1997).*

This research addresses productivity and sustainability of the matsutake crop, as well as management options for enhancing production and regulating the harvest.

Focus: *Sampling methods, productivity, impact of tree thinning and logging on pine and chanterelle mushrooms. Effects of raking on pine mushroom productivity. Monitoring of wild edible mushrooms. Spatial and temporal pine mushroom production.*

Dr. Randy Molina
Title: *Biology, ecology and social aspects of wild edible mushrooms in the Pacific Northwest: a preface to managing a commercial harvest (Molina, R. et al. 1993)*
This overview paper provides information on the biology of forest fungi, describes the major edible fungi in the Pacific Northwest, integrates a perspective on the social aspects of the mushroom harvest, summarizes the development of the commercial mushroom industry, and suggests research and monitoring protocols for developing management guidelines.

Title: *Developing an Inventory and Monitoring Protocol for Commercially Harvested Forest Mushrooms (Molina, R. et al. 1994)*
The authors of this paper acknowledge the controversy about how the forest products' industry should be managed on public lands and note the concerns around the destruction of forest habitat and the gradual loss of the mushroom resource. They suggest that forest resource managers need reliable knowledge about mushroom productivity, yields of commercially harvested species and how these yields may change with variations in forest community composition, climatic conditions, soil types, and timber harvesting and mushroom harvesting activities. They believe that ongoing cooperative studies will provide baseline inventory data on mushroom productivity and habitat ecology so informed decisions can be made.

Focus: *Sampling methods, productivity, impact of tree thinning and logging on pine and chanterelle mushrooms. Effects of raking on pine mushroom productivity. Monitoring of wild edible mushrooms.*

Dr. Jane Smith
Focus: *Morel productivity after tree thinning, prescribed burns and genetic variability. Possible mycorrhizal formation by morels.*

U.S. Department of Agriculture, Forest Service, Grants Pass
Pacific Northwest Research Station, Grants Pass, OR 97526
Dr. Mike Amaranthus
Focus: *Silvicultural treatments, forest floor vegetation on chanterelle productivity. Effects of burn on morel production. Productivity and impact of mushroom harvest on pine mushroom. Monitoring edible mushrooms. Spatial and temporal pine mushroom production.*

U.S. Department of Agriculture, Forest Service, Portland
Pacific Northwest Research Station, Portland, OR 97208
Dr. Max

Focus: *Monitoring mushroom productivity. Efficiency of various sample size shape and numbers for statistical analysis.*
Dr. Weigand
Focus: *Prescription, development and refining of agro-forestry systems. Management practices to increase pine mushroom productivity.*

California

Humboldt State University, Biology Department
Aracata, CA USA
Dr. D. L. Largent
Focus: Chanterelle monitoring and responses to environmental factors.

Mexico

Instituto de Ecologia
Km 2.5 antigua carretera Xalapa a Coatepec, (cerca del Jardin Botanico),
Xalapa, Veracruz 91000, Mexico
Dr. Gaston Guzman
Focus: Systematics of Mexican agaricales and ethnobotanical uses of edible mushrooms including pine mushrooms.

University of Berkeley, Department of Biology
San Francisco, CA USA
Dr. I.H. Chapela
Title: *Wild Edible Mushrooms in Mexico: A Challenge and Opportunity for Sustainable Development (Bandala, V.M., L. Montoya and I.H. Chapela)*
Members of rural communities collect wild edible mushrooms, both for immediate consumption and to obtain additional income through small-scale sales in local markets. With NAFTA there is a trend toward inclusion in global markets. Mushroom production is changing from a source of local self-sustenance to a commodity in the international market, challenging the productive base of Mexican foresters, as well as legal and regulatory systems at the local, national and international levels.

Dr. Chapela is also continuing his research on comparing strains of pine mushrooms from Mexico with Canadian, Pacific Northwestern and Californian pine mushrooms.

Recommended Criteria for Mushroom Research Projects

Projects must be planned and conducted *over a long-term period*. Mushrooms are ephemeral and fruiting is unpredictable and highly dependent on soil moisture. As a result, reliable mycological data can only be collected from research that has been conducted *for a minimum of 5 years*.

Funding must be guaranteed for the project duration.

Data are analyzed by accredited institutions that provide proof of intended cooperation.

If professional *Provincial or Federal mycologists* are involved with the research, *letters of intent* should be submitted.

The *project structure should encourage collaboration* between researchers in the Skeena-Bulkley Region and mycologists in other parts of British Columbia and the Pacific Northwest.

Data from mushroom projects should be collected in such a manner that results can be *compared to research projects currently being done* in Mexico, Japan, elsewhere in Canada, and in the Pacific Northwest of the United States of America.

The *involvement of local researchers and residents* is imperative for the success of all research and monitoring projects. Currently there are a number of pine mushroom research projects being conducted in the region by First Nations' people. It makes sense that new projects build and expand on what has already been done. In this way the data can be analyzed on a larger landscape level.

Security on mushroom research sites is a problem. Research sites must be protected from commercial and recreational pickers. Many different techniques have been tried without success. It is therefore recommended that personnel be present on the research site every day during mushroom season to prevent pickers from disrupting the research project, or that a physical barrier such as a fence be constructed on mushroom research sites.

Research Priorities

Based on our research and discussion with people in the region, we have identified the following five priority areas for mushroom research in the Skeena-Bulkley region.

1. Further characterization of pine mushroom habitat, including site associations, age and structure of forests, and extent of distribution in our region.

2. Based on the habitat characteristics, map (GIS) productive mushroom ground for land use planning and timber supply analysis. Also include habitat characteristics as part of the regional BEC 'Site Identification and Interpretation' field guide so that silvicultural prescriptions acknowledge the potential for pine mushrooms.

3. Examine alternative silvicultural effects on mushrooms either through small, controlled, research plots or adaptive management regimes over larger areas.

4. Socio-economic analysis of the mushroom industry in the Skeena-Bulkley Region, including the need for licensing and monitoring. Also include an economic analysis of the revenue returns from mushroom harvests, timber extraction, and combined management scenarios (i.e. partial cuts).

5. Explore the potential for developing a more diversified mushroom industry by including mushrooms other than the pine. Extend community awareness through workshops on basic mushroom identification, field tours of potentially commercial mushrooms, mushroom conservation and forestry, licensing and marketing, etc.

Strategies to Maintain the Pine Mushroom

Research should be part of an overall strategy to maintain the pine mushroom. The strategy must include forest management **for** mushrooms and monitoring of mushroom productively in managed forests.

Timber Management

There are a number of forest management strategies that may work to assure the continuity of the pine mushroom in the Prince Rupert Forest Region. These strategies range from complete preservation or protection of the pine mushroom habitat to varying degrees of disturbance to the habitat.

As an integral part of each strategy, one must ensure the retention or development of large old trees. These trees are needed to act as host trees for fungi that require large, old trees. Later on, such trees will provide large woody ground debris to host the saprophytic fungi. One must also ensure that for retained trees, a variety of species remain. The known hosts for the pine mushroom must be among them. One must not select against some fungi by removing all trees of a given species. These principles apply in all stands, systems and age classes.

Place highly productive pine mushroom sites in permanent reserves. Where suitable, incorporate highly productive mushroom sites into forest ecosystem networks and connecting corridors that link valley bottoms to alpine ecosystems. It is recognized that the pine mushroom productivity of the site will gradually decline over time as the forest increases in age, but for the next several decades these sites will remain productive for pine mushrooms, and will provide sources of inoculum for recolonization of adjacent disturbed areas.

Extend the length of rotation of timber harvest until past the productive pine mushroom stage. Harvests of timber can be delayed until the forest reaches an age when pine mushroom productivity has declined. The present rotation age for clearcut harvesting is approximately 100 years. Rotations can be extended to 150, 200, 250, or 300 years, to an age when the site is no longer highly productive for pine mushrooms. The extended rotations could include intermediate thinnings or selection harvesting entries throughout the extended rotations, to a level that would not negatively impact the pine mushroom habitat. At the end of the extended rotations, the timber could be clearcut, with retention of single trees and patches of full stand structure to maintain host species and entries of inoculum for colonization of the regenerating forest.

Log single trees to very small groups of two to six trees. This type of selection harvest removes no more than a specified level of basal area or retains a specified level of crown closure. For example one might remove 25 to 30% of the basal area or retain 70 to 75% of the existing crown closure. This system allows filtered sunlight in but minimal direct light and little change to temperature and moisture regime.

Utilize a group selection system to create small canopy gaps (openings) in the forest. Canopy gaps can range in size up to 1 hectare, but the most appropriate size to minimize impact on the pine mushroom habitat would be in the 0.05 to 0.25 hectare range. Remove no more than 25% of the stand basal area in any given entry. Space entries every 25 to 30 years to allow for regeneration. During these years the needed light, heat and moisture regime for the pine mushroom will re-establish allowing the fungus to re-colonize from adjacent stands.

Clearcut an opening while retaining a combination of single trees and patches of full stand structure: the single trees and patches must be dispersed more or less evenly across the opening. Single trees across the opening will act as hosts for the pine mushroom and over time will provide well dispersed, rotted wood for the saprophytic fungi. The patches of full stand structure will provide "lifeboat centers" of inoculum for recolonization into the harvested openings. From 20 to 25% of the stand should be retained to ensure sufficient structure to accomplish the objective of providing adequate host trees and centers of inoculum.

If one had to choose between leaving only single trees or leaving islands, the islands would be the better choice. Compared to single trees, the islands of full stand structure provide a more effective "lifeboat" function because the habitat conditions remain more constant. The drawback is that the islands are less effective at providing good dispersal of rotted wood across the openings because the trees are concentrated in small areas.

Pine Mushroom Plantations and Inoculations

Before environmental manipulation of a forest site for pine mushrooms is conducted we must understand the impact of these measures on the entire ecosystem. For instance, many people have said that forests should be fertilized or irrigated to increase pine mushroom productivity. Application of these methods may adversely affect the forest ecosystem and therefore should not be used without considering the impact on the entire ecosystem.

Pine Mushroom Plantations. In Asia, pine mushrooms are cultivated in pine stands that have been specifically established for pine mushroom production. In Oregon, Douglas-fir Christmas tree farms are inoculated with truffles for both truffle and Christmas tree production. These models should be attempted for enhancing pine mushroom productivity. Controlling soil temperature and moisture using tunnels or ice is feasible only on pine mushroom plantations where one can control the many variables.

Pest Control. Insect damage to growing pine mushrooms can be efficiently controlled only on pine mushroom plantations. The effects of pesticides on natural ecosystems are poorly understood so should be avoided until more information is available.

Monitoring the Pine Mushroom Sites

The first step in a monitoring program is to provide baseline data on the productivity of good, medium and poor mushroom sites. When baseline data has been provided, monitoring projects should include the following.

Monitor changes in forest mushroom productivity. Good, medium and poor mushroom sites should be monitored for changes in mushroom species composition and productivity.

Harvest effects. The effects of long-term harvesting and varying silvicultural systems on the productivity of known shiro and good mushroom sites should be monitored for a period of no less than 10 years. The effects of different harvesting techniques such as pulling mushrooms versus cutting mushrooms on the long-term productivity of mushrooms should be done.

Development of single shiros. Shiros should be monitored over a long-term period to analyze development from initiation to senescence.
Genetic changes in shiro and fruiting bodies after prolonged harvesting. Harvesting mushrooms over a prolonged period may cause genetic changes in a population.

Weather patterns. The influence of weather patterns on the long-term productivity of pine mushrooms should be recorded.

Tree health. Monitor the long term effect of fruiting body removal on tree health. Removing fruiting bodies could negatively impact tree health if the mycorrhizal association is critical to the tree.

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Appendix A … Additional Research Topics

These projects cover a wide range of research under the topics of inventory, biology, ecology, productivity, forest practices, socio-economic research, and mushroom harvesting. If the mushroom program expands, FRBC might consider these.

Inventory

1. *Correlate and theme good, medium and poor pine mushroom sites with the Biogeoclimatic Ecosystem Classification (BEC) system at the zonal, sub-zonal, variant and site series levels.* Pine mushrooms are always associated with conifer hosts and particular vegetation types in BC. Information on sites conducive to pine mushrooms can be used in timber harvesting decisions.

2. *Create a GIS with good, medium and poor pine mushroom sites for the Skeena-Bulkley Forest region.* Once data on pine mushroom productivity are in a GIS, they can be correlated to a number of biotic and abiotic factors across the landscape. Preliminary maps have been created for some sites in the Skeena-Bulkley Forest Region (See enclosed maps).

3. *Identify good, medium, poor and potentially good pine mushroom sites for the entire Skeena-Bulkley Forest region.* Increasingly, the value of pine mushrooms exceeds the value of timber on forest sites in the Skeena-Bulkley Forest Region. It is imperative that these sites be identified and that timber harvest decisions include information on pine mushroom productivity. Identifying these sites, is the initial step to all future research projects.

4. *Develop models that can predict where future good, medium and poor pine mushroom sites may be located in the region.* Long-term forestry planning must include pine mushroom productivity. Decisions on long-term planning will be more accurate with pine mushroom information.

Biology of Pine Mushrooms

1. *Determine the degree of mycorrhization of pine mushrooms.* Mycorrhizal fungi are essential to forest trees for providing them with soil nutrients and water. There are many different fungi that form mycorrhizae with a number of different hosts. It is often reported that directly beneath a pine mushroom fruiting body, the roots are blackened and appear to be dying. It is important to understand whether pine mushrooms form mycorrhizae or are mildly pathogenic with their hosts.

2. *Map and determine shiro growth patterns and development for different sites that have high pine mushroom productivity.* Pine mushroom fruiting is directly related to the health of the underground vegetative stage, the shiro. Some shiros grow in circles, some in arcs and some with no apparent pattern. Understanding the development and stages of shiro growth will facilitate understanding the biology of fruiting body production.

3. *Correlate shiro growth and mushroom production and development.* Japanese and American scientists have mapped and described the different stages of both shiro growth and the shiro zone above which a fruiting body develops. Comparisons between Northern BC, American and Japanese shiro growth will provide valuable information on the biogeography of pine mushrooms.

4. *Study the longevity of shiros.* Pine mushrooms are capable of fruiting for many years on a site. How long the shiros persist in a soil will provide information on how to manage a site for pine mushroom production.

5. *Determine factors that influence spore viability, germination, mycelial growth and mycorrhizal formation.* Understanding the life history of pine mushrooms will provide a basis for future ecological and forestry research. Much research has been conducted on the matsutake species so data collected from BC experiments can be compared to Japanese data. These are essentially laboratory experiments.

6. *Determine the time frame from inoculation to fruiting body development.* In Japan, managing a site over a period of 15 years increases matsutake fruiting body production. An understanding of the time frame between pine mushroom inoculation and fruiting is necessary before forests can be managed to increase fruiting body development.

7. *Research the taxonomic position of different populations of pine mushrooms in the region.* Currently all pine mushrooms in North America are considered to be *Tricholoma magnivelare.* To understand the fungus completely and to manage it, we must understand if we are dealing with one or more species.

8. *Determine the genetic diversity of different shiro and fruiting bodies for various pine mushroom populations.* Different species are adapted to different habitats. We must understand if the same species of pine mushroom is adapted to a variety of habitats or if there are a number of different species adapted to specific habitats.

9. *Examine the influence of soil microbes on vegetative growth.* The growth of many mycorrhizal fungi can be enhanced by growing the fungus with a suit of beneficial bacteria and other microbes. Their influence on the growth of pine mushroom mycelia should be further examined.

10. *Examine the method of pine mushroom dispersal through forests.* How a new population establishes in a forest is important information for management decisions to promote pine mushrooms productivity.

11. *Research the degree of vegetative spread (root contacts, mushroom tissues, etc.) of pine mushrooms in forests.* Most mushrooms are capable of growing and establishing new populations by either spores or mushroom tissue.

12. *Where applicable, determine the influence of man made disturbances such as air pollution on pine mushroom productivity.* High air pollution is the major factor responsible for the decline of ectomycorrhizal fruiting bodies in Europe. While this may not be a

problem in BC at the present time, pine mushroom sites close to industrial pollution may be similarly affected.

Ecology

1. *Correlate host species and age to good, medium and poor pine mushroom sites.* Pine mushrooms are reported to be most commonly associated with BC conifers that are from 60 to under 200 years old. Is this true for the entire region? These theories should be substantiated and proven scientifically.

2. *Correlate soil moisture and temperature to pine mushroom productivity.* Research has proven that mushroom fruiting is triggered by appropriate soil moisture and temperature levels. Determining these levels is important for managing sites for pine mushroom sites.

3. *Determine the fruiting patterns of pine mushrooms for different parts of the region and correlate to weather patterns.* The pine mushroom harvest begins with the onset of the fall rains. Correlating precipitation to pine mushroom fruiting will allow us to manipulate ecosystems for pine mushroom production.

4. *Determine the influence of abiotic factors such as slope, aspect, humus type and depth, and soil structure on fruiting body development and productivity.* Pine mushrooms are always reported to be present where there is a thick A_e soil layer and where there is no standing water, just moist soil. Northern exposed sites may produce pine mushrooms earlier than southern exposed sites.

5. *Correlate the composition and dominance of the understory and herbaceous layer to pine mushroom productivity.* It is reported that good pine mushroom sites are dominated by Ericaceous shrubs and candy stick plants.

6. *Research the importance of pine mushrooms in the diet of forest animals.* The health of an ecosystem includes all organisms. Mushrooms are important to many animals for food. Mushrooms may rely on animals for spore dispersal. This interaction between animals and mushrooms must be further understood.

Forest Productivity

1. *Research the degree of mycorrhization of pine mushrooms with various hosts.* Some fungi are obligate mycorrhizal formers, others are facultative mycorrhizal formers. If pine mushrooms are facultative mycorrhizal formers, then their role in tree health may not be that critical. Furthermore, growing pine mushrooms under artificial conditions may be a viable alternative for maintaining pine mushroom populations.

2. *Determine the mycorrhizal dependency of various hosts at different ages on pine mushrooms.* There is a degree of specificity between host plant and mycorrhizal fungi. Some hosts are highly dependent on a suit of mycorrhizal fungi for their growth. Are pine mushrooms critical for healthy tree growth?

3. *Examine the functional role of pine mushrooms in the symbiotic association between host and fungus.* Mycorrhizal fungi promote tree growth by a variety of methods such as moving water and/or nutrients from the soil to the host; by protecting roots from pathogens; and by increasing the hormonal levels around the root thereby increasing fine root production.

4. *Determine the role of pine mushrooms in tree health.* Pine mushrooms are reported to be pathogenic and form mycorrhizae with their hosts. Roots, found under fruiting bodies and appearing diseased may be the decomposing part or Zones IV, V and VI of the shiro.

Forest Practices

1. *Forest age versus pine mushroom productivity.* If forest harvesting is postponed for a period of time in an area with high value pine mushroom growth, determine at what age of forest would it be reasonable to plan for harvest after the pine mushroom has declined in productivity.

2. *Ectomycorrhizal relationships.* Given large-scale stand replacing disturbances such as clear cuts, determine if, and by what process, ectomycorrhizal fungi and their hosts re-establish their symbiotic relationships.

3. *Timber harvesting strategies.* Determine how removal of the forest canopy affects the pine mushroom. Given the range of timber harvesting strategies available to the forest industry, determine what percent of the forest canopy can be removed without significantly affecting pine mushroom growth.

4. *Effects of canopy openings on fungal species.* Correlate changes in fungal species through time with canopy openings, heat, light, moisture, forest floor, and soil chemistry.

5. *Rate of pine mushroom re-colonization from 'lifeboat' or timber islands.* Determine what size of retained timber 'island' or 'lifeboat' is required to provide for pine mushroom re-colonization in the surrounding opening. Research the rate of spread, and look at optimum spacing for the timber islands.

6. *Compaction.* Given that vehicular traffic compacts the soil, determine how this compaction affects the growth of the pine mushroom.

7. *Re-establishing suitable pine mushroom conditions.* Determine how long it take to re-establish suitable conditions of light, heat and moisture in various sized canopy openings.

8. *Impact of added slash on mushroom production.* For selective logging where there is significant limbing and topping, develop guidelines as to what amount of added slash is acceptable, and what is too much. Look at the affects of added slash on soil chemistry, nutrient status and mushroom production.

9. *Control or Natural Burns.* Fire or heat treatment can stimulate fungal spore germination of many different species. The impact of various intensities of burns on pine mushroom productivity should be explored further.

Mushroom Harvest

1. *Methods of harvesting.* Pine mushrooms are reported to form mycorrhizae with their host tree. Raking will destroy this association so that both, or one of the host tree or the pine mushroom is negatively impacted. Research must look for appropriate methods that cause the least impact on the mycorrhizal association.

2. *Compaction.* Pickers by their trampling on mushroom sites may destroy shiros and in turn the mycorrhizal association. Soil compaction on both shiro development and fruiting body production should be examined in detail.

3. *Pests.* It is reported that 20% of the pine mushroom harvest in BC is destroyed because of insect infestations. Methods for control of pests at buying stations or other venues should be investigated.

4. *Post harvest processing and handling of mushrooms.* Look at ways to maintain the quality of fresh mushrooms, post harvest and to add value through processing or alternative usage.

Socio-Economic Research

Socio-economic research and development should always take place in consultation with the stakeholders and communities that are affected by the research and the outcomes.

1. *The economic impact on local communities varies from place to place.* Determine the costs and benefits to the small business infrastructure within each of the relevant Skeena-Bulkely communities. Document the demands for goods and services.

2. *Value-added opportunities within the pine mushroom market.* Mushrooms do not have a long shelf life. Identify and research the opportunities for post harvest technologies.

3. *Given existing regulations* such as the Litter Act, the Ecological Reserve Act, the Wildlife Act, the Park Act, the Environmental Management Act, the Waste Management Act, and Fire Prevention Regulations, and, given the vastness of the picking area and the difficulty of access, *study and build on existing efforts to enforce these regulations*. Work cooperatively with the RCMP, Ministry of Forests, Ministry of Environment, Lands and Parks and Search and Rescue. The Gitxsan and Nisga'a Nations, as well as the City of Terrace are enforcing regulations. Use their expertise to expand to other communities.

4. *Communicate with the pickers.* Given the diversity among harvesters and buyers (some are transient, others use English as a second language), develop educational methodology to address this diversity. Educational topics could

include the preservation of the forest ecosystem; the existence of legislation and enforcement; personal health and safety, and wilderness skills; the mitigation of risks associated with cash transactions; and the skills and procedures for handling confrontations.

5. *Local communities rely* on the non-taxed income generated by the pine mushroom industry. Determine the impact of the temporary cash based industry on local communities. Identify the pros and cons.

6. *Determine the influence of the pine mushroom harvest on seasonal users of the local forest.* Recreational hikers and pickers, anglers, hunters and related guiding business have a right to use the forest also. Measure the social and economic costs to these groups.

7. *Develop an accurate economic model* that is based on long-term sustainable mushroom productivity and provides site specific picking history; long-term pine mushroom market value fluctuations; tree productivity and ecology, and site specific timber volumes; site specific history of timber harvest volumes and methods; historical timber market value fluctuations. These factors must be correlated to weather patterns. In this way management decisions can be made based on multi resource use.

8. *Identify missed economic opportunities around the pine mushroom harvest.*

Appendix B … Maps

Forest Region and District Boundaries

(From Anonymous (1997), courtesy Province of British Columbia, Ministry of Forests, Victoria, BC).

Known Commercial Pine Mushroom Harvesting Areas in British Columbia

(From de Geus (1995), courtesy of the Integrated Resources Policy Branch, Ministry of Forests, Victoria, BC).

Pine Mushroom Site Maps

Prepared by the Gitxsan Strategic Watershed Analysis Team and Fred Philpot (Copy of this report at Library, MOF Regional Office, Smithers, has full set of maps attached.)