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Development and potential of the cultivated and wild-harvested mushroom industries in the Republic of Korea and British Columbia

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Abstract

Inspired by collaborative work among researchers from the two jurisdictions, we explore the commercial mushroom industry in the Republic of Korea and British Columbia, Canada, searching for similarities and differences that may guide future development. First, we provide a history of forest mushroom use in both areas and summarize the development of the cultivated mushroom industry. Second, we describe the forest-harvested commercial mushrooms. We focus on pine mushroom (*Tricholoma magnivelare*) and provide an overview of the management in Korea of the closely related matsutake (*Tricholoma matsutake*) that could be translated to pine mushroom management in British Columbia. Generally, the cultivated mushroom industry in Korea is much larger and more diverse, reflecting local traditions of mushroom use. There is potential for expansion of the industries in both jurisdictions, especially in British Columbia, through the exploration and exploitation of novel native forest mushrooms and through the cultivation of additional exotic species with demonstrated market value.

KEYWORDS: *commercially harvested forest mushrooms, cultivated mushrooms, non-timber forest products, NTFPs.*

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Introduction

Over the last 50 years, the abundance and diversity of mushrooms marketed as food and medicine around the world have steadily grown. The mushroom industries of the Canadian province of British Columbia and the Republic of Korea (hereafter referred to as Korea) are similar in some respects, yet very different in others. In both areas, growth of the industry represents new prospects, but also new challenges. For example, the growing importance of mycological non-timber forest products (NTFPs) such as pine mushrooms (matsutake), chanterelles, and morels (see Table 1 for scientific names) in British Columbia has resulted in a commensurate need for reliable information to guide the development of the wild-harvested commercial mushroom industry (Forest Practices Board 2004). Moreover, deregulation of the marketing of cultivated commercial mushrooms in the province is creating opportunities and challenges for that industry (B.C. Ministry of Agriculture and Lands 2004) and a need for further research and development.

On the other side of the Pacific Rim, much of the forested land is recovering from the devastation caused by the conflict on the Korean Peninsula in the 1950s. This recovery will mean increased opportunities for development of mushrooms as a forest resource in Korea. Although much of the pertinent research on developing mushroom industries should be done locally, information from different jurisdictions with ecosystems that overlap to some degree can point to opportunities as well as precautions.

British Columbia and Korea are both economically developed with significant exports of matsutake (pine mushroom) and other mushrooms. They also have some ecosystem similarities, but they have significant differences in area, population, and forestry. Korea has 10 times the population in 1/10th the land area. The forested area of Korea is 1/10th and the value of forest industry exports is 1/10 000th of that in British Columbia. Forest ownership is mostly private in Korea and mostly public in British Columbia (Crown land). Conifers dominate more of the forests of British Columbia, and the climate of Korea is on average more clement. A relatively new jurisdiction, British Columbia has a relatively young commercial mushroom industry. Korea, on the other hand, grows many more species commercially, and mushrooms are historically a much more important feature of the local diet.

We explore the similarities and differences in commercial mushroom production in Korea and British Columbia and use this information to illustrate some potential guideposts for future commercial development of mycological forest products.

In this report, we explore the similarities and differences in commercial mushroom production in these two areas and use this information to illustrate some potential guideposts for future commercial development of mycological forest products. The first section focusses on commercially cultivated mushrooms and the second on wild-harvested mushrooms, especially pine mushrooms, or matsutake, because they are a dominant aspect of the mushroom industry in both areas.

Fungi are eukaryotic, heterotrophic, and osmotrophic. They develop a rather diffuse, branched, tubular body (radiating hyphae making up mycelia or colonies), and reproduce by means of spores (Kendrick 1985). The term "mushroom" describes the reproductive structure or fruiting body of a fungus. "In this sense a mushroom, like a potato or persimmon, is not an organism, but a part of an organism" (Arora 1986:4). Commercial mushrooms are either produced in cultivation or harvested from the wild, including forests. The species produced in cultivation are all decomposers (or saprobes) capable of completing their life cycles on dead organic matter. Most of the forest-harvested mushrooms are ectomycorrhizal and can therefore form fruiting bodies only when growing with living host trees. Others, such as fire-associated morels, have more complex life cycles combining attributes of decomposers and mycorrhizal fungi (Pilz *et al.* 2007).

TABLE 1. Mushrooms with commercial activity or potential in the Republic of Korea and British Columbia. Given the state of knowledge about the native mushrooms in both jurisdictions, a "–" under "Native" could mean that the species has not yet been reported.

		Republic of Korea			British Columbia		
Species	**Common name[a]**	**Native**	**Wild-harvested**	**Cultivated**	**Native**	**Wild-harvested**	**Cultivated**
Agaricus bisporus	button mushroom	–	–	+	–	–	+
Agaricus brasiliensis	Brazilian blazei, almond portobello	–	–	+	–	–	–
Agrocybe aegerita	swordbelt mushroom	–	–	–	–	–	+
Amanita hemibapha subsp. *hemibapha*		+	+	–	–	–	–
Armillaria mellea	honey mushroom	+	+	–	–	–	–
Armillaria ostoyae and others	honey mushroom	–	–	–	+	+	–
Auricularia auricula	cloud ears	+	+	+	+	+	–
Auricularia polytricha	wood ears	+	+	+	–	–	–
Boletus edulis	king bolete	–	–	–	+	+	–
Boletus mirabilis	admirable bolete	–	–	–	+	+	–
Boletus smithii	Smith's bolete	–	–	–	+	+	–
Boletus zelleri	Zeller's bolete	–	–	–	+	+	–
Calvatia gigantea	giant puffball	–	–	–	+	+	–
Cantharellus cibarius	chanterelle	+	+	–	–	–	–
Cantharellus cibarius var. *roseocanus*	rainbow chanterelle	–	–	–	+	+	–
Cantharellus formosus	Pacific golden chanterelle	–	–	–	+	+	–
Cantharellus subalbidus	white chanterelle	–	–	–	+	+	–
Chlorophyllum rachodes	shaggy parasol	–	–	–	+	+	–
Clavulina cristata		+	–	–	+	+	–
Clitocybe nuda	blewit	–	–	–	+	+	
Coprinus comatus	shaggy mane	+	–	+	+	+	–
Cordyceps militaris	caterpillar fungus	+	+	+	+	–	–
Craterellus cornucopioides	horn of plenty	+	+	–	+	+	–
Craterellus tubaeformis	winter chanterelle	+	–	–	+	+	–
Dictyophora indusiata	long net stinkhorn, veiled lady	+	+	–	–	–	–
Flammulina velutipes	enokitake, velvet foot	+	+	+	+	–	+
Fomes fomentarius	amadou, tinder conk	+	–	–	+	–	–
Fomitopsis officinalis	quinine conk	–	–	–	+	+	–
Ganoderma applanatum	artist's conk	+	+	–	+	+	–
Ganoderma lucidum	reishi, ling chi	+	+	+	–	–	+
Ganoderma tsugae		+	–	–	+	+	–
Gomphus clavatus	pig's ears	–	–	–	+	+	–
Grifola frondosa	maitake, hen-of-the-woods	+	+	+	–	–	–
Gyromitra esculenta[b]	false morel[b]	+	–	–	+	+	–
Gyromitra gigas[b]	snowbank false morel[b]	–	–	–	+	+	–
Hericium abietis	conifer coral mushroom	–	–	–	+	+	–
Hericium erinaceus	lion's mane, pom pom	+	+	+	+	+	–
Hericium ramosum	comb hericium	+	+	–	+	–	–
Hydnum repandum	hedgehog mushroom	+	+	–	+	+	–
Hygrophorus russula	Russula–like waxy cap	+	+	–	+	–	–
Hypholoma capnoides	clustered woodlover	–	–	–	+	–	–
Hypholoma fasciculare	sulfur tuft	–	–	–	+	–	+[c]
Hypholoma sublateritium	red woodlover, kuritake	–	–	–	+[d]	–	–
Hypomyces lactifluorum on *Russula*	lobster mushroom	—	–	–	+	+	–
Hypsizygus marmoreus		+	–	+	–	–	–
Hypsizygus ulmarius	elm oyster mushroom	–	–	–	+	–	–
Inonotus obliquus	chaga	+	+	–	+	–	–
Lactarius deliciosus	saffron milkcap	–	–	–	+	+	–

TABLE 1. *Continued*

Species	Common name[a]	Republic of Korea			British Columbia		
		Native	Wild-harvested	Cultivated	Native	Wild-harvested	Cultivated
Lactarius rubrilacteus		–	–	–	+	+	–
Laetiporus conifericola	chicken-of-the-woods	–	–	–	+	–	–
Leccinum aurantiacum		–	–	–	+	+	–
Leccinum scabrum	birch bolete	+	–	–	+	+	–
Lentinula edodes	shiitake	+	+	+	–	–	+
Lentinus lepideus	train-wrecker	+	+	–	+	–	–
Lycoperdon perlatum	gemmed puffball	+	–	–	+	+	–
Lyophyllum decastes	fried chicken mushroom	+	–	–	+	+	–
Macrolepiota procera	parasol mushroom	+	+	–	–	–	–
Marasmius oreades	fairy ring mushroom	+	–	–	+	+	–
Morchella elata	black morel	–	–	–	+	+	–
Morchella esculenta	yellow morel	+	+	–	+	+	–
Phellinus spp.	conks	+	+	+	+	–	–
Pholiota nameko	nameko	–	–	–	–	–	–
Piptoporus betulinus	birch polypore	+	–	–	+	–	–
Pleurocybella porrigens	angel wings	+	–	–	+	+	–
Pleurotus citrinopileatus	golden oyster mushroom	–	–	+	–	–	+
Pleurotus cystidiosus	abalone mushroom	–	–	+	–	–	+
Pleurotus djamor	pink oyster mushroom	–	–	+	–	–	+
Pleurotus eryngii	king oyster mushroom, cardoncello	–	–	+	–	–	+
Pleurotus ostreatus	oyster mushroom, hiratake	+	+	+	+	+	+
Polyozellus multiplex	blue chanterelle	+	+	–	+	+	–
Ramaria botrytis		+	+	–	–	–	–
Ramaria campestris		+	+	–	–	–	–
Rhodophyllus crassipes		+	+	–	–	–	–
Russula virescens	green-cracking russula	+	+	–	+	–	–
Sarcodon aspratus		+	+	–	–	–	–
Sparassis crispa	cauliflower mushroom	+	+	+	+	+	–
Stropharia rugosoannulata	king stropharia	+	–	–	–	–	–
Suillus brevipes	short-footed suillus	–	–	–	+	+	–
Suillus granulatus		+	–	–	+	+	–
Suillus lakei	Lake's suillus	–	–	–	+	+	–
Suillus luteus	slippery jack	+	–	–	+	+	–
Suillus subolivaceus		–	–	–	+	+	–
Trametes versicolor	turkey tail	+	+	–	+	+	–
Tremella foliacea	brown witch's butter	+	+	–	+	–	–
Tremella fuciformis	silver ear	+	+	–	–	–	–
Tricholoma caligatum	booted tricholoma	–	–	–	+	+	–
Tricholoma magnivelare	pine mushroom	–	–	–	+	+	–
Tricholoma matsutake	matsutake	+	+	–	–	–	–
Tuber gibbosum	Oregon white truffle	–	–	–	+	+	–
Verpa bohemica	early morel	–	–	–	+	+	–
Volvariella volvacea	paddy straw mushroom	+	–	–	+	–	+
Wolfiporia extensa	fuling, tuckahoe	+	+	+	+[d]	–	–

[a] Common names primarily after Arora (1986), Stamets (2005), and RogersMushrooms (n.d.).

[b] Poisonous when raw.

[c] Cultivated mycelium used in British Columbia for *Armillaria* speices biocontrol (Chapman *et al.* 2004).

[d] Known from only one collection in British Columbia, as reported in Pacific Forestry Centre (n.d.) and University of British Columbia (n.d.)

Pre-Cultivation History and Uses of Edible and Medicinal Mushrooms in Korea and British Columbia

Some 2327 species of wild edible and medicinal fungi are collected, consumed, and traded worldwide (Boa 2004). The historic use of wild fungi has been documented in Chile by archeological records going back 13 000 years (Rojas and Mansur 1995) and by written record in China for over 2000 years (Boa 2004). Wild fungi are used for food, medicine, and a variety of other ceremonial and utilitarian purposes such as tinder, smudge, styptic, dyes, and fabric.

Fossil evidence shows that humans have occupied eastern Asia for over a half-million years (Diamond 1997). Accounts of medicinal mushrooms in eastern Asia (e.g., Ying *et al.* 1987) are replete with examples, suggesting a long tradition of mushroom consumption. In one ancient example from the Korean Goryeo Dynasty (918–1392 BCE), *Wolfiporia extensa* was listed as one of the medicinal materials sent to the Chinese Song Dynasty (Institute of Korean Culture 1971). Species indigenous to each region of Korea were recorded during the Joseon Dynasty in a work entitled *Sejong-sillog-jilij*i (CE 1454). Five mushroom species were mentioned, including matsutake and shiitake (Institute of Korean Culture 1971). According to Jung (1993), the *Dongui-bogam* (*Exemplar of Korean Medicine*), written by Heo Jun in 1613, recorded seven medicinal mushrooms (*Auricularia auricula*, *Grifola umbellata*, *Lentinula edodes*, *Morchella* sp. possibly *esculenta*, *Phellinus linteus*, *Tricholoma matsutake*, and *Wolfiporia extensa*).

Habitation of North America began relatively recently, most likely around 12 000 BPE with the migration of Clovis people from Asia (Diamond 1997). The Thompson aboriginal, or First Nations, people of southern interior British Columbia have historically consumed a variety of wild-harvested mushrooms, including chanterelles (*Cantharellus* spp.), shaggy manes (*Coprinus comatus*), oyster mushrooms (*Pleurotus* spp.), pine mushroom (*Tricholoma magnivelare*), cottonwood or poplar mushroom (*Tricholoma populinum*), slippery top (*Hygrophorus gliocyclus*), unidentified puffballs, and a mushroom called "thunder-storm head" or "lightning" mushroom (Turner *et al.* 1987, 1990; Turner 1997). In contrast, the British Columbia coastal First Nations are not known traditionally to have consumed mushrooms (Turner 1995).

Indian paint fungus (*Echinodontium tinctorium*) was used as the source of red pigment in many parts of the province, and various bracket fungi (e.g., *Fomes fomentarius* and *Fomitopsis pinicola*) were used as tinder, for tanning animal hides, and as a smudge that repelled insects (Turner 1998; Marles *et al.* 1999). The Tlingit, Haida, Tsimshian, and other coastal First Nations used the large conks of the brown trunk rot fungus (*Fomitopsis officinalis*) for carving spirit figures and for medicine (Blanchette *et al.* 1992). Various other fungi were used in traditional medicines by the Thompson people (Turner *et al.* 1990) and other First Nations, including bracket fungi such as *Fomitopsis pinicola*, *Inonotus obliquus*, *Ischnoderma resinosum*, and *Trametes suaveolens* (Marles *et al.* 1999). Spores of puffballs (possibly *Bovista* and *Lycoperdon* spp.) were dusted on wounds and infections by the Bella Coola people (Turner 1973).

As food, commonly cultivated mushrooms are rich in protein and carbohydrates, moderate in fibre, low in fat and calories, and a good source of essential amino acids, vitamins, and minerals (Chang and Miles 2004). As medicine, they have long been recognized in Asia for their curative and preventive properties (e.g., Ying *et al.* 1987). The bioactive compounds in mushrooms—polysaccharides, glycoproteins, ergosterols, triterpenes, and antibiotics—exhibit anti-inflammatory, anti-cancer, anti-cholesterol, anti-diabetic, anti-fatiguing, anti-fibriotic, anti-microbial, anti-oxidative, anti-viral, and chemo-protective properties (Stamets 2002).

Cultivated Mushrooms

History of Mushroom Cultivation

Mushroom crops were first cultivated in eastern Asia starting with *Auricularia auricula* in China about CE 600 (Chang 1993). Cultivation in Korea was first recorded in the book *Salrim-gyeongje* (in 1715) during the Joseon Dynasty (Institute of Korean Culture 1971). Though the described cultivation method is primitive, it indicates a fundamental understanding of growth requirements. Extensive mushroom cultivation in Korea started in the mid- to late 1900s, first with shiitake (1957), then button mushroom (1965), and oyster mushroom (1974). Since then, about 14 mushroom species (including enokitake, reishi, king oyster mushroom, and fuling) have been cultivated and marketed (You 2003). Government institutes and mushroom spawn companies have developed techniques for the cultivation of new mushrooms.

Similar to the situation in Korea, large-scale commercial cultivation of button mushrooms in British Columbia grew from the early 1950s well into the late 1980s (J. Curtis, B.C. Ministry of Agriculture and Lands, pers. comm., 2005). Originally, they were grower co-operatives with growers benefiting from combining their marketing and selling efforts. Currently, seven marketing and distribution companies operate in British Columbia.

The Species and Their Value

In British Columbia, the only cultivated species for which there is data is the button mushroom (*Agaricus bisporus*) and its strains and growth forms such as white button (Figure 1a), brown button, crimini, portabellini, and portobello. Although species and varieties referred to as "specialty mushrooms" are cultivated in the province, no published data exists for them (Table 1; B. Chalmers, Western Biologicals, pers. comm., 2005). It has been reported that *Pleurotus ostreatus* (oyster mushroom) and *Sparassis crispa* are commercially harvested from the forests (Berch and Cocksedge 2003), but we don't know how important this activity is because no data has been collected. However, we know from personal experience that these species and others are collected for personal use. *Ganoderma lucidum* is an important medicinal mushroom (e.g., Gao *et al*. 2004) that is both wild-harvested and cultivated in Korea

FIGURE 1. Examples of commercially important cultivated mushrooms in British Columbia (a) (photo credit: J. Curtis, B.C. Ministry of Agriculture and Lands) and the Republic of Korea (a–g): (a) typical button mushroom, *Agaricus bisporus*; (b) enokitake, *Flammulina velutipes*; (c) *Sparassis crispa*; (d) king oyster mushroom, *Pleurotus eryngii*; (e) monkey head, *Hericium erinaceum*; (f) maitake, *Grifola frondosa;* (g) shiitake, *Lentinula edodes*.

and is reported to be cultivated in British Columbia as well. We know from British Columbians engaged in the practice that similar species, the native *Ganoderma applanatum* and *Ganoderma tsugae*, are collected from forests for nutraceutical[1] use.

According to the B.C. Ministry of Agriculture and Lands (2004), about 25 000 t of button mushrooms worth $74.5 million[2] were produced in 2003, accounting for 97% of the total provincial mushroom production. Based on these data, we can estimate that specialty mushrooms accounted for only 3% of total production, or about 1000 t.

In Korea, many species and varieties of edible and medicinal mushrooms are cultivated; some of them are also harvested from forests (Table 1). The cultivated edible mushrooms include *Agaricus bisporus* (button mushroom), *Flammulina velutipes* (enokitake), *Lentinula edodes* (shiitake), *Hypsizygus marmoreus*, *Pleurotus eryngii*, and *Pleurotus ostreatus* (oyster mushroom). The cultivated medicinal mushrooms include *Agaricus brasiliensis*, *Cordyceps militaris*, *Ganoderma lucidum*, *Sparassis crispa*, *Phellinus* spp., and *Wolfiporia extensa*. This last species is also harvested from Japanese red pine (*Pinus densiflora*) forests. (see Figure 1 for photographs of some of these species).

In 2003, Korea produced a similar amount of button mushroom (19 790 t) to that in British Columbia, but with this the similarity ends. Total Korean mushroom production in 2003 was 181 828 t, including 62 081 t of oyster mushrooms, 38 839 t of shiitake, 41 232 t of enokitake plus other species. Production of these food species increased 209% from 1993 to 2003 (Yoo *et al*. 2005). In addition, *Agaricus brasiliensis*, *Ganoderma lucidum*, and *Phellinus* spp. are abundantly cultivated in Korea as medicinal mushrooms.

There may be tremendous opportunity for expansion of the specialty edible mushroom industry in British Columbia if the economics are right. However, we have heard that mushrooms such as shiitake are imported from China more economically than they are produced in the province. Increased transportation costs may change this economic viability. In addition, many native fungal species have known or unexplored medicinal and nutraceutical potential. According to Boa (2004), 92 edible and medicinal fungi can be cultivated, including eight *Agaricus* species, seven *Ganoderma* species, and nine *Pleurotus* species. Many of these species are native to British Columbia. Stamets (2005) listed edible and medicinal mushrooms that can be cultivated locally, some of which may be indigenous (Table 1). The forests of British Columbia therefore provide unexplored resources for the collection of new isolates of known cultivated fungi, species that are not yet cultivated, and wild-harvested medicinal fungi. Wild-harvesting of medicinal mushrooms would have to be approached cautiously and with an eye to sustainability. The conks or fruiting bodies of many medicinal fungi are perennial, developing over many years; to harvest them from the wild could easily deplete the resource.

In addition to producing useful fruiting bodies, fungal mycelia produce antibiotics used in medicine (Sur and Ghosh 2004), fermentation products used in the food industry (Koizumi 2001), and enzymes used industrially for the biotechnology of wood (Mai *et al*. 2004) and ecologically friendly bioremediation of contaminated sites (Stamets 2005; Brar *et al*. 2006). On reforestation sites in the interior of British Columbia, cultivated mycelium of the native fungus *Hypholoma fasciculare* is being tested for use against *Armillaria ostoyae* root disease in forest plantations (Chapman *et al.* 2004).

The Industry

In 2004, 49 commercial button mushroom growers were located mainly in the lower Fraser Valley, but also near Princeton and in the interior of British Columbia. Farms averaged 5600 m^2 of growing beds, with the largest business having 18 600 m^2 (B.C. Ministry of Agriculture and Lands 2004). In the same year, the button mushroom industry employed about 2000 people. Production increased 190% from 1993 to 2003, while the number of growers decreased 18% from 2000 to 2003. These and other British Columbia mushroom growers also produce some specialty mushrooms, but the production numbers are probably small.

In contrast to the situation in British Columbia, in 2002 there were 16 374 commercial mushroom growers in Korea cultivating oyster mushroom, shiitake, enokitake, and button mushrooms with 7088, 8119, 174, and 993 growers, respectively. Average farm size

[1] Foods claimed to have a medicinal effect on human health.
[2] All dollar values cited are in Canadian currency.

was 824 m^2 for oyster mushroom production, 85 m^2 for shiitake, 4804 m^2 for enokitake, and 1919 m^2 for button mushroom.

Characteristics and Trends in the Industries

Since the 1980s, the British Columbia button mushroom industry has been expanding and the recent deregulation of mushroom marketing presents new challenges and opportunities for continued growth (B.C. Ministry of Agriculture and Lands 2004). Availability of suitable compost is an important issue for the industry along with the expansion of various existing and new markets, value-added processing, further development of specialty mushrooms, and technical improvement to production systems (B.C. Ministry of Agriculture and Lands 2004). Compost is a mixture of straw or hay, manure, cereal grain, and gypsum. In Korea, other substrates such as corn bran, cotton seed pulp, and beet pulp are used.

Until April 2004, marketing of button mushrooms in British Columbia was regulated under the *Natural Products Marketing Act* (B.C. Ministry of Agriculture and Lands 2004). The British Columbia Mushroom Marketing Board administered the Act, allocated marketing quota of *Agaricus* mushrooms, and licensed designated marketing agencies through which all *Agaricus* mushrooms were officially sold. Growers may now sell their product through marketing agencies or independently. This restructuring favours a free-market approach and brings the industry in line with other North American mushroom producing regions. As a representative body for cultivated *Agaricus* mushroom growers in British Columbia, the new Mushroom Industry Development Council, officially launched on January 1, 2005, undertakes research, grower education, and generic promotion.

Recently, the consumption of edible mushrooms in Korea has been increasing due to interest in health food and pharmaceutical effects (You 2003). Government and company researchers continue to develop new cultivation techniques and products. For instance, a production method for shaggy manes (*Coprinus comatus*) has recently been developed.

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Wild-Harvested Mushrooms

Early History of Matsutake (Pine Mushroom) and Forest Mushroom Use

Among the wild-harvested forest mushrooms in British Columbia, pine mushroom (*Tricholoma magnivelare*) was probably the first to receive large-scale commercial attention. Although pine mushrooms were commercially harvested in Oregon and Washington in the 1930s (references in Redhead 1997a), anecdotal information indicates that the commercial harvest in British Columbia began after Japanese–Canadians interned in the interior of British Columbia during the Second World War, recognized and began to harvest this close relative of the familiar Japanese matsutake (*Tricholoma matsutake*). Currently, more than 10 companies in British Columbia buy and export pine mushrooms (Berch and Cocksedge 2003), and thousands of people are harvesters. Many First Nations groups that may not have traditionally eaten pine mushroom are now active commercial pickers (Hebda *et al*. 1996) and are increasingly becoming involved in their management.

In addition to mentioning matsutake and shiitake in the book entitled *Sejong-sillog-jiliji* (CE 1454), the *Dongui-bogam* (*Exemplar of Korean Medicine*) recorded seven medicinal mushrooms of which two are relevant here: *Tricholoma matsutake* and *Morchella* sp., possibly *esculenta*. *Jeungbo-salrim-gyeongje* (Yu Jung-Im 1776) described methods for storing matsutake, including preservation with clay and brining with salt. Although preservation with clay is no longer used, mushrooms are stilled preserved in brine (Jung 1993).

The Species and Varieties

The mushrooms wild-harvested in British Columbia and Korea are interestingly similar. In Korea, the wild-harvested commercial mushrooms include matsutake (*Tricholoma matsutake*; Figure 2a), *Amanita hemibapha* subsp. *hemibapha*, *Armillaria mellea, Auricularia* spp., *Cantharellus cibarius*, *Ganoderma lucidum*, *Morchella esculenta*, *Polyozellus multiplex*, *Ramaria botrytis*, and *Sarcodon aspratus* (Figure 3 a–g). In British Columbia, the most important wild-harvested mushrooms are the pine mushroom (*Tricholoma magnivelare*; Figure 2b), *Boletus edulis*, *Cantharellus* spp., *Hydnum repandum*, *Morchella* spp., *Polyozellus multiplex*, and *Sparassis crispa* (Figure 3 h–l). Pine mushrooms are an acceptable though lower-value substitute for matsutake to the Japanese market (see Table 2). Many other species are wild-harvested and marketed in both countries (Table 1) in lesser amounts.

FIGURE 2. Wild-harvested pine mushrooms: (a) Korean matsutake, *Tricholoma matsutake*; (b) British Columbia pine mushroom, *Tricholoma magnivelare*.

FIGURE 3. Examples of commercially important wild-harvested mushrooms in the Republic of Korea (a–g) and British Columbia (h–l): (a) *Amanita hemibapha*; (b) *Armillaria mellea*; (c) *Cantharellus cibarius*; (d) *Ganoderma lucidum*; (e) *Polyozellus multiplex*; (f) *Ramaria botrytis*; (g) *Sarcodon aspratus*; (h) *Boletus edulis*; (i) *Cantharellus formosus*; (j) *Morchella* sp.; (k) *Polyozellus multiplex*; (l) *Sparassis crispa*.

TABLE 2. Matsutake and pine mushroom imports into Japan by year and country (Source: Ministry of Finance Japan n.d.)

Country	2000		2001		2002			2003		
	Volume (t)	Value[a]	Volume (t)	Value	Volume (t)	Value	Unit cost (yen/kg)	Volume (t)	Value	Unit cost (yen/kg)
China	1308	6795	1531	9175	997	4909	4925	1119	5576	4984
North Korea	1309	2183	211	1180	502	1894	3770	284	971	3422
Republic of Korea	387	3468	181	2964	229	2851	12 445	147	2073	14 116
Canada	272	1346	328	1768	208	1084	5209	371	1355	3654
United States	87	449	80	475	73	413	5661	182	752	4130
Others	89	326	64	273	100	318	3179	118	444	3763
TOTAL	**3452**	**14 567**	**2395**	**15 835**	**2109**	**11 469**		**2221**	**11 171**	

[a] Value in million yen.

Boa (2004) listed over 1100 species of edible and medicinal fungi from over 80 countries. When this list is compared with the species that are commercially harvested in Korea and British Columbia, many opportunities are clearly available for other species to be developed commercially. Some examples of edible mushrooms with commercial potential in British Columbia are species of *Clavulina*, *Laccaria*, *Lactarius*, *Lycoperdon*, and *Russula*, all of which could be locally abundant. Similarly, *Cordyceps*, *Fomitopsis*, *Heterobasidion*, *Phaeolus*, and *Phellinus* species could have commercial potential for wild-harvesting as medicinal fungi if their harvest can be proven sustainable. Picking mushrooms, such as *Lactarius* and *Russula* species, without disturbing the habitat has no negative effect on future mushroom harvest (Egli *et al*. 2006). In stark contrast, raking the forest floor in search of pine mushrooms severely decreases mushroom production for many years (Luoma *et al*. 2006). However, perennial fruiting bodies of fungi that might be harvested for medicinal purposes, such as *Fomitopsis* species, may take years to develop and therefore could be much more susceptible to over-harvesting.

At least 10 species of mushrooms commercially harvested in Korea occur in British Columbia, but are not yet harvested commercially (Table 1). For instance, many species of *Ramaria* and *Russula* occur in British Columbia, but their taxonomy is confusing and little is known about their edibility. The case of *Hygrophorus russula* is interesting and may highlight cultural differences in culinary preferences or taxonomic confusion (i.e., it may be that the Asian and North American species are not the same). Although this mushroom is harvested and consumed in Korea and Japan, one North American author declares:

> *As far as the edibility of* Hygrophorus russula *is concerned, I have two words for you: Aw-ful. The species is edible and enjoyed by many people, according to field guides. I assure you that something is wrong with these people. The texture is slimy and insipid, and the taste is foul. The beautiful red shades, incidentally, disappear on cooking.*
> (Kuo 2007)

Other species have not been well documented or may occur only rarely in British Columbia. For instance, *Wolfiporia extensa* is seldom found, as indicated by the presence of only one collection of this fungus at the Pacific Forestry Centre, Victoria and none at the University of British Columbia, Vancouver herbaria.

Although *Amanita hemibapha* is commercially harvested in Korea and other *Amanita* species are harvested for food in various parts of the world (Boa 2004), there is little chance that *Amanita* species will be harvested for food in British Columbia because so many of them are poisonous, even deadly (e.g., *Amanita gemmata*, *Amanita porphyria*, and *Amanita smithiana*).

Importance and Value

Matsutake is the most important edible wild mushroom in Korea. Production peaked at 1313 t in 1985, but has declined by about 7% every year since (Koo and Bilek 1998). This is due to a lack of matsutake forest management (Koo and Bilek 1998), damage by pine midge-gall disease (*Thecodiplosis japonensis*) (Lee *et al*. 1997) and forest fire (Youn 2000). In 2001, a forest fire on the east coast of Korea damaged 85% of matsutake forests in Samcheok, one of the chief producing areas, and in 2003 only 306 t of matsutake were harvested.

Similarly in British Columbia, pine mushroom is the most important commercially harvested wild mushroom. Although no data exist on volume or value of harvested wild mushrooms, de Geus (1995) estimated that in 1993, 125 t of pine mushrooms were harvested province-wide with $3.8 million paid to pickers. Wills and Lipsey (1999) estimated that in 1995 around 250 t of pine mushrooms were exported to Japan and as much as 392 t in 1996. They proposed that if pine mushroom from British Columbia were valued in the Japanese market as highly as matsutake from Korea, the British Columbia crop would be worth six times its present value. Will and Lipsey (1999) stated that improved management of the productivity and quality of pine mushroom could dramatically increase revenues.

Forest pests will also affect the harvest of wild mushrooms in British Columbia as the pine midge-gall disease did in Korea. In British Columbia, mountain pine beetle (*Dendroctonus ponderosae*) and its associated bluestain fungus currently infest over 4 million ha of pine forests (Eng *et al*. 2004), forming one of the largest outbreaks of an insect pest ever recorded. Although initially this may create more opportunities for harvesting morels because their fruiting seems to be stimulated in beetle-attacked areas (Keefer 2005), some projections estimate that the beetle could devastate most of the pine forests within the next several decades. This would significantly decrease the available habitat for pine mushroom production in parts of the province, such as the Chilcotin Plateau, where pine is the major host tree.

Statistics Canada provides data on the export of numerous mushroom commodities (Table 3). Wild-harvested mushrooms shipped fresh, regardless of the species, all fit under one category—"mushrooms, fresh or chilled" (commodity code 07095900)—not in the category for fresh or chilled *Agaricus* species. For 2003–2005, the average annual value for the former commodity exported from British Columbia was over $12 million (Table 4) and would include pine mushroom, chanterelles, boletes, morels, and other species. However, it is possible to estimate the value of the pine mushrooms, because almost all of them are shipped fresh to Japan; almost no other fresh or chilled mushrooms are exported to Japan, and 99.1% of the fresh mushrooms shipped to Asia go to Japan. Assuming that virtually all of the fresh mushrooms shipped to Japan during the summer and autumn are pine mushrooms, the annual average value is over $6 million.

Wills and Lipsey (1999) estimated that 750 t of chanterelles, 100 t of boletes, and 0.5 t of other wild-harvested mushrooms (lobster, sweet tooth, hedgehog, etc.) were harvested in British Columbia in a good year, as well as 225 t of morels combined with the Yukon yield. In Korea in 2003, 70 t of *Sarcodon aspratus*, 60 t of *Ramaria botrytis*, 7 t of *Auricularia* species, and 0.02 t of other combined species were wild-harvested.

Fresh mushrooms (excluding *Agaricus* species) exported from British Columbia during April–June are assumed to be primarily morels. Canadian statistics state that these exports averaged over $1 million for 2003–2005 (Table 4), with a peak of over $2 million in 2004. Over 220 t of morels were gathered in burned forests of the Kootenay region in 2004 (Keefer 2005), with perhaps an equal amount produced in burned forests in the rest of the province. Using a median wholesale price of $6.60/kg fresh weight (Keefer 2005) and assuming an

TABLE 3. Statistics Canada (n.d.) commodities for mushrooms and other fungi with effective date of January 2002

Commodity code	Commodity
07095100	Mushrooms of the genus *Agaricus*, fresh or chilled
07095900	Mushrooms, fresh, or chilled
20031000	Mushrooms of the genus *Agaricus* prepared/preserved other than by vinegar or acetic acid
07115100	Mushrooms of the genus *Agaricus*, provisionally preserved, but not for immediate consumption
07123100	Mushrooms of the genus *Agaricus*, dried, cut, sliced, etc., but not further prepared
20039000	Mushrooms, other than genus *Agaricus*, prepared/preserved other than by vinegar or acetic acid
07115900	Mushrooms and truffles, provisionally preserved, but not for immediate consumption
07123900	Mushrooms and truffles, dried, cut, sliced, etc., but not further prepared
07095200	Truffles, fresh, or chilled
20032000	Truffles prepared or preserved other than by vinegar or acetic acid
07123200	Wood ears (*Auricularia* spp.), dried, cut, sliced, etc., but not further prepared

TABLE 4. Average seasonal value ($CDN) of wild and cultivated mushroom products exported from British Columbia* (March 2003 to February 2005), excluding *Agaricus* spp. (Source: Industry Canada n.d.)

Season	Destination	Fresh/chilled	Dried
Spring (April–June)	USA	308 424 [ab]	183 449 [ab]
	Asia	12 323 [abef]	—
	Europe	872 292 [ab]	54 553 [ab]
Summer (July–September)	USA	539 822 [abcd]	168 605 [abc]
	Asia	2 790 734 [abcd]	52 679 [ac]
	Europe	277 030 [abc]	443 084 [abc]
Autumn (October–December)	USA	291 133 [acdef]	38 369 [acef]
	Asia	4 382 352 [acdef]	4 002 [abef]
	Europe	2 344 731 [acef]	127 423 [ace]
Winter (January–March)	USA	153 026 [abef]	64 771 [abef]
	Asia	9 239 [abef]	—
	Europe	141 612 [abef]	71 677 [aef]
TOTAL		**$12 122 718**	**$1 208 612**

* Asian countries importing non-*Agaricus* mushrooms from British Columbia include: Japan (99.1%), Republic of Korea (0.6%), and China (People's Republic of China and Taiwan (0.3%). European importers include: France (65.0%), Switzerland (11.2%), Netherlands (< 9.0%), Norway (4.2%), Germany (3.8%), Spain (3.3%), Luxembourg (2.0%), UK (1.0%), Sweden (0.5%), and Belgium (< 0.1%).

[a] Probably includes major cultivated species (*Lentinula edodes*, *Pleurotus ostreatus*, etc.).

[b] Probably includes *Morchella* spp.

[c] Probably includes *Boletus* spp. and *Cantharellus formosus*.

[d] Probably includes *Tricholoma magnivelare*.

[e] Probably includes *Craterellus* spp., *Hypomyces lactifluorum*, *Polyozellus muliplex*, *Sparassis* spp., etc.

[f] Probably includes *Hydnum repandum* and *Hydnum imbricatum*.

overall harvest of about 440 t, a total wholesale value of $2.9 million was estimated.

British Columbia exports many morels and, to a much lesser extent, other wild-harvested species such as boletes and chanterelles in dried form. Statistics Canada reports on exports of dried mushrooms, but because species are not separated, and dried product can be retained for export outside of the fruiting season, it is impossible to estimate how much of the over $1 million is accounted for by morels (Table 4).

The Industry

In Japan, matsutake production peaked in 1953 at 6484 t and since then has declined annually (Koo and Bilek 1998). In 2003, matsutake production was only 80 t. The reasons for the decline include logging, climate warming, and disease or pests, which killed over half the pine trees in matsutake forests. People no longer collect fallen pine needles and twigs for fuel, thus the increasingly thick needle layers create a poor soil environment for matsutake mycelium. This decline in domestic production over the last five decades led to increased imports of matsutake and pine mushroom and new income opportunities in many countries, including Korea and Canada, especially British Columbia (Table 4).

In British Columbia, 2000–5000 people are estimated to harvest pine mushrooms (de Geus 1995). The pickers sell their harvest locally at roadside stands to buyers who sort the mushrooms into grades. Most buyers work as employees or contractors to mushroom companies. These companies acquire one or more species and set field prices. Exporters focus on international and domestic marketing of wild-harvested mushrooms. Wills and Lipsey (1999) identified 16 companies exporting wild food mushrooms of several species from British Columbia, but seven companies accounted for 90% of pine mushroom exports to Japan.

In Korea, the number of matsutake-picking households was 19 370 in 1995, but declined to only 10 224 households in 2002.

In British Columbia, pine mushrooms are sorted into six grades (Figure 4; de Geus 1995). In Korea, exporters sort matsutake according to Japanese grades (Table 5),

TABLE 5. Japanese matsutake grades

Grade	Class	Characteristics
Grade 1 – Completely intact veil	Good	• Completely intact veil • Good shape • ≥ 100 g per mushroom
	Fair	• Completely intact veil • Good shape • 50–100 g per mushroom
	Poor	Completely intact veil • Good shape • ≤ 50 g per mushroom
Grade 2 – Semi-opened cap		• Some opening between cap and stem
Grade 3 – Opened cap		• Completely open between cap and stem
Out of standard		• Wormy, broken, abnormal

TABLE 6. Korean matsutake grades

Grade	Characteristics
Grade 1	• Young mushroom • Veil is fully attached • > 8 cm tall
Grade 2	• Veil less than one-third opened • Asymmetrically slender stem • 6–8 cm tall
Grade 3	• Veil opened more than one-third • Less than 6 cm tall
Off grade	• Deformed, wormy, wet
Mixed grade	• Unsorted collection

but many pickers are used to a five-tiered grading system (Table 6), which creates some difficulties. Pine mushrooms from British Columbia are shipped fresh to Japan in refrigerated cardboard boxes, while in Korea matsutake are either similarly mass-shipped or individually packaged to showcase mushrooms of the very best grade.

Habitat and Ecological Information

In both British Columbia and Korea, commercially important edible wild mushrooms are harvested mostly in September and October, except for morels in British Columbia, which are harvested in May and June.

In British Columbia, pine mushroom occurs most productively on sites with well-drained, coarse-textured soil, in mature and older forests (80–120+ years old)

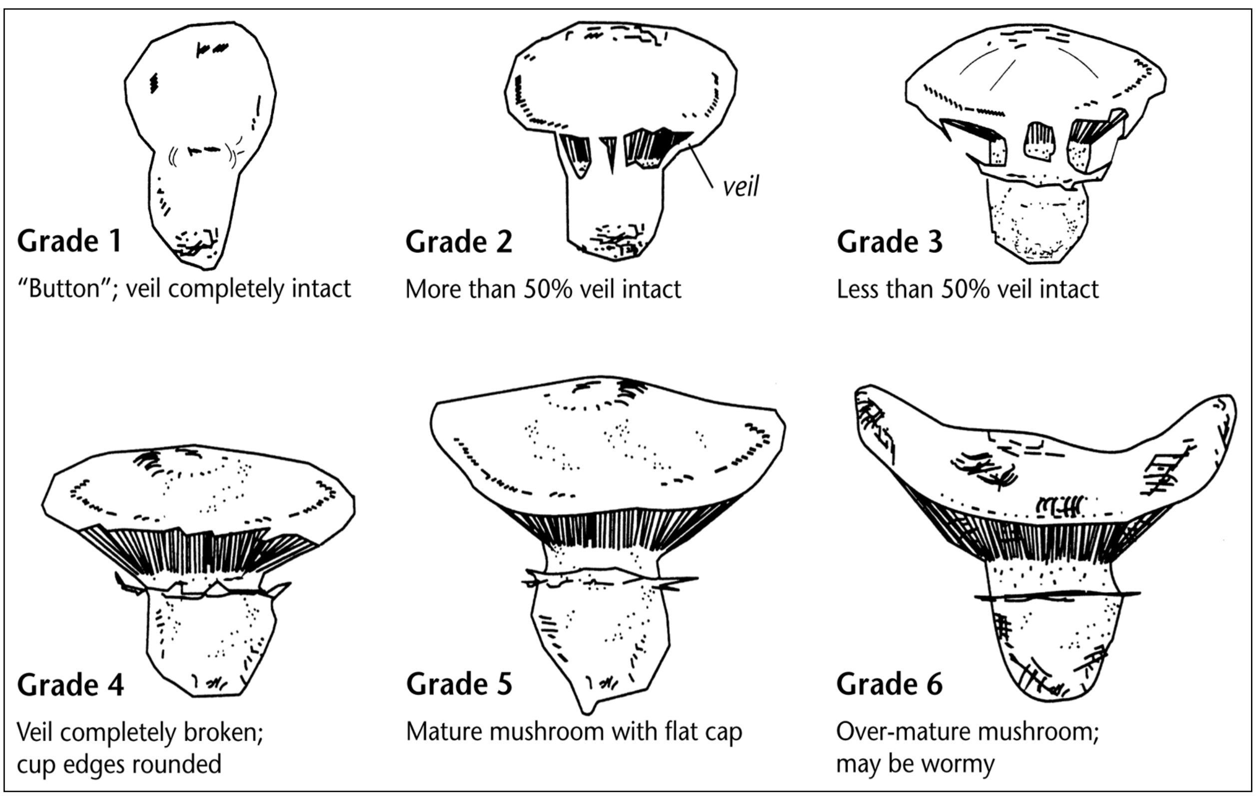

FIGURE 4. British Columbia pine mushroom grades (de Geus 1995).

dominated by western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), or lodgepole pine (*Pinus contorta*) (Berch and Wiensczyk 2001; Kranabetter *et al.* 2002, 2005; Ehlers *et al.* [2007]). In Korea, the optimum environment for matsutake is a forest dominated by Japanese red pine (*Pinus densiflora*) on southern or western aspects of relatively dry ridges with coarse-textured, well-drained soil (sandy loam or loamy sand) of granite or granite gneiss origin with little weathering.

In British Columbia, only a small amount of research has been done on the ecology of other commercially important forest mushroom species. On northern Vancouver Island, Pacific golden chanterelle is found in moist, rich sites in association with 60–80-year-old western hemlock forests (Ehlers 2004). In southeastern British Columbia, morels fruiting in forests that burned the previous year occur most abundantly in moist, water-shedding sites in association with various plant species (R. Winder and M. Keefer, Pacific Forestry Centre and private consultant, unpublished information, 2006).

Methods for Improving Productivity of Matsutake and Pine Mushroom

For British Columbia, nothing has been published concerning methods for increasing the productivity of commercially important forest mushrooms. However, Carrier and Krebs (2002) reported that irrigating northern forests can increase the productivity of forest mushrooms in general.

In contrast, extensive work has been done in Asia, including Korea, on increasing the productivity of commercially important mushrooms, especially matsutake. Attempts have been made recently to artificially cultivate matsutake (e.g., colonizing seedlings by growing them in existing shiros[3] (Ka *et al.* 2006), but Park and Ryoo (1998) concluded that significant progress will not be made until researchers work together to understand the complex ecological characteristics of this fungus.

The extent of forest canopy closure affects the temperature and humidity in the underlying soil and the fruiting of matsutake. The number of canopy branch layers has a significant effect on the occurrence of fruiting bodies, which are especially productive with one to three overlapping layers (optimum two). Reduced matsutake productivity is associated with an open canopy or a dense canopy with more than three layers of branch overlap. In Japan, matsutake production was correlated with stand density and diameter breast height. Based on these concepts, researchers in Korea (Song *et al.* 1999) developed a relative spacing index (RSI) to establish optimum conditions for matsutake production:

$$\text{RSI} = \frac{(\text{average distance between two trees}) \times 100}{\text{height of tree}}$$

Results indicated that the optimal relative spacing index for productive matsutake forests is 35%.

Since 2000, the Korean Forest Service has been supporting stand improvement activities to conserve and enhance matsutake production. The main practices include thinning and pruning for adjustment of stem density, clearing understorey shrub and herb growth, removing organic litter from the forest floor, and establishing irrigation systems (Lee *et al.* 2000). The process first classifies candidate stands into three categories: matsutake forests, forests next to matsutake forests, and non-matsutake forests. From this follows the decision about whether stand improvement activities should be carried out and, if so, exactly what practices should be used. In matsutake forests and forests next to matsutake forests, practices focus on enhancing production volume and expanding the production area. In non-matsutake forests, if it is determined that the forest could support matsutake in the future, stand activity is carried out to improve the suitability of the forest.

The schedule of activities and forest practice methods (Table 7) are decided based on ecological characteristics of the forest and the age of the pine trees (Figure 5). In the case of young pine-dominant forests, forest practices are carried out for only 2 years. In mature matsutake-producing stands of pine, these practices are carried out in the years 1, 3, and 5 of a 5-year protocol. In these matsutake and pine forests, canopy thinning and understorey clearing are done gradually over time because sudden environmental change can decrease matsutake production. Forest practices are carried out for three and four years for young and mature broadleaf-invaded forests, respectively.

Biological indicators are used to determine when declining matsutake forests need to be managed. One indicator is the ectomycorrhizal mushroom community associated with the matsutake, which changes with

[3] Perennial, below-ground mycelia of the fungus.

TABLE 7. Schedule of environmental improvement activities in matsutake forests in Republic of Korea based on ecological characteristics of forest and pine tree age

	Forest Characteristics			
	Young forest (16–35 years)		Mature forest (36–50 years)	
Year	***Pinus densiflora* dominant**	**Broadleaf-invaded**	***Pinus densiflora* dominant**	**Broadleaf-invaded**
1st	• thinning • clearing understorey • removing organic litter	• thinning • clearing understorey • removing organic litter	• pruning • clearing understorey • removing organic litter	• thinning • clearing understorey • removing organic litter
2nd	• pruning • clearing understorey • removing organic litter	• thinning • pruning • removing organic litter		• pruning • removing organic litter
3rd		• pruning • clearing understorey • removing organic litter	• pruning • clearing understorey • removing organic litter	• pruning • clearing understorey • removing organic litter
4th				• pruning • clearing understorey
5th			• pruning • clearing understorey • removing organic litter	

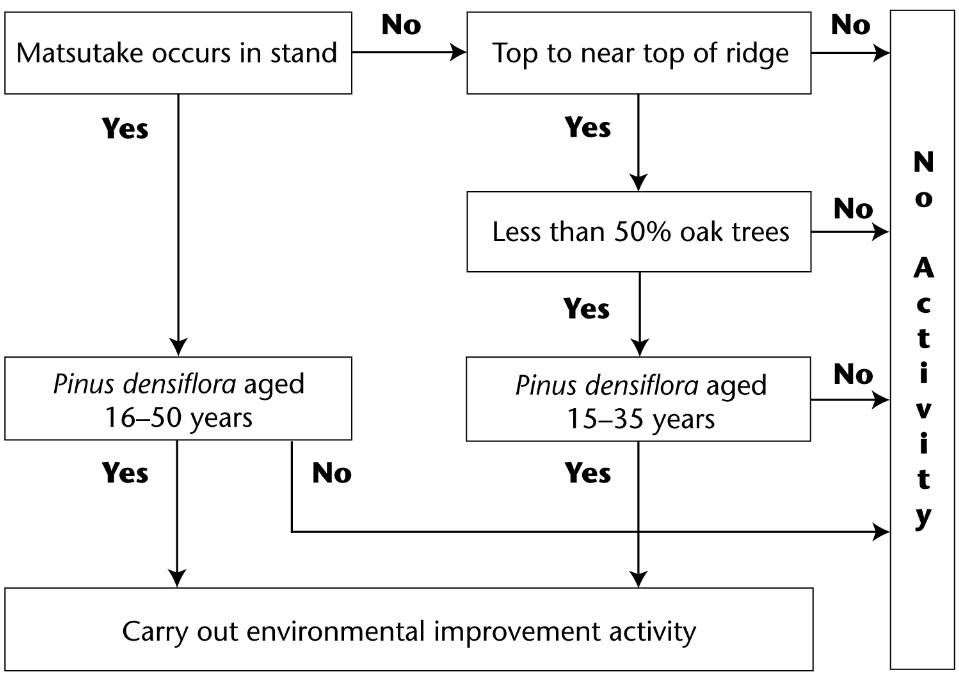

FIGURE 5. Flowchart of decision making for environmental improvement activity of forest stands for matsutake production, Republic of Korea.

the development of the matsutake shiro. *Boletopsis leucomelaena*, *Sarcodon scabrosus*, and *Tricholoma flavovirens* mostly appear in young matsutake forests where production is increasing. *Amanita pantherina*, *Laccaria amethystea*, *Lactarius* spp., *Russula* spp., and *Suillus bovinus* usually occur in forests with declining matsutake production (Park *et al.* 1998, citing Ogawa 1991). Senescing matsutake forests also develop more saprophytic mushrooms, while ectomycorrhizal mushrooms decline due to the increasing humus layer. Many of these fungal species also occur in British Columbia and some of them, such as *Boletopsis leucomelaena*, have been observed in pine mushroom forests (T. Ehlers, Tysig Consulting, pers. comm., 2005).

Another indicator used in Korea is the soil enzyme dehydrogenase, which is active in the degradation of organic matter. The dehydrogenase activity of soil in mature forests is 150–200 μg triphenylformazan (TPF)/gram of soil, but drops to around 50 μg TPF/gram of soil at the expanding front of the shiro and to less than 10 μg TPF/gram of soil in the physiologically inactive and degenerate mycorrhiza zones (Huh *et al.* 1998; Hur and Park 2001).

Stand Management to Improve Matsutake Quality

In addition to overall improvement of stand conditions for matsutake conservation and production, short-term activities are used in Korea to improve matsutake number, weight, and quality. The goal is to create the optimal environment for the matsutake, especially for the incorporation of moisture into the developing mushroom. Two basic approaches are used.

In the first, emerging matsutake buttons are covered with a 4–5 cm thick cap of soil or an inverted plastic cup with a 5 mm hole in the bottom (for aeration). The soil coating creates a longer stem and the plastic cup creates larger mushroom size and greater weight. In both cases, mushrooms suffer less damage from moulds and insects. The young mushroom is harvested when the soil above it cracks. The plastic cup must be removed 1–2 days before harvesting to permit the mushroom to become less watery and the tantalizing aroma of the mushroom to redevelop. The plastic cup is sometimes used during dry conditions, but can lead to mould development during moist periods. In general, the plastic cup method is not highly recommended because it can lead to inferior quality if management is careless. In addition, the pickers worry that the cup makes the mushrooms easy to find by other pickers.

In the second method, matsutake forests are irrigated. The productivity of matsutake and other forest mushrooms depends on weather conditions, especially precipitation and temperature. The matsutake consists of about 90% water and needs about 500–600 mm of precipitation during the fruiting period for optimal production. However, precipitation during this time is usually only 160–300 mm. In addition, matsutake production is linked to the accumulation of this precipitation about 15 days before the appearance of the first mushroom on site. Therefore, it is recommended that pickers correctly time irrigation at matsutake sites.

Policy, Support, and Challenges

Policy and Regulation

Most of the forested land of British Columbia is under provincial jurisdiction including forests where commercially important mushrooms are harvested. Timber harvesting is managed under various tenures (e.g., tree farm licences, timber sales, woodlots, and community forests) and the provincial government collects revenues from harvesting on Crown land. In contrast, no tenure system exists for NTFPs such as mushrooms, and no revenues are collected. The lack of a tenure system creates many challenges (Forest Practices Board 2004) and leaves little incentive for pickers to manage the resources when they cannot be sure that they, rather than other pickers, will benefit from their efforts. Also, no regulations govern the management of NTFPs, although Section 168 of the *Forest and Range Practices Act* (in which they are called "botanical forest products") allows for such regulations to be made (B.C. Ministry of Forests and Range 2003).

Despite this lack of tenure and regulation, management of pine mushroom habitat is starting to be incorporated into forest management. For instance, in the Timber Supply Review for the Kispiox TSA, the Chief Forester of British Columbia recognized that "pine mushrooms are undeniably an important botanical forest product, the habitat for which must be considered in forest management and planning" (Pedersen 2003:28). Consequently, he reduced the timber supply in the short term by 4%. Also, high value pine mushroom habitat has recently been mapped in the Cranberry TSA to provide input into timber supply analysis and integrated resource management (Trowbridge 2005).

In northwestern British Columbia, the Nisga'a Lisims government has adopted a land use plan for their First Nations treaty land that designates a special management area for pine mushroom and a botanical forest products zone within the area designated for forest resource use (Nisga'a Lisims Government 2002). In addition to pine mushroom, the prescribed NTFPs include black morel, oyster mushroom, king bolete, blue chanterelle, funnel chanterelle, lobster mushroom, chicken-of-the-woods, hedgehog mushroom, and cauliflower mushroom. The policy requires that forest management decisions take into account the cumulative effects of land use on NTFP habitat. In 2005, permits were issued for commercial harvesters and buyers of NTFPs. Fees were assessed depending on citizenship and age with younger and older harvesters exempt from payment (Nisga'a Lisims Government n.d.)

In Korea, matsutake harvesting on national and public forests has traditionally been carried out by people living in the neighbourhood. Since the 1990s, however, this neighbourhood system has broken down because more and more people are harvesting matsutake. Because of increasing conflicts, harvesting regulations were developed. Harvesting rights for forests owned nationally or publicly are now being sold to neighbourhoods. The cost of these harvesting rights is one-tenth of the value of the mean production over a 4-year period, which takes into account the annual variation in productivity (Koo and Park 2004). Officially, harvesting rights must be sold through open public tender to people living close to the matsutake forest, but most of the rights are in fact privately contracted to local residents, who are often the village head. The village head then holds the rights and the village residents organize teams to harvest in the allocated area. A portion of the income is contributed to the village development fund (Koo and Park 2004).

Under Korea's Songyi Use Restriction Notice, in provinces where matsutake is harvested each forestry co-operative is required to store production records for 5 years. The notice went into effect when matsutake exportation to Japan started in 1967. At that time, all matsutake had to be exported to Japan to acquire foreign currency. The notice established open and public education and qualification criteria for matsutake sorters and buyers, for selection of equipment, and for sorting grades (see ***http://www.foa.go.kr***, in Korean). The notice was deregulated in 1995 because the government eased its restrictions on export, and a portion of the matsutake harvest was sold on the domestic market.

Because all other wild-harvested mushrooms in Korea have much less value than matsutake, no regulations apply to their harvest.

Support and Challenges

Redhead (1997b) reported that while over 1250 species of macrofungi—including mushrooms and other species forming macroscopic fruiting structures—had been reported for British Columbia, this was only a fraction of the species actually present. Lee (1990) reported 885 species of macrofungi in Korea, but that number has since grown to 1600. For both jurisdictions, more research on the biodiversity of native fungi is needed for their potential to be fully appreciated and realized.

In Korea, four full-time scientists at the Korea Forest Research Institute in Seoul carry out research and extension programs on commercially harvested wild mushrooms such as shiitake and matsutake. The National Institute of Agricultural Science and Technology and Agricultural Technology Centres of eight provinces carry out research and extension activities pertaining to oyster mushrooms, enokitake, and button mushrooms. The Korean Forest Service provides support for the conservation and improvement of matsutake resources and the promotion of NTFP exports. Since 2000, it has supported the development of techniques for enhancing matsutake productivity, including thinning and pruning for stand density adjustment, clearing understorey shrubs and forbs, removing organic litter from the forest floor, and establishing irrigation systems. The financial sources for this environmental improvement activity consist of 40% federal government subsidy, 20% provincial government subsidy, and 40% private fees. Forestry co-operatives collect data on imports, exports, and production of mushrooms. The number of producer associations, though not easily counted, is estimated to be more than 100.

The British Columbia provincial government has one industry specialist in Greenhouse Vegetables and Mushrooms in the Ministry of Agriculture and Lands who deals primarily with commercially produced button mushrooms. The new British Columbia Mushroom Industry Development Council undertakes research, grower education, and generic promotion of *Agaricus* production. At other agencies, a few researchers are investigating medicinal properties of indigenous mushrooms. Dr. Eduardo Jovel at the University of British Columbia has done some preliminary work on medicinal properties of native fungi. At the Pacific Agri-Food Research Centre, Dr. Thomas Beveridge has investigated some of the medicinal properties of pine mushroom (*Tricholoma magnivelare*). There is also some research on the productivity of wild-harvested fire morels (Keefer 2005) and chanterelles (Ehlers 2006). Neither the federal nor provincial government employs specialists or researchers to work exclusively on wild-harvested mushrooms. However, some federal and provincial forest and agriculture employees address NTFPs along with other responsibilities.

The recent formation of the Interagency Non-Timber Forest Resources Committee in British Columbia provides a mechanism to communicate, co-ordinate, and strategize on issues of importance to NTFPs among ministries; other provincial, federal and local agencies; First Nations governments; existing NTFP sectors and related industries; and research and other organizations. In British Columbia, the Agri-Food Futures Funds, with funding from the Ministry of Agriculture and Lands and Agriculture and Agri-Food Canada, operated the Mushroom Industry Initiative until the end of March 2004. The new British Columbia Cultivated Mushroom Industry Initiative has developed a draft Strategic Plan for 2006–2010. It emphasizes the importance of the *Agaricus* component (97% of production by volume), but also recognizes the lack of specialty mushroom industry data, including types grown, production costs, numbers of producers, volume produced and sales, and the need for research on production methods and new specialty mushroom products. The major funding source of forestry-related research is currently the Forest Investment Account (FIA), which assists government in developing a globally recognized, sustainably managed forest industry. No equivalent funding source is focussed on the NTFP industry. With the publication of the special report on NTFPs by the Forest Practices Board (2004), interest in NTFPs shifted and they were listed as topic areas for research in the Forest Science Program of the FIA.

British Columbia has 25 universities, university-colleges, colleges, and institutes (B.C. Ministry of Advanced Education n.d.), but only one faculty member (at Royal Roads University) is working full-time specifically on NTFPs. Although many faculty members in British Columbian universities, colleges, and institutes study native plants and animals, relatively few work on native mushrooms. A number of educational institutions, including Malaspina College, the University of Victoria, the University of British Columbia (Vancouver and Okanagan), the University of Northern British Columbia, and Thompson Rivers University, discuss commercially important mushrooms or NTFPs in various courses, but only Royal Roads University offers courses and a certificate program specifically on NTFPs. In 2004, Royal Roads University announced the creation of the Centre for Non-Timber Resources (Royal Roads University n.d.) to support and encourage sustainable utilization of non-timber forest resources in the temperate and boreal regions of the world.

No professional association yet represents the pickers, buyers, or exporters of commercially important wild-harvested mushrooms. Because of this, the industry has no voice. Five mushroom clubs for interested amateurs exist in the province (in Vancouver, Victoria, Kelowna, Roberts Creek, and Fraser Valley). Although these clubs encourage people to learn about mushrooms, they do not directly support commercial mushroom harvesters. In fact, mushroom club members express concerns about the sustainability of commercial mushroom harvesting and the competition they often experience between recreational and commercial pickers.

The University of British Columbia (University of British Columbia n.d.) and the Pacific Forestry Centre (Natural Resources Canada n.d.) have international herbaria with British Columbia fungal collections that can be searched online. From these Web sites, it is possible to determine where and when voucher specimens of fungus species have been collected in the province. As of 1997, however, "for more than 90% of the province, there has been documentation of less than 1% of the macrofungal flora" (Redhead 1997b:2). Clearly, specific mushrooms occur in parts of the province where they have not yet been documented.

Commercial harvesters of fire morels use the British Columbia Ministry of Forests Protection Branch Web site to find the locations of wildfires in the province in the previous year (B.C. Ministry of Forests and Range n.d.) and, therefore, where big morel crops might be expected to occur.

As earlier indicated, one of the major obstacles to fully assessing the extent of the wild mushroom industry in British Columbia is the lack of specific import and export data. Although Statistics Canada reports on various categories of mushroom commodities, such as "mushrooms, fresh or chilled," only the button mushrooms are specifically monitored (as "mushrooms of the genus *Agaricus*, fresh or chilled"). Virtually all other species of imports and exports are lumped together (Table 2). Statistics Canada uses the Standard Classification of Goods (SCG) to collect commodity data and to uniquely identify such data. The SCG is an extension of the international Harmonized Commodity Description and Coding System of the World Customs Organization. The inter-agency committee on NTFPs is working with Natural Resources Canada on a project to add specific NTFP mushroom species to this system.

Conclusions and Issues

> *The potential exists for further development of wild-harvesting edible and medicinal mushrooms in both Korea and British Columbia, but research into its sustainability is essential.*

Before the wild-harvested and cultivated mushroom industries in British Columbia and Korea can develop to their full potential, the following important issues and challenges need to be addressed.

- The specialty mushroom cultivation industry in British Columbia has the potential for expansion with native species, new native strains of fungi, such as *Pleurotus* and *Ganoderma*; and with non-native species that are already cultivated elsewhere. The collection of data specific to specialty mushrooms would facilitate new business development and market assessment.
- The potential exists for further development of wild-harvesting edible and medicinal mushrooms in both areas, but research into its sustainability is essential. As forests develop and land uses change, it will be important not to lose resources that provide the genetic stock, substrates, and in some cases, the habitat necessary for cultivated and (or) wild-harvested production.
- The fungal resources of British Columbian and Korean forests are not fully known. Research and extension on the diversity, abundance, distribution, and identification of these resources are sorely needed.
- Commercialized mushroom cultivation in both jurisdictions appears to be following similar growth patterns even though the outcomes to date have been different. The historical basis for mushroom consumption in Asia has led to a market that is much more diverse than that of North America, and a market that could grow substantially if the health claims associated with some mushrooms can be verified or more solidly established. Although the North American market can be expected to grow in line with population growth, the use of mushrooms as nutraceuticals must contend with a preference for fast-acting drugs and as food with a history of European-based cuisines which have less emphasis on mushrooms. Still, the growth of Asian populations in British Columbia may move us toward greater diversity of mushroom cultivation. Better culinary research could explore the use of Korean mushrooms in North American food products and vice versa, thereby expanding the potential market for products from both areas.
- The extension of expertise and the support for mushroom industries highlight an interesting contrast in approaches and markets between the two jurisdictions. The focus in British Columbia is on a single mushroom crop (*Agaricus bisporus*), with some tentative support for other specialties. Extension and support in Korea are more diversified, reflecting the greater variety of important cultivated species. Interaction between innovative entrepreneurs and extension specialists appears to play an important role in maintaining the stability of established markets as well as the development of new markets.
- Security and exclusivity of access to specific NTFP resources in specific land bases in British Columbia, similar to those for timber in the province and matsutake in Korea, could provide incentive for sustainable NTFP harvesting or managing for improved productivity. Incorporation of pine mushroom habitat into forest planning would contribute to the sustainability of this industry in British Columbia.
- To improve the management of NTFPs such as pine mushroom, we need to know more about their ecology, phenology, and responses to disturbance and change (e.g., climate change, timber harvesting, and mountain pine beetle attack) and to apply this knowledge to operations. The Korean experience in managing matsutake shows that it is feasible to boost the productivity of wild-harvested mushrooms using a "light development" approach to forest resources. For wild-harvested mushrooms with underdeveloped markets, this is an attractive option for stabilizing productivity and growing commercial activity. For wild-harvested mushrooms with developed markets, this option can be used to counter declining productivity.
- Economic monitoring of international NTFP trade will only be possible when the World Customs Organization and Statistics Canada use more specific commodity categories.
- Without a unified voice, the NTFP industry cannot effectively communicate with government and other industries. An NTFP industry association, as has been recently established in Quebec (L'association pour la commercialisation des champignons forestiers), would provide this voice.

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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)].

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Test Your Knowledge . . .

Development and potential of the cultivated and wild-harvested mushroom industries in the Republic of Korea and 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. To conserve and enhance matsutake production, the Korean Forest Service supports stand improvement activities that include:
   - A) Thinning, pruning, clearing understorey vegetation, removing surface litter from the forest floor, and irrigating
   - B) Removing all of the ectomycorrhizal trees
   - C) Liming and fertilizing the stands
   - D) Prohibiting all stand management activities in forests adjacent to matsutake forests

2. Opportunities for diversification of the mushroom industry in British Columbia are:
   - A) Diminishing because of climate change and tree diseases
   - B) Historically challenging because of the lack of fungal diversity in British Columbia
   - C) Numerous because of the number of underutilized species and potential for improved management of wild harvests
   - D) Unpredictable because of the North American and European markets

3. World-wide, the commercial mushroom industry is:
   - A) Limited because so few species have any value
   - B) In decline because no mushroom species can be cultivated and it is impossible to determine what stand types will support wild-harvested mushroom species
   - C) Growing dramatically due to the activities of forest pests and pathogens
   - D) Already significant because over 2000 species are collected, consumed and traded

Answers

1. A 2. C 3. D