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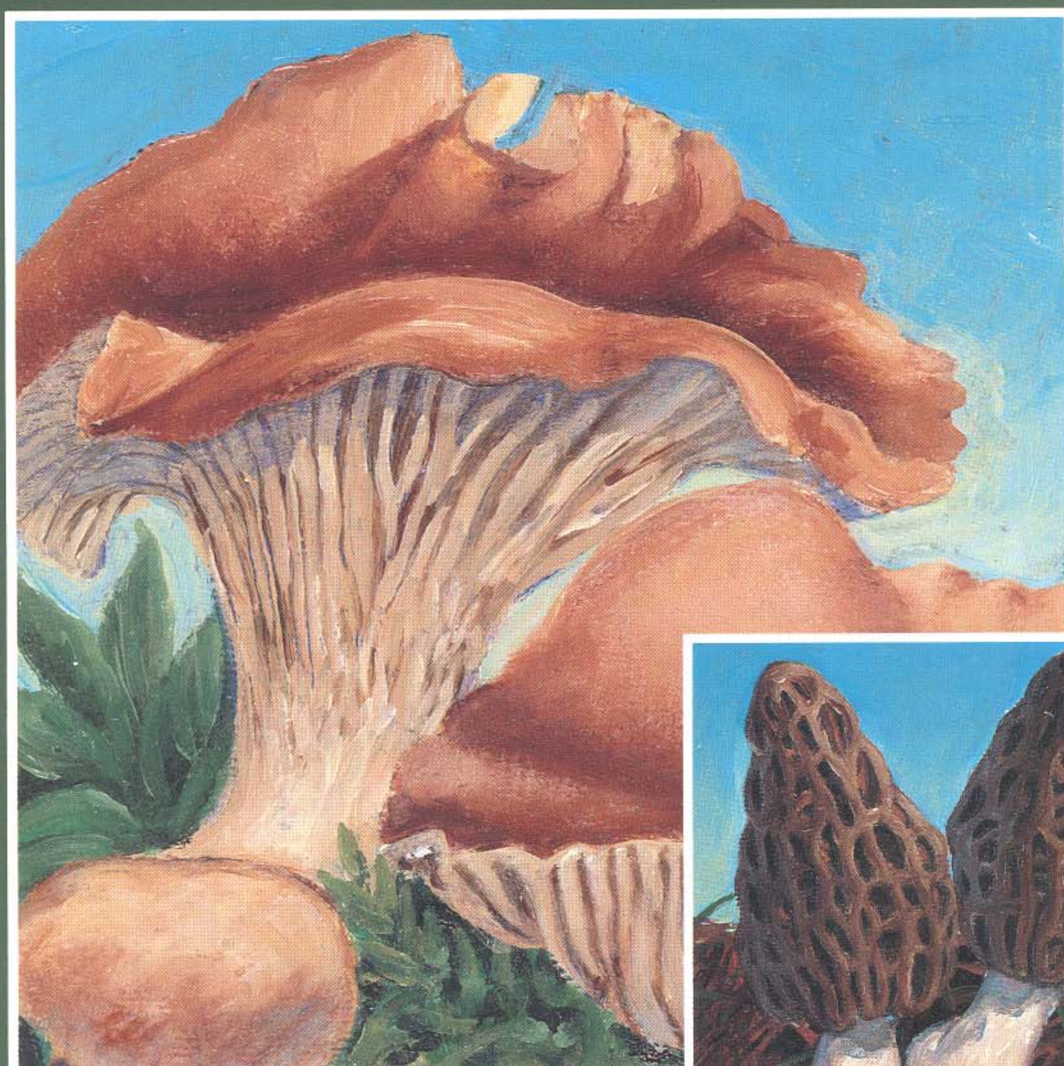
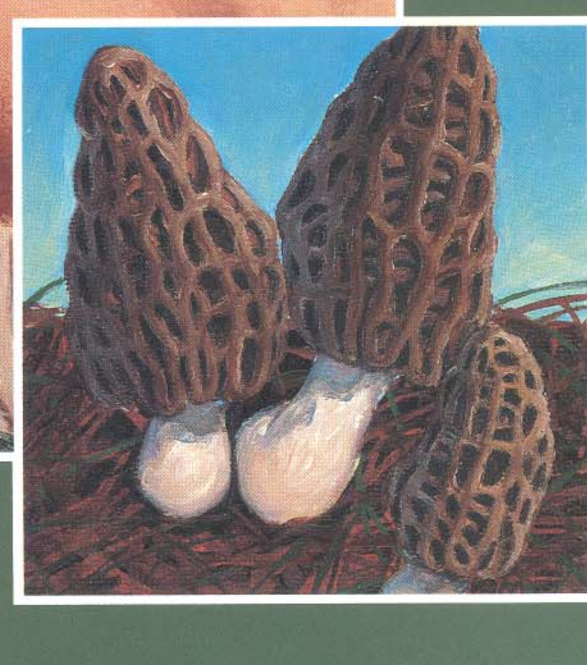
Biology, Ecology, and Social Aspects of Wild Edible Mushrooms in the Forests of the Pacific Northwest: A Preface to Managing Commercial Harvest

Randy Molina, Thomas O'Dell, Daniel Luoma,
Michael Amaranthus, Michael Castellano, and Kenelm Russell





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Abstract

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The commercial harvest of edible forest fungi has mushroomed into a multimillion dollar industry with several thousand tons harvested annually. The development of this special forest product industry has raised considerable controversy about how this resource should be managed, especially on public lands. Concerns center around destruction of forest habitat by repeated entry and harvest, gradual loss of the mushroom resource by potential overharvest, conflict between recreational users and commercial harvesters, and regulation and monitoring of future harvests. A key to wisely managing the edible mushroom resource is common understanding among resource managers, the mushroom industry, and the concerned public about the biology of these unique forest organisms, their ecological importance in forest ecosystems, and effects of forest disturbance on their survival. The primary objectives of this overview paper are to provide information on the biology of forest fungi, describe the major edible fungi harvested in the Pacific Northwest, integrate a perspective on the social aspects of the mushroom harvest issue, summarize the development of the commercial mushroom industry, and suggest research and monitoring protocols for developing management guidelines.

Keywords: Fungi, mushrooms, mycorrhizae, monitoring, forest ecology, forest management, special forest products, recreation.

Contents

Introduction

Production forestry typically emphasizes timber and timber products. At a recent regional symposium on special forest products, however, a wealth of commodities ranging from berries and seeds to floral greenery and shrubs was discussed and evaluated for regional economic value and inclusion in forest management schemes. Notable among these products were the highly prized, edible forest mushrooms, namely the chanterelles, morels, and American matsutake. Declining timber revenue in rural communities in the Pacific Northwest has increased the importance of income from nontimber products such as mushrooms.

Commercialization and development of new forest products has heightened public concerns about use and abuse of forest resources. The commercial harvest of mushrooms is no exception, and considerable controversy surrounds the proper management of this resource, especially on public lands. Concerns center around destruction of forest habitat by repeated entry and harvest, gradual loss of the mushroom resource by overharvest, conflict between recreational users and commercial harvesters, and regulation and monitoring of future harvests. The mushroom industry is frustrated by regulations and permit systems that differ among administrative units. The private timber industry worries about trespass and liability problems on their lands and how much Federal land will be closed to timber harvest to protect the mushroom resource. The State of Washington implemented licensing requirements for wild mushroom buyers and dealers in 1989. Other States will likely follow suit. California, for example, recently stopped all mushroom harvesting, including recreational picking, in many State parks to control habitat disturbance. National Forests throughout Washington, Oregon, and California are developing management guidelines for mushroom harvest and monitoring the resource for sustained productivity.

A key to wisely managing the edible mushroom resource is a common understanding among resource managers, the mushroom industry, and the concerned public about the biology of these unique forest organisms, their ecological importance in forest ecosystems, and effects of forest disturbance on their survival. Equally important is recognizing that much remains to be learned about the productivity of valuable mushrooms, the effects of mushroom harvesting and forest management practices on future productivity, and the socioeconomic aspects of this new industry. Careful examination of what we do not know will guide research and monitoring programs that promote sound management decisions. The primary aim of this overview paper is to facilitate information sharing as an initial step in developing management strategies.

This paper is divided into five sections so that users with different backgrounds and information needs can readily access material on forest mushrooms and their harvest:

- "Forest Mycology" introduces mycology and emphasizes the biology and ecology of fungi in forest ecosystems.

- "Major Edible Fungi in the Pacific Northwest" describes the major edible fungi harvested in the Pacific Northwest. It is not intended as a field guide for identifying forest mushrooms but to introduce managers to them. Comprehensive field guides for Pacific Northwest mushrooms are listed in appendix 1.

- "Recreational, Social, and Folk Aspects of Fungi" integrates a perspective on the folk use and social aspects of mushrooms with the mushroom harvest issue.

- "Commercial Aspects of the Wild Mushroom Industry" summarizes the development of commercial mushroom harvest over the last decade and current regulations in place or being considered.

- "Monitoring Wild Edible Fungi" discusses concerns of those who must manage this resource and suggests research and monitoring protocols for developing management guidelines.

Forest Mycology

Most edible fungus species belong to groups generally referred to as mushrooms and cup-fungi. This section provides some basic information about the placement of mushroom and cup-fungi in the fungus kingdom, their life cycles, and ecosystem function. (See Carroll and Wicklow 1992, Kendrick 1992, and Moore-Landecker 1990 for greater detail on the biology of fungi.)

Mushrooms are the reproductive structures **(fruiting bodies)** of organisms that otherwise live as microscopic threads of cells in various substrates such as soil, wood, or living tissues of associated plants[1]. The threadlike cells **(hyphae)** in mass are referred to as the **mycelium.** Fruiting bodies are produced from the mycelium to carry out sexual reproduction-the formation and release of **spores.** Picking a mushroom-removing the fruiting body from the mycelium-is analogous to picking an apple from a tree.

The life cycle of a typical mushroom is shown in figure 1. The gills or pores of a mature mushroom actively discharge spores, which are dispersed by the wind. Under suitable conditions, the spores germinate and begin to grow. For many species, hyphae of the germinating spores fuse to establish the adult mycelial stage. Ectomycorrhizal fungi must form their symbiosis with plant roots to develop the mycelial stage in the soil, and spores of many ectomycorrhizal fungi must be stimulated by host plant roots to germinate. The mycelium grows through the soil and enlarges; when environmental conditions are appropriate, the sexual stage is initiated, forming mushroom primordia or buttons. The mushroom primordia then expand into the mature mushroom in which the final sexual process takes place that produces the spores.

Though many thousands of mushroom and cup-fungus species form conspicuous **(macroscopic)** fruiting bodies, these species represent only a small fraction (<1 percent) of the fungal kingdom. **Macrofungi,** as they often are called, produce fruiting bodies that are readily apparent to the unaided eye. Macrofungi often have a **stalk** to elevate the **cap** (which contains the spore-bearing surface**, the hymenium)** into the air (fig. 1). Spores allow fungi to disperse and survive until conditions are right for germination and establishing a new colony. They also may serve to insert new ganetic diversity into established colonies. This general structure differs a great deal among species of macrofungi, with capless and stalkless forms at the extremes. Truffle fungi represent another variation in form. The stalk has been lost and the cap or cup has evolved to form small, potatolike fruiting bodies in the soil. Animals ranging from worms and insects to squirrels and deer disperse truffles by eating them; the spores pass through the digestive tract unharmed (Maser and others 1978).

[1] For the reader's convenience, defined terms are printed in bold type at first mention.

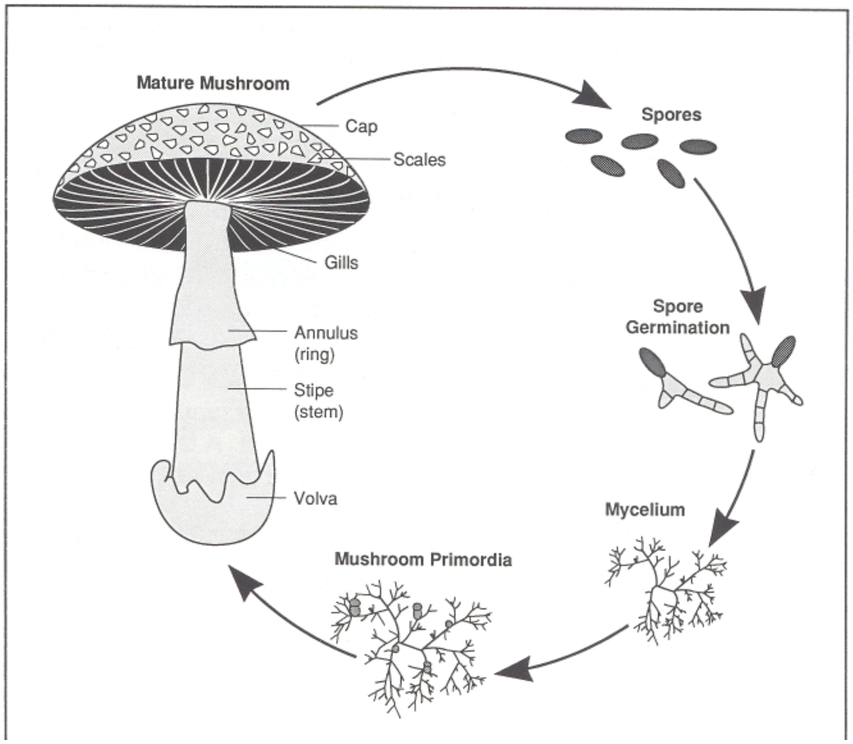

Figure 1-Anatomy and life cycle of a typical mushroom, showing many anatomical features that are used to characterize and identify mushrooms. Many species develop only a few of these features, and some groups have different anatomy; for example, pores rather than gills house the spores of the boletes.

The macrofungi of commercial importance belong to the classes Basidiomycetes and Ascomycetes, the most highly evolved groups in the fungus kingdom. These two groups are distinguished by differences in the cells that give rise to the sexual spores. Basidiomycetes include most of the mushrooms and have spores borne on the outside of mother cells **(basidia).** Ascomycetes include the cup-fungi and bear spores within mother cells **(asci).**

Macrofungi generally are classified as pathogens, saprobes, and mutualists, although gradations exist among these categories. **Pathogens** attack and often kill living tissues and may kill the host organism. Some of the more familiar parasitic fungi are conks such as *Heterobasidion annosum* and the recreationally picked, edible "honey mushroom," *Armillaria ostoyae.* Both species also are capable saprobes, so we find them on both live and dead hosts.

A true **saprobe** lives only on dead organic matter such as heartwood of standing trees, woody debris, or fallen leaves; for example, *Fomitopsis pinicola* (red belt fungus) and *Sparassis crispa* (cauliflower mushroom) use dead heartwood. These saprobes may so structurally weaken a tree that it breaks in a wind storm. Many small- to medium-sized saprobes decompose the organic layers of the forest floor: stems, branches, and leaves. The genera *Aleuria, Clitocybe, Collybia, Marasmius, Morchella, Mycena, Naemataloma, Phoiiota,* and *Scutellinia* represent some of the variety of saprobes. Some, such as certain species of cup-fungi and *Psilocybe,* occur only on animal dung.

Disease and decay typically are considered as killing valuable trees and causing economic damage, but pathogens and saprobes are important components of healthy, productive forest ecosystems. When scattered trees are killed in a dense forest, for example, the resulting small openings enhance forest habitat diversity. Fungi specializing in decay of tops of trees create habitat for animals that nest in cavities. Saprobes are major players in the complex biological processing machinery of the decomposition cycle. Without decay fungi to recycle organic material, plant remains would accumulate on the forest floor, thereby reducing soil fertility, yielding a stagnant, nonproductive habitat, and presenting a dangerous buildup of fuels.

In addition to their function as decomposers, fungi are critical links in the complex food web of forest ecosystems. Fungi interact with many soil organisms, including bacteria, other fungi, nematodes, microarthropods, and insects. They serve as prey to and predators of organisms in these groups (Coleman and others 1984, Elliot and others 1980, Ingham and others 1985). A large portion of the total forest ecosystem biomass resides in the living fungi, which rapidly die and recycle their nutrients to the soil (Fogel 1980). This great fungal component not only recycles nutrients but also captures significant amounts of forest nutrients, which reduces leaching loss from the system. The extensive mycelial webs also function in aggregating soil particles and organic matter, thereby providing soil pore space for movement of air and water. Loss of such critical soil structure leads to a decline in ecosystem productivity (Molina and Amaranthus 1991, Perry and others 1987).

The third major group of fungi, the **mutuatists,** live in intimate association with plants and interact in various ways that, in this instance, benefit both partners, hence, **mutuatistic symbiosis.** Among macrofungi, the predominant mutualistic symbiosis in forests takes place with plant roots producing structures called **mycorrhizae.** Because mycorrhizal fungi directly enhance tree survival and growth and produce many of the choice, edible wild mushrooms, we discuss this topic in detail.

Mycorrhizal Fungi

Mycorrhiza literally translates as "fungus-root" and defines the common association of specialized soil fungi with the tiny feeder roots of many forest trees and shrubs. Mycorrhizal associations represent one of the more widespread forms of mutualistic symbioses in terrestrial ecosystems. Indeed, the plant-fungus associations have coevolved over the millennia such that each partner depends on the other for survival.

The mycorrhizal fungus basically serves as an extension of the plant root system, exploring soil far beyond the reach of the roots and transporting water and nutrients to the roots. The uptake of phosphorus and nitrogen are especially critical functions of mycorrhizal fungi, which can release bound forms of these nutrients otherwise unavailable to the roots. In return, the plant is the primary energy source for the fungus, providing simple sugars and vitamins produced in photosynthesis and transported to the roots and then the fungus. Mycorrhizal fungi are less capable of decomposing complex carbon molecules from organic debris than are saprobes. This dependency of fungi on their hosts for growth and survival is critical to mushroom production by mycorrhizal fungi. When trees are harvested, these mycorrhizal fungi die and do not return to produce mushrooms anti! the new forest is well established; many of the valuable edible mycorrhizal fungi reappear in abundance only after the new forest is 20 or more years old.

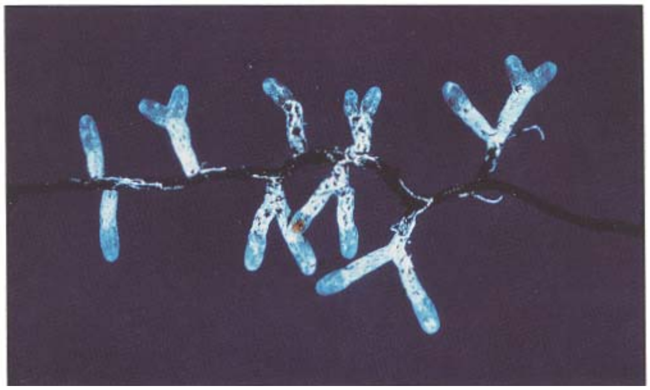

Figure 2-Pine ectomycorrhizae.

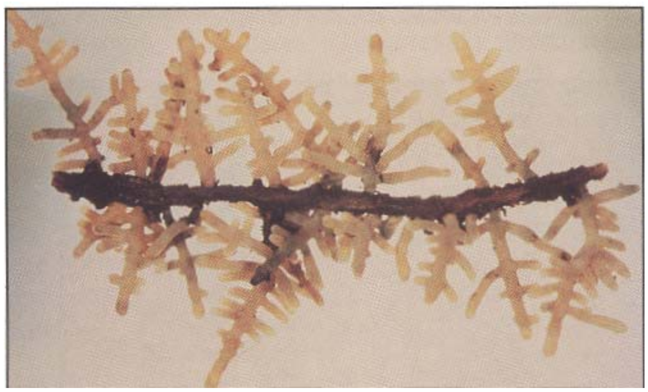

Figure 3-Douglas-fir ectomycorrhizae.

Of the several classes of mycorrhizae, only **ectomycorrhizae** produce edible mushrooms. Figures 2-4 illustrate ectomycorrhizae produced by different fungus-host combinations. Note the variation in pattern and extent of branching. Many ectomycorrhizal fungi produce plant growth-promoting hormones (auxins, gibberellins, cytokinins, and ethylene) that stimulate the branching of feeder roots, thereby increasing the absorptive capacity of the root system and the contact zone between root and fungus tissue. In addition to branching patterns, two key features characterize the structure of ectomycorrhizae. The fungus forms a **sheath or mantle** of fungal tissue around the feeder root (fig. 5). The mantle serves as a storage tissue for nutrients received from mycelium in the soil and physically protects the fine roots from some pathogens and desiccation. The fungus also penetrates between the cortical cells of the root to form a network of fungus tissue called the **Hartig net** (fig. 5). Nutrient exchange occurs within this extensive, intimate contact zone: sugars and vitamins move into the fungus, and water and nutrients move into the plant.

Figure 4-Pine ectomycorrhizae showing extensive fungal growth into the soil.

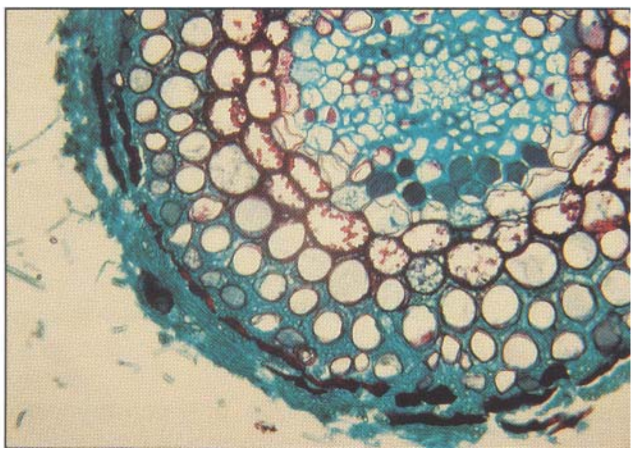

Figure 5-Cross section of a Douglas-fir ectomycorrhiza showing the fungal colonization on the root surface (mantle) and growth between the cortical cells (Hartig net).

The primary benefit to the host comes by way of the extensive growth of the fungus from the mantle into the soil. The microscopic diameter and proliferation of the hyphae allow hosts to receive nutrients from volumes of soil hundreds or thousands of times greater than they could from roots alone (see fig. 4). Mycelial colonization of the soil differs among the ectomycorrhizal fungi; some may grow only a few centimeters into the soil and others can grow several meters from the ectomycorrhiza. Some fungi produce dense, hyphal mats that strongly bind the soil and organic matter. If the mycelium is white or brightly colored, these extensive mats may be readily visible when a bit of the upper organic layer is removed. Other fungi produce colorless or dark mycelia that are more difficult to see with the unaided eye, but their growth into the soil is likewise extensive. This proliferation of fungus mycelium represents the body of the fungus. Within this network, the sexual processes take place and mushrooms and truffles are formed. Disruption of these mycelia by forest disturbance or mushroom harvest and its effects on future mushroom production are key considerations when management guidelines are developed for forest mushroom production.

Ectomycorrhizal hosts in the Pacific Northwest are chiefly trees in the families Pinaceae, Fagaceae, Betulaceae, Salicaceae, and a few Ericaceae. Table 1 lists the major Pacific Northwest genera and species within these families along with their common names. This diversity of ectomycorrhizal hosts in our region supports a great diversity of ectomycorrhizal fungi, making the Pacific Northwest one of the more species-rich regions in the world.

Thousands of fungus species in our region are ectomycorrhizal; Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) alone associates with nearly 2,000 species (Trappe 1977). Some of the common and widespread genera of ectomycorrhizal fungi in the Pacific Northwest are listed in table 2. Well-known edible species occur in the genera *Cantharellus (chanterelles), Boletus* (boletes), *Lactarius* (milky caps), *Tricholoma* (matsutake), *Hydnum* (tooth fungi), and *Ramaria* (coral fungi). Another large and diverse group of less well-known ectomycorrhizal fungi are the truffles (table 2), which produce fruiting bodies beneath the duff or soil surface. Only a few species, most commonly the Oregon white truffle *(Tuber gibbosum),* are harvested and eaten by knowledgeable collectors. Like the mushroom fungi, the truffles are diverse in the Pacific Northwest and are an important food source for many forest mammals, especially squirrels, voles, chipmunks, and other small creatures. These mammals are major prey for such predators as the northern spotted owl *(Strix occidentalis).* Thus, truffles are important in the complex food web of forest ecosystems.

Ectomycorrhizal fungi differ in their ability to associate with different host species. Some fungus species are restricted to specific genera. For example, the Oregon white truffle associates only with Douglas-fir. Many fungi occur only with pines or oaks. Others have broad host ranges as indicated by their widespread occurrence throughout the Pacific Northwest. Those with broad host ranges and wide ecological tolerance (that is, not restricted by specific habitats) are often the most commonly collected fungi. Among the important edible mushrooms, *Cantharellus cibarius is* a good example of this group.

Some fungi may be able to form ectomycorrhizae with a wide range of hosts but are limited in distribution by habitat requirements. The Northwest matsutake *(Tricholoma magnivelare),* for example, forms ectomycorrhizae with many tree species throughout the forests of the Pacific Northwest; however, this fungus seems most abundant in pine forests along the coast and in the Cascade Range. Similarly, the king bolete *(Boletus edulis)* has a **broad host** range (Molina and Trappe 1982), but it is scattered in distribution and often abundant only locally.

The habitat requirements of these ectomycorrhizal fungi and their interactions with particular plant species are poorly understood. Some fungi are more abundant in certain age classes of forests. As plant-species composition changes during forest succession, the fungus communities similarly undergo change. This fungus succession is in response to changes in tree composition, tree age, and soil qualities, such as accumulation of organic matter. The ecological requirements of mycorrhizal fungi, particularly their relation to forest community succession and disturbance events, represent large knowledge gaps needing research attention.

Table 1-Major ectomycorrhizal host genera and species in the Pacific Northwest

Family	Genus	Species	Common name
Pinaceae	*Abies*	*amabilis*	Pacific silver fir
		concolor	white fir
		grandis	grand fir
		lasiocarpa	subalpine fir
		procera	noble fir
	Larix	*lyalli*	subalpine larch
		occidentalis	western larch
	Picea	*engelmannii*	Engelmann spruce
		sitchensis	Sitka spruce
	Pinus	*albicaulus*	white bark pine
		attenuata	knobcone pine
		contorta	lodgepole/shore pine
		jeffreyi	Jeffrey pine
		lambertiana	sugar pine
		monticola	western white pine
		ponderosa	ponderosa pine
	Pseudotsuga	*menziesii*	Douglas-fir
	Tsuga	*heterophylla*	western hemlock
		mertensiana	mountain hemlock
Betulaceae	*Alnus*	*incana*	mountain alder
		rhombifolia	white alder
		rubra	red alder
		sinuata	Sitka alder
	Betula	*papyrifera*	paper birch
	Corylus	*cornuta*	hazel
Ericaceae	*Arbutus*	*menziesii*	Pacific madrone
	Arctostaphylos	*columbiana*	bristly manzanita
		nevadensis	kinnikinnick
		patula	greenleaf manzanita
		uva-ursi	kinnikinnick
Fagaceae	*Castanopsis*	*chrysophylla*	chinquapin
	Lithocarpus	*densiflonus*	tanoak
	Quercus	*crysolepis*	canyon live oak
		kellogii	California black oak
		garryana	Oregon white oak
Salicaceae	*Populus*	*tremuloides*	aspen
		trichocarpa	poplar
	Salix	many species	willows

Table 2-Major genera of ectomycorrhizal fungi in the Pacific Northwest

Epigeous (mushrooms and puffballs)		Hypogeous (truffles and false truffles)	
Family	Genus	Family	Genus
Amanitaceae	*Amanita*	Boletaceae	*Alpova*
	Amanitopsis		*Gastroboletus*
Astraecaceae	*Astraeus*		*Rhizopogon*
Boletaceae	*Boletus*		*Truncocolumella*
	Fuscoboletinus		*Destuntzia*
	L eccinum	Cortinariaceae	*Hymenogaster*
	Phylloporus		*Thaxterogaster*
	Suillus	Elaphomycetaceae	*Elaphomyces*
	Xerocomus	Endogonaceae	*Endogone*
Cantharellaceae	*Cantharellus*	Geastraceae	*Radiigera*
	Craterellus	Geneaceae	*Genabea*
Clavariaceae	*Clavaria*	Gomphidiaceae	*Brauniellula*
	Ramaria	Helvellaceae	*Barssia*
Cortinariaceae	*Cortinarius*		*Balsamia*
	Descolea		*Hydnotrya*
	Hebeloma		*Picoa*
	Inocybe	Hysterangiaceae	*Hysterangium*
	Rozites	Leucogastraceae	*Leucogaster*
Geastraceae	*Geastrum*		*Leucophleps*
Gomphidiaceae	*Gomphidius*	Melanogastraceae	*Melanogaster*
Hydnaceae	*Hydnum*	Pyronemataceae	*Geopora*
Hygrophoraceae	*Hygrocybe*	Russulaceae	*Arcangeliella*
	Hygrophorus		*Elasmomyces*
Paxillaceae	*Paxillus*		*Gymnomyces*
Pisolithaceae	*Pisolithus*		*Macowamtes*
Rhodophyllaceae	*Clitopilus*		*Martellia*
	Rhodophyllus		*Zelleromyces*
Russulaceae	*Lactanus*	Strobilomycetaceae	*Gautieria*
	Russula		*Chamonixia*
Sclerodermataceae	*Scleroderma*	Tuberaceae	*Tuber*
Thelephoraceae	*Corticium*		
	Thelephora		
Tricholomataceae	*Catathelasma*		
	Laccaria		
	Tricholoma		

Major Edible Fungi in the Pacific Northwest

Evaluating edible fungi is similar to appreciating wild flowers; everyone has personal favorites. In this section, the "best" edible mushrooms found in this region have been selected from a great variety of edible species. We present 12 highly regarded, widely distributed edible fungi that are relatively easy to recognize and often sought commercially. The biology and ecology of each fungus are unique. Some are saprophyte that decay organic matter, others are mycorrhizal. Species abundance varies locally. The brief descriptions are intended simply as an introduction to the type of information necessary for studying these organisms and managing their habitats. We present a representative photograph with each description, but the reader must recognize that individuals in each species differ and that field specimens may differ from the picture. **This manual is not intended to be used for identifying fungi.** Mushroom identification takes training and experience. Even with comprehensive field guides, caution is necessary because look-alikes may sometimes confound the novice. Every year, misidentification leads to poisonings. The best advice is still, "When in doubt, throw it out."

Boletus edulis Bull.: Fr. (fig. 6)


Figure 6-King bolete or cep, *Boletus edulis.*

Common name: King bolete or cep

Edibility: Choice

Field description: The king bolete has a thick, bulbous stalk and the cap is covered with a netlike **(reticulate)** pattern of raised vein are pale brown to d reddish brown on th surface. On the underside of the cap, spore-bearing tissues are composed of hollow tubes joined together side by side, forming a spongy, pore-filled surface, as opposed to the gills or folded tissue of other mushrooms. Pores that are white when young and that do not bruise blue further distinguish this highly prized mushroom from other boletes.

Range and habitat: This species is found in Temperate Zone forests throughout the Northern Hemisphere. It fruits from the soil and is found scattered or in groups. At low elevations in our region, the main fruiting occurs in fall, though spring fruitings sometimes are encountered. At higher elevations, late spring and summer fruitings also can be expected. *Boletus edulis* forms mycorrhizae with a broad range of hardwood and conifer species. In our region, conifer species seem to be the most common associates.

Look-alikes: Because of its spongy spore-bearing tissues, the king bolete is not readily confused with mushrooms other than similar boletes. Common boletes in our region with reticulate stalks include *B. calopus* and *B. coniferarum.* These two species taste bitter and bruise blue on injury. Blue-staining or red-pored boletes may be poisonous.

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Cantharellus cibarius Fr. (fig. 7) and **C. *subalbidus*** Smith & Morse (fig. 8)

Common names: Golden chanterelle and white chanterelle

Edibility: Choice

Field description: Chanterelles are trumpet shaped with considerable variation in the thickness and taper of the stem. The golden chanterelle is yellow to yellow orange; the white chanterelle is off-white and bruises yellow orange. The spore bearing surface is veinlike with folds and ridges, as opposed to the gills of typical mushrooms. The flesh is firm and fibrous with a mild fruity aroma that is often likened to apricots.

Figure 7-Golden chanterelle, *Cantharellus cibarius.*

Figure 8-White chanterelle, *Cantharellus subalbidus.*

Range and habitat: *Cantharellus cibarius is* widespread in North Temperate Zone woodlands, and C. *subalbidus is* restricted to Washington, Oregon, and northern California. Both may occur singly but often occur in clusters on the forest floor. Golden chanterelles are found in conifer and hardwood forests, but white chanterelles are confined to conifer woods. Both fruit most commonly in late summer and fall; timing depends on rainfall. Chanterelles are mycorrhizal.

Look-alikes: *Gomphus floccosus* (scaly chanterelle), a mushroom that can cause gastrointestinal distress, has been mistaken for the golden chanterelle but can be distinguished by its hollow, vaselike cap that is rather scaly and dark red orange. At first glance, some gilled mushrooms such as *Chroogomphus tomentosus (wooly* pine spike), *Hygrophoropsis aurantiaca* (false chanterelle), or *Clitocybe* species may masquerade as chanterelles. Close examination shows that their spore-bearing surfaces have thin, deep, sharp-edged gills well differentiated from the flesh of the stem and cap. The edible lobster mushroom *(Russula spp.* parasitized by *Hypomyces lactifluorum) is* deep orange red, with coarse ribbing on the underside of the cap.

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Craterellus cornucopioides Pers. (fig. 9)

Figure 9-Horn of plenty, *Craterellus cornucopioides.*

Common name: Horn of plenty

Edibility: Choice

Field description: The horn of plenty is a hollow, trumpet- to funnel-shaped mushroom that usually occurs with many "horns" arising from a common base. When moist, they are very dark brown (appearing black in the dim light of fog-shrouded woods) but become brown to gray brown in dry weather. The flesh is thin and fibrous, but brittle, with a roughened upper surface and a smooth to slightly wrinkled spore-bearing lower (outer) surface.

Range and habitat: *Craterellus cornucoploides* is widely distributed but uncommon, being found with conifers, hardwoods, and in mixed woods. The mushrooms occur singly or, more commonly, in groups on the forest floor. On the west coast, it fruits from late fall in the north and, towards the south, appears through winter and early spring. Craterellus may form mycorrhizae with hardwoods or conifers.

Look-alikes: Very few fungi outside the genus *Craterellus* could be confused with the horn of plenty; the dark, funnel-shaped mushrooms are distinctive. Polyozellus multiplex (blue chanterelle, edible) occurs in similar groups from a common base, but the mushrooms are spoon to fan shaped (not hollow) and dark blue to gray violet.

Technical literature:

Bigelow, H.E. 1978. The cantharelloid fungi of New England and adjacent areas. Mycologia. 70: 707-756.

Corner, E.J.H. 1966. A monograph of cantharelloid fungi. Annals of Botany Memoirs No. 2. London: Oxford University Press. 255 p.

Smith, A.H. 1968. The Cantharellaceae of Michigan. The Michigan Botanist. 7: 143-483.

Hericium abietis (Weir ex Hubert) K. Harrison (fig. 10)

Common name: Coral tooth mushroom

Edibility: Good

Field description: This white fungus develops a massive, compactly branched form, with spiny teeth hanging like groups of icicles around the tips of the branches. The branches arise from a tough, thick, broad base. The fruiting bodies have the striking appearance of a miniature waterfall frozen in a cascade of ice.

Figure 10-Coral tooth mushroom, *Hericium abietis.*

Range and habitat: *Hericium abietis is* restricted to western North America from northern California to southeast Alaska. It grows saprophytically on fallen or standing dead conifers, especially *Abies spp.*

Look-alikes: *Hericium americanum* (American coral tooth, formerly *H. coralloides)* looks very similar but is found on hardwoods in eastern North America. *Hericium coralloides* (comb hericium, formerly *H. ramosum) is* more open and spreading with teeth all along the branches. The comb hericium is widespread on broad-leaf trees and is common on poplars in our area. *Hericium erinaceus* (hedgehog mushroom) is a simple mass of long teeth hanging from a cushionlike base. It fruits from the exposed heartwood of damaged but still living hardwoods, especially oak.

Technical literature:

Ginns, J. 1984. *Hericium coralloides* N. Amer. Auct. (= *H. americanum sp.* nov.) and the European *H. alpestre* and *H. coralloides.* Mycotaxon. 20: 39-43.

Harrison, K.A. 1973. The genus *Hericium* in North America. The Michigan Botanist. 12: 177-194.

Hallenberg, N. 1983. *Hericium coralloides* and *H. alpestre* in Europe. Mycotaxon. 18: 181-189.

Hydnum repandum L.: Fr. (fig. 11)
Common name: Spreading-hedgehog mushroom

Edibility: Choice

Figure I 9-Spreading-hedgehog mushroom, Hydnum repandum.

Field description: This mushroom is distinguished by brittle spines on the underside of the cap that function in place of gills as the spore-bearing

The cap is 5 to 10 centimeters wide and usually some bright shade of pale orange to salmon, occasionally darker reddish brown. The often off-center stem is somewhat lighter than the cap and about as tall as the cap is wide. The flesh is firm but brittle.

Range and habitat: Widely distributed in woods of all types. *Hydnum repandum* fruits in fall through late spring on the west coast, starting north and finishing south. *Hydum* is presumed (but unconfirmed) to be mycorrhizal.

Look-alikes: *Hydnum umbilicatum* (a good edible) is closely related but is smaller and somewhat trumpet shaped with a deeply indented cap. Many other mushrooms have spines or teeth as the spore-bearing surface, but others are either much tougher (leathery to almost woody) as in the genera *Hydnellum* and *Phellodon* or, if fleshy, are dark colored, scaly, or large (*Sarcodon*). The few that are edible are of inferior quality.

Technical literature

Harrison, K.A.; Grund, D.W. 1987. Preliminary keys to the terrestrial stipitate hydnums of North America. Mycotaxon. 28: 419-426.

Mass Geesteranus, R.A. 1975. Die terrestrischen Stachelpilze Europas. Amsterdam-London: North Holland Publ. Co. 123 p.

Lepiota rhacodes (Vitt.) Quel. (fig. 12)

Common name: Shaggy parasol

Edibility: Choice

Field description: This stately mushroom can be nearly 30 centimeters tall with a cap 40 centimeters wide. In young individuals, the cap is smooth, reddish brown, and drawn close to the stem. As the cap expands up and away from the stem, the outer skin breaks into coarse, patchy scales separated by shaggy white flesh. The smooth stem is white when young and becomes light brown; an ample ring is present. Cuts or bruises to the cap and stem cause the flesh to stain yellow orange then become salmon red to brown. The spore print is white (a spore print is formed when a cap is allowed overnight to drop its spores onto paper).

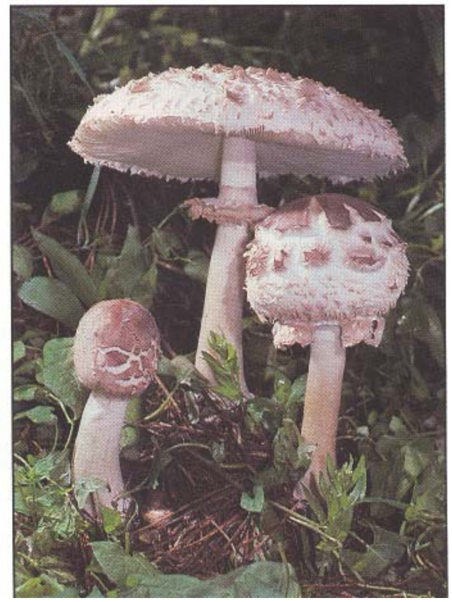

Figure 12-Shaggy parasol, *Lepiota rhacodes.*

Range and habitat: This widely distributed

in meadows, gardens, lawns, compost, ant hills, or disturbed places. Usually it occurs in groups or "fairy rings" that can be up to 30 meters in diameter. The shaggy parasol fruits in fall through early winter on the west coast.

Look-alikes: *Chiorophyllum molybdites* (green-spored parasol) is similar but tends to fruit in summer on lawns. It can cause severe gastrointestinal upset and is best differentiated by the medium to light gray green spore print. The green-spored parasol has not been reported from the Pacific Northwest or northern California. Another similar, but fortunately edible, mushroom, *Lepiota americana* (American parasol) is rarely seen on the west coast. One of the authors (Luoma) found it at the H. J. Andrews Experimental Forest growing among organic debris after record-setting July rains. It seems to be adapted to the humid eastern summers. The American parasol has finer scales on the cap and a wine-red-staining, inflated stem that narrows abruptly towards the top. *Lepiota procera* (parasol mushroom-edible) is another close relative. The parasol mushroom has a taller and thinner stem in proportion to the size of the cap and does not stain orange or red when cut. More common in the Eastern United States, it has been reported from the Southwest but is not known from the Pacific Northwest. Many small *Lepiota* species are poisonous.

Technical literature:

Smith, H.V.; Weber, N.S. 1987. Observations on *Lepiofa americana* and some related species. Contributions to the University of Michigan Herbarium. 16: 211-221.

Morchella esculenta Fr. (fig. 13)

Common name: Edible morel

Edibility: Choice (with caution)

Field description: *Morchella esculenta* exemplifies a typical morel. Morels have been likened to a pine cone perched on a stem. The fertile cap (pine-cone portion) is honeycombed with pits and ridges. The cap and stem are hollow, and the cap arises continuously from the stem. Stem color ranges from white to pallid brown. Colors of the cap range from pale yellow browns through tan and brown to gray brown. The pits are typically the same color or darker than the ridges.

Figure 13--Morel, *Morchella esculenta*.

Morchella esculenta represents the white morel group that includes *M. crassipes* and *M. deliciosa*. Determination of the number of distinct species and their proper names is a current topic of study. The same is true for the black morel group that includes M. angusticeps, M. elata, and M. conica. Black morels are like white morels in general appearance but tend to have ridges that are darker than the pits. All morels are edible, but people must exercise caution the first time they eat them; some people may react adversely, especially when morels are consumed with alcohol. Never eat morels raw.

Range and Habitat: Fruiting in early spring, morels are widely distributed in a variety of habitats including forested and nonforested areas. In the West, black morels can be abundant in burned areas. White morels are more common in the East. Morels are saprophytes.

Look-alikes: *Verpa bohemica* (early morel) has a cap composed of very wrinkled to nearly smooth tissue that is attached at the top of the stem and hangs down like a skirt. Some experts recommend that the early morel not be eaten because a fairly large proportion of the human population is sensitive to it. False morels (*Gyromitra* species) and elfin saddles (*Helvella* species) are irregularly convoluted to brainlike and lack the distinctive pitted and ridged pine-cone cap of the true morels. These two genera are also best avoided because they contain many poisonous species. The few edible species need to be treated with caution.

Technical literature:

Andary, C.; Privat, G.; Bourrier, M.-J. 1985. Variations of monomethylhydrazine content in *Gyromitra esculenta*. Mycologia. 77: 259-264.

Apfelbaum, S.I.; Haney, A.; Dole, R.E. 1984. Ascocarp formation by *Morchella angusticeps* after wildfire. The Michigan Botanist.23: 99-102.

Dissing, H. 1972. Specific and generic delimitation in the Helvellaceae. Persoonia. 6: 425-432.

Harmaja, H. 1986. Studies on the Pezizales. Karstenia. 26: 41-48.

Schmidt, E.L. 1983. Spore germination of and carbohydrate colonization by Morchella esculenta at different soil temperatures. Mycologia. 75: 870-875.

Tylutki, E.E. 1979. Mushrooms of Idaho and the Pacific Northwest-Discomycetes. Moscow, ID: The University Press of Idaho. 133 p.

Weber, N.S. 1988. A morel hunter's companion. Lansing, MI: Two Peninsula Press.

Picoa carthusiana Tulasne & Tulasne (fig. 14)

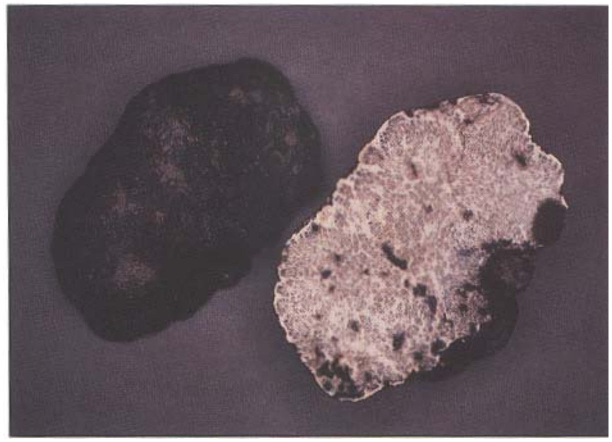

Figure 14-Black picoa, *Picoa carthusiana.*

Common name: Black picoa

Edibility: Choice

Field description: The firm, potato-shaped fruiting body is produced underground and is usually round to slightly irregular. It can be up to 8 centimeters in diameter. The exterior is minutely warty and dark brown to black. The interior spore-bearing tissue is solid and composed of fertile, dark-colored

aroma is pleasant and reminiscent of pineapple.

Range and habitat: *Picoa carthusiana* abounds in Douglas-fir forests, though it was first discovered in Western Europe. It usually fruits in winter, December through March, wherever Douglas-fir occurs in Oregon, Washington, northern California, and British Columbia. *Picoa carthusiana* forms mycorrhizae with Douglas-fir in the Northwest and is reported to associate with a variety of trees and shrubs in Europe.

Look-alikes: Other dark-colored truffles in the Northwest, such as *Genea gardneri*, are not solid inside. The interior composed of dark-colored pockets within pale surrounding tissue and the black, minutely waited exterior generally distinguish *Picoa carthusiana*. At least two *Picoa* species new to science from the Western United States have a smooth brown exterior.

Technical literature:

Gilkey, H.M. 1916. A revision of the Tuberales of California. University of California Publications in Botany. 6: 275-356.

Gilkey, H.M. 1939. Tuberales of North America. Oregon State Monographs. 1: 1-63.

Gilkey, H.M. 1954. Tuberales. North American Flora. Series 2, Pt. 1: 1-36.

Marin, A.B.; Libbey, L.M.; Morgan, M.E. 1984. Truffles: on the scent of buried treasure. Mcllvainea. 6: 34-38.

Marin, A.B.; McDaniel, M.R. 1987. An examination of hedonic response to *Tuber gibbosum* and three other native Oregon truffles. Journal of Food Science. 52:1305-1307.

Sparassis crispa Wulf.: Fr. (fig. 15)

Common name: Cauliflower mushroom

Edibility: Choice

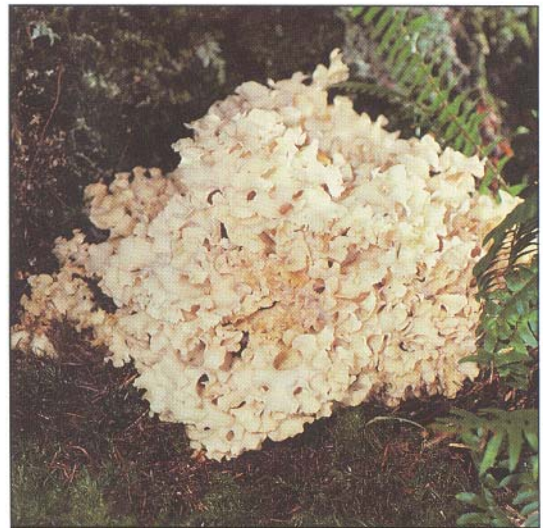

Figure 15-Cauliflower mushroom, *Sparassis crispa.*

Field description: In the Pacific Northwest, the fruiting body is commonly massive (10 kilograms or more) and is composed of flattened, ribbonlike or leaflike, compact branches arising from a common base. This mushroom was long known in the West as *S. radicata*, so named for the characteristic deeply "rooting" base. Arora (1986) likens its appearance to that of a sea sponge, and Smith (1975) describes it as "resembling a cluster of egg noodles."

western North America, particularly from northern California through southern British Columbia. It is usually found in the fall at the base of mature conifer trees in which it causes a brown rot of the heartwood.

Look-alikes: No other species looks like this fungus except *S. spathulata*, an equally edible species of Eastern U.S. hardwood forests.

Technical literature:

Burdsall, H.H., Jr.; Miller, O.K., Jr. 1988. Type studies and nomenclatural considerations in the genus *Sparassis*. Mycotaxon. 31: 199-206.

Burdsall, H.H., Jr.; Miller, O.K., Jr. 1988. Neotypification of *Sparassis crispa*. Mycotaxon. 31: 591-593.

Tricholoma magnivelare
(Peck) Redhead (fig. 16)


Figure 16-Matsutake, pine mushroom, or white matusutake, *Tricholoma magnivelare.*

Common name: Matsutake, pine mushroom, or white matsutake

Edibility: Choice

Field description:
Matsutake is a robust mushroom that is first white but soon develops pale brown to yellow-brown stains. The stout stem is solid, tough, and fibrous. It is smooth above and scaly below the thick, sheathing ring that flares out in young specimens. The cap edge develops from a cottony and inrolled form to one that hangs down, with a distinctive vertical aspect at maturity. The magnificent aroma is spicy-aromatic, similar to a sweet cinnamon odor. The spore print is white.

Range and habitat: *Tricholoma magnivelare* is widespread in North America but most abundant in Washington, Oregon, and northern California. It forms mycorrhizae with a broad range of hosts, but commercial harvest is concentrated in *Pinus contorta* forests. Fruiting typically begins soon after the advent of the fall rainy season and progresses from north to south.

Look-alikes: White matsutake has been known as *Armillaria ponderosa*, but botanical nomenclatural rules dictate the current Latin name. It has several imitators in our region; all but the first mentioned lack the distinctive aroma. *Tricholoma caligata* is most similar and may have a cinnamon odor, but the scales of the cap and stem are darker brown than in *T. magnivelare*. *Tricholoma zelleri* has orange-yellow to orange-brown tones and an unpleasant smell. *Hygrophorus subalpinus* (edible) is white with similar stature, but is found in the spring soon after snow melt. *Catathalasma* species also are robust and tough but are gray brown with gifts running part way down the stem. *Tricholoma matsutake* is the "true" pine mushroom of eastern Asia.

Technical literature:

Kinugawa, K.; Goto, T. 1978. Preliminary survey on the "matsutake" (Armillaria ponderosa) of North America. Transactions of the Mycological Society of Japan. 19: 91-101.

Ogawa, M. 1979. Microbial ecology of "shiro" in *Tricholoma matsutake* and its allied species. IX. *Tricholoma ponderosum* in *Pseudotsuga menziesii-Tsuga heterophylla* and *Pinus contorta* forests. Transactions of the Mycological Society of Japan. 20: 370-382.

Redhead, S.A. 1984. Mycological observations, 13-14: on *Hypsizygus* and *Tricholoma*. Transactions of the Mycological Society of Japan. 25: 1-9.

Tuber gibbosum Gilkey
(fig. 17)

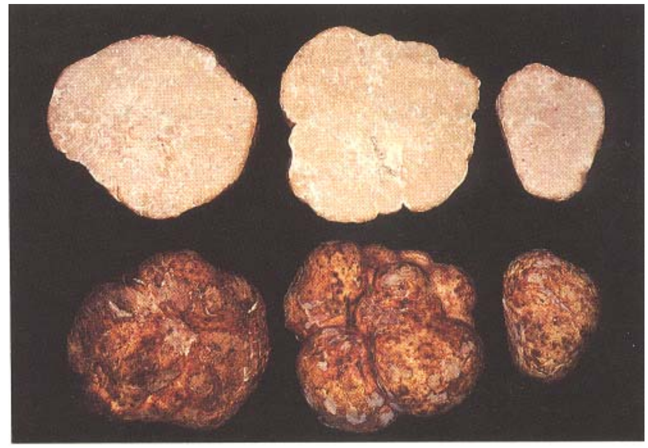

Figure 17-Oregon white truffle, *Tuber gibossum.*

Common name: Oregon white truffle

Edibility: Choice

Field description: The potato-shaped fruiting body is produced underground and is usually round to irregularly knobby and firm. It can be up to 7 centimeters in diameter. The exterior lacks hairs or warts and is whitish when young, becoming pale brown or bruising reddish brown.
The interior spore-bearing tissue is marbled shades of white when young, becoming brown to dark brown with white veins when mature. The aroma is characteristically strong and garlicky or cheesy to pungent metallic with age.

Range and habitat: The Oregon white truffle occurs from northern California to British Columbia west of the Cascades. It is found singly, or more commonly in groups, exclusively under Douglas-fir, with which it forms mycorrhizae. The main fruiting season is late fall through early spring.

Look-alikes: Many *Tuber* species overlap in distribution. The smooth, pale reddish-brown exterior and the pungent, garlicky odor usually serve to distinguish *T. gibbosum.*

Technical literature:

Gilkey, H.M. 1916. A revision of the Tuberales of California. University of California Publications in Botany. 6: 275-356.

Gilkey, H.M. 1939. Tuberales of North America. Oregon State Monographs. 1: 1-63.

Gilkey, H.M. 1954. Tuberales. North American Flora. Series 2, Pt. 1: 1-36.

Marin, A.B.; Libbey, L.M.; Morgan, M.E. 1984. Truffles: on the scent of buried treasure. McIlvainea. 6: 34-38.

Marin, A.B.; McDaniel, M.R. 1987. An examination of hedonic response to *Tuber gibbosum* and three other native Oregon truffles. Journal of Food Science. 52: 1305-1307.

Recreational, Social, and Folk Aspects of Fungi

Attitudes Toward Fungi

Humans have interacted with fungi throughout history: some of the oldest known religious artifacts are stones carved in the shape of mushrooms. Almost everyone has an opinion about mushrooms. Some people fear mushroom poisoning or the aura of death and decay associated with them. Others are enthusiastic almost to the point of mania; a recent cookbook produced by the San Francisco mushroom society reflects this attitude in its title, "Wild About Mushrooms." Wasson and Wasson (1957) coined the terms "mycophilic" for those who esteem fungi (myco- mushroom + p*hile*lover) and "mycophobic" for those who dislike them.

Some people unreasonably fear and loathe fungi. Literary allusions to fungi are often deathly with overtones of evil and decay. Their weird shapes and colors and their rapid appearance and disappearance (compared to green plants) have led fungi to be associated with magic and deviltry.

Why do some people fear mushrooms and others delight in them? Some of these attitudes have a cultural basis; for example, many people of Asia and continental Europe are fond of fungi, but people of the United Kingdom often abhor them. Although exceptions to these preferences toward fungi do occur, Americans of British origin are often mycophobic, whereas many with roots in continental Europe learn from their parents and grandparents to love mushrooms. Preferences also are evident in which mushrooms people choose: matsutake is most eagerly sought by Asians, and Europeans often prefer boletes, chanterelles, or morels.

Mushrooms need not be feared any more than wild plants. Some plants are deadly if eaten, others cause various degrees of illness, and some are delicious. So it is with fungi. When you gather wild berries, you do not pick randomly and then decide which to eat. Similarly with mushrooms, you learn to recognize a few favorite species (like chanterelles or morels) and treat the others with respectful caution. No mushroom is so poisonous that touching it is hazardous (unlike poison oak, for example).

At the other end of the spectrum are those whose fascination with fungi becomes almost obsessive. They may sing praises of the most humble of mushrooms and devote endless hours pursuing fungi. Some mycophiles devote their lives to studying fungi (mycologists) or collect such treasures as mushroom stamps (mycophilatelists), books, or artwork. Another attitude toward fungi is indifference. So what? Why should anyone care about fungi, pro or con? With the growing controversy about the fungal resource on public lands, however, more people are becoming concerned with the fungi as a land management issue. Recognition of the importance of fungi is growing in fields ranging from forestry to medicine.

Interactions With Fungi

Different attitudes among people about fungi translate into different actions. Some people kick or trample mushrooms in the mistaken belief that they are eliminating a fungal "pest." To illustrate the widespread ignorance of fungal biology in America, consider the nuclear physicist who thought he would rid his oak tree of a fungal parasite by knocking the mushrooms off the tree trunk. The simplest understanding of fungal biology-that mushrooms are the fruit of a more extensive, longer lived organism-shows that killing an apple tree by picking all of the apples would be as likely!

Another, more informed attitude towards fungi is tolerance. The casual observer may notice mushrooms and may even see enough beauty in them to refrain from destroying them, though they may not care to pick them. Because finding mushrooms is a learned skill, individuals sometimes become interested enough to study mushroom identification.

Passions about fungi rise in those who actively collect them, whether for the dinner table, sale, or scientific study. Most people who pick mushrooms do so because they like to eat them. But there are other unique and unusual uses of fungi, such as painting on large, woody conks or close-up photography and painting of mushrooms in natural settings. Dried mushrooms are used in floral arrangements in Europe. Some mushrooms are prized as sources of natural dyes for wool and other fibers. Ink and paper can be made from fungi (Rice 1991). These are mostly home uses, but the products are becoming popular in gift shops and at mushroom shows.

Mushroom hunting is often a family activity. The location of a favorite patch is as jealously guarded as a good fishing hole. Mushroom picking easily can be combined with other outdoor recreation. For this reason and because of public interest in nature studies, mushroom hunting is gaining popularity.

Commercial harvest of wild fungi is also growing. The past 10 years have witnessed a tremendous increase in mushroom picking on forest lands throughout the Pacific Northwest. Four species, *Boletus edulis, Cantharellus cibarius, Morchella esculenta,* and *Tricholoma magnivelare,* account for most commercial harvest. These species, sold or exported fresh or shipped in brine for canning, are exclusively for culinary use. They can bring significant income: on a good day of picking matsutake, a picker might earn hundreds of dollars. Good days may be interspersed with many days of little or no success, however.

Fungi have a long history of medicinal use. A few species were included in the European and Native American pharmacopoeia; many more were and are used in traditional Asian medicine. Native Americans used puffball spores on wounds to reduce inflammation and infection. *Polyporus officianalis,* as the name suggests, was "officially" recognized by medieval apothecaries. The Asian fungal pharmacopoeia includes hundreds of species used for tonics, as aphrodisiacs, and in preparations where they are combined with various plants.

This history of medicinal fungi prompts the question, What use does modern medical science make of fungi? So far, very little. Western medicine is just beginning to experiment with potentially beneficial mushrooms (of course, many antibiotics were derived from microscopic molds). Evidence is accumulating that some species of mushrooms contain powerful stimulants of the immune system. In many experiments, extracts of some mushrooms have caused shrinkage of experimentally induced tumors in mice or elevated white blood cell count of human patients. Because immune-related disorders, such as HIV and many cancers, are among the most costly and difficult to treat of diseases, medicinal use of mushrooms may well increase.

Although some species show great promise, fungi are no panacea. In fact, an extract of one of the most well-known, traditionally used mushrooms *(Ganoderma lucidum,* or ling-chih) caused tumors to grow faster when injected into mice. Much more research is needed in this area; unfortunately, our mycophobic culture is slow to perceive the great potential value of fungi. See Jong and Donovick (1989) for a detailed review.

Some forest fungi can aid forest regeneration. To improve seedling growth and survival, ectomycorrhizal fungi can be introduced to forest nurseries as spores during irrigation. *Rhizopogon parksii,* a trufflelike fungus, is collected on a small scale and sold to nurseries for inoculum.

Mushrooms can be used to make a wide variety of colorful dyes. Fresh or dried mushrooms of certain species can be simmered in water and used to dye silk, cotton, wool, and other fibers. Mineral salts, called mordants, often are added to the dye bath to help fix the dye to the fiber. Different combinations of fungi and mordants yield an amazing range of colors.

Mushroom dyes are slower to fade than most vegetable dyes. Another unique aspect of mushroom dyes is the diversity of colors obtained from a single species with different mordants. *Dermocybe phoenicea,* for example, produces red, blue, purple, and gray depending on the mordant used. By premordanting fiber with several mordants, multiple colors can be obtained from a single dye bath. For more information on dyeing with fungi, see Rice and Beebee (1980).

The potential for fungi as forest products has barely been explored. New uses will be discovered, and the variety of commercially important species will increase. This increase may exacerbate the growing conflicts between different groups of users of fungi, particularly between those who want to harvest forest fungi commercially and those who make other uses of the forest.

Amateur mycologists are among the most vocal users of fungi. They typically start out to learn which mushrooms are safe to eat and move on to learn all they can about fungi. Oregon and Washington have 18 amateur mushroom societies (appendix 2). These societies go on group forays, sponsor mushroom shows, and produce educational publications. Although many mushroom enthusiasts are not affiliated with any organization, those who are exert important effects on regulating the industry. Recent regulations passed in Washington State were partly due to the efforts of amateurs. The Oregon Mycological Society is working with the Mount Hood National Forest to investigate the effects of picking on subsequent chanterelle harvests. Amateurs contribute significantly to the science of mycology. For example, members of the North American Truffling Society (based in Corvallis, Oregon) have discovered many truffle species previously unknown to science.

Professional mycologists are keenly interested users of the fungal resource. In fact, regulation of mushroom collecting is imposing logistical constraints on their work. In the past, professional mycologists have tended to collect fungi whenever, wherever, and however they chose, except in National Parks. Today collecting of fungi for any purpose is prohibited in many State parks in California and Washington, and most National Forests in Oregon and Washington are requiring permits of some sort even for scientists.

Another group of mushroom enthusiasts are those who seek them for religious or recreational purposes. The roots for these practices are in the religious ceremonies of Siberians, Mezoamericans, and others. Modern use grew dramatically during the "psychedelic" era of the 1960s and 1970s. The principal fungi used are species of *Amanita, Stropharia* and *Psilocybe,* some of which occur on National Forests. This use of wild fungi is both regular and illicit.

Yet another interaction of people with fungi is to be poisoned by them. Perhaps the most frequent cause of mushroom "poisoning" is spoilage. Some enthusiasts will eat mushrooms that are too old for safe consumption, perhaps because they expect mushrooms to be slimy and do not recognize the incipient rot. Some fungi, including the popular edible morels, can persist in the wild for a long time without changing appearance, but contamination by spoilage organisms may increase during this time. A second frequent cause of poisoning is an individual's idiosyncratic response. Just as some people are allergic to particular foods, others react to mushrooms. Often people can eat many kinds of mushrooms, but certain species upset their stomachs. Third are the truly toxic fungi, which produce symptoms ranging from gastrointestinal upset to lingering and painful death. Luckily, few mushroom species are seriously poisonous and many are too small to tempt the picker. Some deadly *Amanita* species are large and superficially resemble *Volvariella* species, which are widely consumed in Asia. This similarity has led to several tragic poisonings when recent immigrants have assumed that their knowledge from elsewhere could serve them equally well here. Some small but deadly mushrooms superficially resemble some *Psilocybe* species. People are sometimes fatally poisoned from misidentification of psychoactive fungi.

Health concerns are an important regulatory issue and have received considerable attention in Europe. For example, the French mushroom markets are closely regulated and inspected by certified mushroom inspectors. It was only after multiple poisonings that these regulations were developed. The sole purpose of the market is for selling mushrooms. Mushrooms must be displayed one layer thick in special boxes and intact with all their parts to allow for positive identification and inspection. Common and Latin names must be on the boxes. Access to the market is carefully controlled and sellers must live within the local area serviced by the market. No market regulation of wild mushrooms exists in the Northwest, although regulations seem likely soon, preferably before a poisoning by purchased mushrooms stimulates legislative action. Spoilage is another issue that needs addressing. Ensuring high quality of their products is obviously in the interest of those marketing wild fungi, so regulating freshness by law may not be as important as ensuring proper identification of wild-harvested fungi.

People hunt mushrooms to share in nature's bounty, to admire the beauty and diversity of life, to make money or beautiful and useful objects, and to learn about how nature works. These values are similar to those that motivate people to hunt, fish, harvest timber, or collect plants. Just as conflicts over appropriate uses led to regulated management of other commercial and recreational activities, mushroom collecting will undergo increased regulation.

Resource Conflicts

Much of the following discussion of resource conflicts deals with widespread current perceptions rather than hard evidence. Accurate or not, perceived conflicts raise fears that management schemes must address; for example, overpicking of mushrooms is commonly feared to cause a decrease in future abundance. No data currently support or refute this concern, so it is still valid and a candidate topic for research. If people have picked chanterelles in the same place for years, that they become upset when "their" patch is picked by others or the forest is clearcut is hardly surprising, whether they are collecting for home, commercial, or scientific purposes.

Just as fishing grounds are sometimes disputed, conflicts occasionally arise over access to productive mushroom grounds. Although newspapers have recently reported armed confrontations in the woods, knowledgeable sources claim that these reports are exaggerated. With increasing demands on a limited resource, such conflicts are likely to grow and must be addressed in regulating mushroom harvest. National Forests have adopted various regulations including exclusive harvest rights obtained by competitive bidding, similar to timber sale auctions. Other public lands, such as California State parks, are becoming completely off limits to any mushroom collecting.

Whether scientist, amateur, or commercial harvester, most collectors of fungi do not own the land where they gather fungi, and landowners may not be compensated. Therefore, mushroom collecting without permission raises the issue of theft from public lands or private property. Additionally, landowners have valid concerns about liability for injury or poisonings resulting from mushroom collecting on their land.

Other conflicts arise between mushroom pickers and people using forest land for other purposes. Possible conflicting uses include harvest of other forest products, such as timber, and some recreational activities. Two concerns are typically raised about logging. First is the disappointment experienced by the mushroom hunter returning to a favorite patch only to discover a fresh clearcut. Second is the concern that timber harvest may damage the fungi. This concern is valid; ectomycorrhizal fungi stop fruiting when a forest is clearcut, but for how long is not known. Some popular fungi, morels for example, abound after disturbance (including clearcutting and broadcast burning). Some thrive in young forests. Other species may require habitat provided only by old-growth forests. Effects of logging on fungi is an area of research needing immediate attention. Apparent declines in mushroom harvest in Europe have occurred over the past few decades, but to what extent these declines result from intensive forest management, pollution (Arnolds 1991), overharvest, or other causes is uncertain.

Conflicts with recreational users of the forest occur when they feel that harvest of fungi is an inappropriate activity for a recreation area or that it harms the forest. This type of concern extends from heavily used county and State parks to National Parks and Wilderness Areas. Wilderness Areas are primarily recreational areas, and commercial harvest is prohibited; activities such as fishing, hunting, and berry collecting are allowed, however.

Resolving Conflicts

The conflicts we have identified will not go away by themselves: creative solutions must be sought. The need for sound information on which to base management decisions is urgent. The major categories of required information are both socio-economic and biological. Socioeconomic questions include:

- Who is collecting fungi? In what quantities?
- Which species? From what areas?
- What are the collectors needs and expectations? (For example, are they earning significant income from harvesting wild fungi?)
- How does the income of local pickers and the influx of nonlocal pickers affect the economy of a community?
- What is the value of mushrooms versus other resources on a given unit of land?

Biological questions include:

- What amounts of which species of fungi are produced on public lands?
- What amounts can be harvested on a sustained yield basis?
- How does forest management affect the different species of fungi?
- Can edible wild mushroom harvest be enhanced by forest management?
- Which species, if any, are in danger of local or regional depletion?
- Can accurate methods be developed to determine local or regional fungal diversity?
- What strategies will best maintain fungal biodiversity?

Rational management cannot proceed without answers to these and other questions. In the meantime, regulations are being adopted arbitrarily. Different forests have different regulations, which creates confusion for commercial and amateur pickers alike. It is not unusual for pickers to begin in northern California and range beyond the Canadian border in a 15-day period in search of profitable flushes of certain mushroom species. Regulation of fungal harvests should be considered in the context of other "special forest products." Standardizing regulations among regions is important. But we may need to tailor regulations to local conditions, because local variation in environmental conditions affect fungal populations differently.

Commercial Aspects of the Wild Mushroom Industry

Gathering fungi from Pacific Northwest forests is evolving from a subsistence, recreational, or educational activity to a multimillion-dollar industry. This evolution is being accompanied by concerns for sustaining fungi as a natural resource and the development and enforcement of regulations. We will briefly recount the history of the wild mushroom harvest, then consider the current harvest and regulations.

Historical Development

Four stages characterize the evolution of mushroom harvesting. Each stage adds a new group of users, with different motives for collecting fungi.

- Native Americans used fungi in their hunting and gathering. This use is poorly documented in the United States, but it has received attention in South America (Fildalgo and Prance 1976).

- Immigrants from Europe and Asia brought traditions of collecting and eating a wide variety of forest fungi. For many decades, mushroom gathering was practiced by relatively few people with an ethnic background for it (that is, recent immigrants from continental Europe and Asia) or scientific curiosity.

- Interest in fungi exploded with increased desire for wild foods and with the rediscovery that some species are hallucinogenic (Wasson 1957). By the 1970s, amateur mushroom societies were overwhelmed by the influx of new members, and pastures were frequented by "magic-mushroom" seekers.

- In the early 1980s, commercial harvest of wild mushrooms began in earnest. All that a knowledgeable entrepreneur needed to make a seasonal income from fungi was transportation and a market. Markets were largely restricted to produce retailers and restaurants, either local and or in metropolitan regions of the Eastern United States or California.

The next evolution of the industry was the development of foreign markets. This development was accompanied by the appearance of mushroom buyers close to harvest areas and dealers who air-freighted fresh mushrooms or packed them in brine for canning by foreign purchasers.

Two characteristics distinguish the wild mushroom industry from other forest resource-based industries. One is the lack of compensation to owners of land from which the resource is harvested: it is largely an industry based on "theft." The other unique feature is lack of regulation: the wild mushroom industry is to a great extent unregulated, unreported, and untaxed. Most pickers are paid in cash, with little incentive for anyone in the chain to report income to the State or Federal revenue services.

The failure to compensate landowners and the lack of regulation, along with concerns over possible resource depletion, are driving the current phase of evolution. This phase includes attempts to monitor the harvest, provide compensation (at least for some lands such as National Forests and State lands), and regulate how much is harvested by various users.

Harvest figures for forest mushrooms are difficult to obtain because no crop statistics and regulatory harvesting laws existed, until recently. In 1989, Washington State passed the first law in the United States, requiring licensing for mushroom buyers and dealers and annual harvest reporting for all commercial wild mushrooms.

Production in 1989-90

The first report by the Washington State Department of Agriculture and the Washington Agricultural Statistics Service became available in October 1990 (Washington State Department of Agriculture 1990). Mushroom production numbers from these reports should be interpreted with caution because of the newness of the law. Considerable improvement was noted in the 1990 crop report, and with time, production numbers should reflect the actual market. The Washington harvest reports for 1989 and 1990 are estimated to represent about 10 and 20 percent, respectively, of the actual crop.

Table 3-Total pounds and dollars collected from wild mushroom harvesting in Washington, 1989-90

	1989		1990	
Fungus species	Pounds	Dollars	Pounds	Dollars
Tricholoma magnivalare	2,600	35,075	106,327	602,530
Boletus edulus	4,060	24,315	15,799	122,655
Cantherellus spp.	248,850	586,355	277,530	437,922
Hydnum repandum	*0*	*0*	5,615	9,376
Hericium sp.	37	108	122	212
Lactarius deliciosus	*0*	*0*	*100*	151
Polyozellus multiplex	*0*	*0*	937	1,406
Laetiporus sulphureus	5	15	75,836	88,087
Sparassis radicata	2,145	6,366	10,999	16,549
Pleurocybella porrigens	*1*	3	0	0
Other	0	0	79	20
Total	257,700	652,247	493,344	1,278,910

The production of wild mushrooms in Washington increased in 1990 compared to 1989 (table 3). In 1989, 20 licensed buyers and 4 licensed processors (dealers) reported buying 257,700 pounds (117 136 kg) of wild mushrooms with a wholesale value of $652,247 or $2.53 per pound. The 1990 report showed almost double the pounds harvested (493,344 lb [224 227 kg]) with a value of $1,278,910 or $2.59 per pound. The increase is partly reflected by the fact that as legitimate mushroom buyers and dealers learned about the law, they purchased the required license. The average price per pound, however, differed little from one year to the next.

The 1989 report showed that the bulk of the "reported" crop came from just two counties. Grays Harbor and Mason counties accounted for 50 and 47 percent of the crop, respectively. Chanterelles accounted for 97 percent of the crop (248,850 lb [113 114 kg] valued at $586,355). The average wholesale price for the chanterelles was $2.36 per pound. The next most popular species was *Boletus edulis* with 4,060 pounds harvested, with an average price of $5.99 per pound. The most valuable species was *Tricholoma magnivalare* or matsutake, with 2,600 pounds harvested at an average price of $13.99 per pound. In contrast, the 1990 report showed a much wider production distribution over most western Washington counties. Mason and Grays Harbor counties are still production leaders, but other counties made notable gains. Unfortunately, 1990 data did not provide detail on species prices per pound. Only averages for all species can be calculated. Table 4 summarizes the harvest by counties for the two years.

The 1989 Washington report also showed that processors (dealers) handled about 39,000 pounds of morels. In contrast, the estimated 1987 Oregon morel production was worth about $2.6 million, about the same as that State's annual blueberry crop, or half of its strawberry crop. In 1988, British Columbia exported about 500 tons of matsutake to Japan with an estimated value of about US$9 to 10 million. None of the 1989 buyers or dealers reported exporting any mushrooms to either Germany or Japan (Washington State Department of Agriculture 1990). When seasonal weather is good for forest mushroom production, markets can boom, which affects local rural economies.

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Table 4-Total pounds and dollars collected from wild mushroom harvesting in various counties of Washington, 1989-90

	1989		1990	
County	Pounds	Dollars	Pounds	Dollars
Clallam	0	0	41,256	94,017
Clallam (west)	0	0	9,754	12,633
Cow litz	700	1, 610	10, 227	12, 424
Grays Harbor	108,270	281,715	54,122	495,127
Jefferson	2,750	6,325	800	1,074
Klickitat	0	0	39,572	151,043
Kitsap	250	310	0	0
Lewis	1,270	3,160	101,157	101,984
Mason	138,465	344,086	152,071	303,850
Pacific	1,195	3,126	6,043	9,997
Pierce	0	0	937	1,406
Snohomish	1,250	3,750	27,056	33,441
Thurston	3,550	8,165	48,780	54,646
Yakima	0	0	1,288	3,918
Total	257,700	652,247	493,344	1,278,910

Picking for Supplemental Income

Picking and selling wild edible mushrooms provides supplemental seasonal income for many. Washington is estimated to have from 700 to 900 commercial mushroom pickers earning from a few dollars to $3000-5000 in a good season. One advantage of mushroom harvesting is that a picker with a car and reasonable woods lore can become an independent businessperson. The influx in the 1970s and 1980s of Southeast Asians brought an increase in pickers to the region. They found the abundant Pacific Northwest mushrooms similar to those in their homeland, and it was only natural to market them. They could pick and sell mushrooms without fluency in English-a distinct advantage to newcomers to the United States. Others make part of their annual income by moving from one seasonal woods crop to the next (Acker 1986).

Forest Land Ownership Patterns in Washington and Oregon

Washington and Oregon have different forest land ownership patterns. Oregon has more Federal and much less State land than does Washington. Nearly two-thirds (62 percent) of Oregon forest land is in some kind of public ownership. Washington has about 30,000 small private forest landowners (more than 10 acres) which, when combined with the large industrial forest landowners, accounts for about half of the forest land. Oregon's 25,000 similar small forest landowners plus the large industrial forest landowners, account for about 37 percent of the forest land.

Landowner Regulation of Wild Mushrooms

Traditionally, both public and private forest landowners have generally ignored wild mushroom harvesting on their lands. The emergence of commercial mushroom picking as a relatively new industry has attracted the attention of forest

Private landowners wishing to sell their wild mushroom resource can use sale procedures similar to those being developed by government agencies. The procedures for selling wild mushrooms are new, and as markets develop and land managers gain experience, these procedures will become fairly standardized.

Wild Edible Mushroom Task Group

In October 1985, at the urging of several Washington mycological societies, Commissioner of Public Lands Brian Boyle convened the Wild Edible Mushroom Task Group. Representatives came from State and Federal government, industrial and small private forest landowners, the wild mushroom industry, and mycological societies. An early task was a white paper detailing issues on commercial harvesting of wild edible mushrooms (Acker 1986).

After 16 months of meetings and discussion, the task group focused on three major points: to promote mushroom farming as a cottage industry using primarily nonmycorrhizal mushrooms; to plan research on ecology, habitat, and production of nonmycorrhizal mushrooms; and to investigate ways to regulate and sustain the resource.

Recommendations of the task group were implemented in a variety of events. Seminars on growing mushrooms for market were held in western Washington in 1987-88. A baseline study of chanterelle growth and fruiting was begun by the Oregon Mycological Society (Portland) in the nearby, restricted-access Bull Run Watershed. A report was completed that details research needed for determining the effect of commercial wild mushroom harvesting on the resource (Russell 1987). The "Special Forest Products Workshop" held in Portland in February 1990 and the "Biology and Management of Wild Edible Mushrooms in Pacific Northwest Ecosystems Workshop" in Springfield, Oregon, in October 1991 brought concerned mushroom resource managers and users together to develop working relations.

Washington State's Wild Mushroom Harvesting Act

Gradually, consensus began to shape into legislation for regulating the wild mushroom resource in Washington. Two wild-mushroom-harvesting bills (one adopting harvest limits and seasons on Department of Natural Resources lands, and one amending the existing specialized forest products law to include mushrooms) failed passage by the 1986 legislature. A new tack was taken emphasizing education, and the 1988 legislature gave nearly unanimous passage to a mushroom harvesting law requiring licensing and reporting of data as described. This law took effect in January 1989 and was amended in 1990 to improve definitions. The Washington State Department of Agriculture administers the act.

A variety of groups are involved in the commercial mushroom industry. Mushroom harvesters pick wild mushrooms for sale or as employees of a mushroom buyer or dealer. Mushroom buyers buy wild mushrooms from harvesters for eventual resale, often at roadside or other buying stations. Mushroom dealers purchase and handle wild mushrooms in any manner whatsoever for eventual resale, either wholesale or retail. Under this definition, restaurants purchasing wild mushrooms from buyers and serving them are considered dealers. Restaurants buying mushrooms directly from harvesters could qualify for the lower priced buyer license.

Basic Requirements of the Act

The law requires annual licensing of persons who buy and process wild mushrooms for market. Buyer and dealer licenses are $75 and $375 per year, respectively; harvesters (pickers) are exempt (Revised Code of Washington 1989).

Mushroom buyers must send a prescribed form to the Washington State Department of Agriculture each month that includes the site of purchase; amount by weight of each species obtained; approximate location of harvest site; date of purchase; price paid to harvester; and name, address, and license number of dealer to whom mushrooms are sold. Other information also may be required. Dealers must complete a similar form when obtaining wild mushrooms from sources other than licensed buyers.

By December 31, dealers shall send to the Department of Agriculture a prescribed form that includes, for each variety of mushroom, the quantity by weight sold within Washington, within the United States, and to individual foreign countries; and other information as might be required.

The Washington State Department of Agriculture publishes annual harvest totals in conjunction with U.S. Department of Agriculture crop reporting statistics, as well as a description of where processed wild mushrooms were sent. This law should prove invaluable in tracking the often mysterious path of wild mushrooms through the marketplace. Accumulation of statistics will help attract attention to the research needs for this special forest resource.

Washington State Regulations

The Washington Department of Natural Resources may not legally give away any resource with marketable value. Resources include things like gravel, sand, timber, and edible mushrooms; all resources must be sold at fair market price. Currently, the department may sell wild mushrooms by leasing a tract of land to an individual or company at a bid price. Security for protecting the resource is to be provided by the leaseholder. A direct purchase system similar to that of two National Forests is planned but has not been implemented.

The Washington Department of Wildlife manages numerous tracts of wildlife habitat, lands. The department allows recreational mushroom picking for persons with hunting or conservation licenses but does not allow commercial harvesting on these lands. The Washington Parks and Recreation Commission, National Park Service, and National Forest Wilderness Areas also allow recreational picking but not commercial harvesting. The hunting and conservation licensing requirements do not apply.

Government Regulations Elsewhere

Several other States were surveyed to determine whether they had laws regarding wild mushroom harvesting. Idaho, Michigan, Minnesota, Oregon, Texas, and Wisconsin responded that they had none. Wisconsin has a law for wild ginseng *(Panax quinquefolia L.)* that requires harvesters and dealers to have $5 and $100 annual licenses, respectively. Texas reported in an official letter that mushrooms more than 6 feet tall or 3 feet in diameter could not be harvested. Washington is the only state or province in North America known to have a law for commercial harvesting of wild mushrooms. Switzerland, Italy, Germany, and possibly a few other European countries have various kinds of regulations that enact regional closures or limits on mushroom harvesting.

The USDA Forest Service has been the Pacific Northwest leader in developing fee systems for selling the wild mushroom resource to commercial harvesters. Several systems are either in development or have been implemented. Some industrial forest landowners are allowing mushroom harvesting without a fee to create "good will." Others find it uneconomical to pursue. Patrolling or other means to prevent trespassing and mushroom theft is costly but could be combined with other security functions.

How to determine the type and cost of a wild mushroom permit is difficult. Should wild mushrooms be sold by land area or by the pound? By bid or permit? Low-cost methods that seem to be evolving are over-the-counter permits that either pay the landowner for a specified amount of mushrooms or are good for a certain period; for example, the Umatilla and Wallowa-Whitman National Forests in southeastern Washington and northeastern Oregon sell 3-day commercial harvesting permits for $10 and 30-day permits for $50. Personal use permits are free and have a picking limit of 5 gallons. Mushroom buyers using Federal land as a purchasing station are required to have a $100 annual permit and a free industrial camping permit. While on Federal land, these buyers may purchase mushrooms only from pickers with valid Federal harvesting permits.

The Olympic National Forest in Washington allows up to two annual permits for 50 pounds of mushrooms for family or individual personal use. This free permit is available by phone or mail from Ranger District offices. A 3-day commercial mushroom-harvesting permit allows harvest of 100 pounds at an appraised price of around $0.20 per pound, which may fluctuate. Commercial permits must be picked up at a District office. An accepted mushroom identification guidebook must be carried with the permit.

Monitoring Wild Edible Fungi

The days have ended when the forest may be viewed only as trees and trees only as timber. The soil and water, the grasses and the shrubs, the fish and wildlife, and the beauty that is the forest must be integral parts of the resource manager's thinking and actions.

-Senator Hubert Humphrey, 1976

Could Senator Humphrey's view include mushrooms as well? Certainly, fungi are an integral component of the forest ecosystem, and the public is increasingly concerned over forest management. Since the days of Senator Humphrey, the scope and intensity of public interest have expanded from the simple "timber only" days to now include many special forest products such as mushrooms. As a consequence of increased public interest, monitoring has grown in importance. Monitoring of National Forest system land management and use is required by the National Forest Management Act (NFMA), NFMA regulations, National Environmental Policy Act (NEPA), NEPA regulations, the Endangered Species Act, and many other laws. Similar laws are in effect for Washington's forest lands (for example, the State Environmental Policy Act, SEPA). The extent of monitoring and the kind of documentation required are not specifically identified for the mushroom resource.

Washington has completed a forest resource plan for the next decade, and special forest products, including mushrooms, are covered. Likewise, National Forests in the Pacific Northwest have completed their first set of Forest plans mandated by the National Forest Management Act. These Forest plans specify Forest activities, outputs, and effects for the upcoming decade. Essential to each Forest plan was the development of a monitoring and evaluation plan to ensure that the environmental effects of forest management are acceptable. None of these plans includes monitoring populations of wild edible fungi on National Forests, however. Monitoring is needed to determine the carrying capacity of the land, to balance competing uses, and to ensure that management practices do not deplete the mushroom resource.

Monitoring can be defined as the repeated recording or sampling of similar information for comparison to a reference. The monitoring purpose determines what information is collected and what comparisons are made. Monitoring disturbance from mushroom harvest can be as simple as observing or photographing a site before and after picking; it can be as complex as a regional experiment designed to investigate the effects of an array of forest practices on the abundance and diversity of ectomycorrhizal fungi. Two critical features must be maintained regardless of how simple or complex a monitoring project is required: first, observations must be repeated; and second, the observations must be compared to an established reference. Three kinds of monitoring are suggested for wild, edible forest fungi.

Detection

Detection is the most fundamental kind of monitoring because it develops a benchmark for future comparisons. Its purpose is to document the current production of edible fungi and variability with space and time. Baseline information is necessary to determine mushroom abundance and assess with time whether production is declining. Many detection questions need answering. How many commercial edible mushrooms are produced in the Pacific Northwest? How many are harvested? By whom? How much variation occurs from year to year? How is the variation related to forest composition, age, and condition over a wide area? Poorly documented historical rates of production, ephemeral fruiting, and natural variation with climate confound assessment of production. The following approach is suggested to develop baseline evaluation monitoring for the mushroom resource. This undertaking can be accomplished only with open communication and cooperation from a wide array of forest owners, managers, scientists, mushroom pickers, buyers, and dealers.

Detection monitoring approaches should tie into existing databases. On Federal lands, existing ecology plots and managed stand surveys already have detailed information on species composition, plant association, forest structure, productivity, and soil. These existing surveys cover a wide variety of environments, forest ages, and conditions and are well referenced for locating in the field. A stratified sampling of these plots could be used for monitoring edible fungi. Mushrooms of commercial value, such as the chanterelle, matsutake, and morels, could be sampled at these sites.

Because mushroom fruiting occurs over a relatively short period, varies from year to year, and differs with mushroom species, determining when to sample is a great challenge. The onset of fall rains is the strongest determinant for the beginning of the mushroom season, so detection monitoring should be correlated with rainfall. Probably the best indication of commercial mushroom fruiting is the presence of pickers and buyers. Their presence could initiate the field surrey of selected ecology and managed-stand plots. Sampling could be repeated throughout the fruiting period to assess total production. Mushroom locations, species, numbers, and weights should be recorded. Scientists could train local forest crews on inventory methods and mushroom identification. Selected sites could be visited in successive years to determine annual variation. Plant associations, species composition and age, soils, and aspects can be compared to determine optimum conditions for mushroom fruiting. The monitoring personnel need to work with pickers, buyers, and dealers to estimate total production within an area.

Detection monitoring will require establishing "control areas" where mushroom harvest is restricted. Maintaining controls may be difficult in many forest areas where access cannot be limited. Detection monitoring may have to be done in management areas or special mushroom study areas where picking is not allowed. Coordination with administration and law enforcement personnel will be essential to maintain the integrity of these study sites.

Evaluation

Evaluation monitoring, the second kind of monitoring, is triggered by results of detection monitoring. If detection monitoring indicates declining mushroom harvest, additional evaluation monitoring is necessary to determine the extent and cause of the effect. For evaluation, additional data can specify causes such as harvest rate, disturbance type, or change in habitat. Evaluation monitoring can also include studies that evaluate strategies for continued production of edible mushrooms.

The declining yield of edible mushrooms in European forests in recent decades has generated great concern and increased interest in evaluation monitoring. These declines may be at least partially explained by the general decline of these forests because of atmospheric pollution. A demonstrated decline in mycorrhizal colonization has sometimes resulted from increasing sulfur dioxide concentration (Anderson and Rygiewicz 1991). Allocation of carbon from plants to mycorrhizal fungi also can be decreased by high concentrations of ozone (Matson 1984).

Because mycorrhizal fungi are most active in the upper soil and humus layers, they are sensitive to increases in soil temperature, soil compaction, and erosion that can accompany forest harvest. The intensity of light reaching the soil surface influences soil temperature. These factors in turn affect the composition of the mycorrhizal fungi on the site (Luoma 1989, Luoma and others 1991); for example, evaluation monitoring indicates that large increases in surface soil temperature can negatively affect the growth of mycorrhizae (Meijer 1970). Bowen (1980) observed a 90-percent decline in mycelial growth when soils were compacted from bulk densities of 1.20 grams/cubic centimeter to 1.60 grams/cubic centimeter.

But mushroom production does not necessarily decline with disturbance. The effect likely depends on the type and intensity of disturbance. Morels, for example, often fruit profusely after fire. Matsutake mushrooms may prefer open understory conditions maintained by understory burns. Chanterelles often fruit abundantly in partial-cut areas with numerous skid trails (personal observations, Amaranthus and Luoma). Timber stand improvement practices also may influence fruiting body production. Fertilization, however, has had variable effects on mushroom production, increasing the occurrence of some species and decreasing many others (Garbaye and LeTacon 1982, Menge and Grand 1978, Ohenoja 1978).

Effects of mushroom and truffle harvest on yield have received little study. The limited data for mushrooms in the Pacific Northwest indicate no conclusive evidence of reduced yield as a consequence of picking. Annual variation in mushroom abundance often shows a clear correlation with precipitation and temperature (Eveling and others 1990, Tominga 1975). Carefully designed evaluation monitoring is required because mushroom species differ in their fruiting response to changing environmental conditions, which compounds the difficulty of making generalizations about the effects of human activities.

Controversy has focused on the detrimental effects of commercial harvest on wild edible mushroom yields and forest health, yet little evaluation monitoring exists to document adverse effects in the Pacific Northwest. Basic misunderstandings about the nature of mushrooms often has resulted in concern over harvest. Under the proper conditions, the mycelium of a particular species can produce annual crops of mushrooms, similar to an apple tree producing annual crops of apples. Many factors, including duff removal, mushroom picking before spore maturation, soil compaction, grazing, fire suppression, and forest harvest, may affect fruiting-body production. Evaluation monitoring can help forest managers assess the effects of these activities.

Truffles are somewhat different. In Europe, they are found by trained dogs with negligible disturbance to the soil. In the Pacific Northwest, they have been harvested by raking the forest floor. Disturbance to soil and fine roots of host trees can be drastic. At one site, raking an area 2 years in a row appeared to virtually eliminate truffle production in the third year (Trappe 1990).

Research

Research monitoring is the third and most detailed kind of monitoring. It is intended to provide detailed information on forest ecosystems at intensive research sites and where continuing, long-term studies are in place. Such studies would investigate the role of fungi in ecosystem processes and require intensive and specific research design and interaction with other studies over the long term. What role do the fungi play in forest recovery, stability, and productivity? Are soil processes such as nutrient cycling affected by mushroom harvest? A great opportunity to include research monitoring for wild, edible fungi exists within other long-term studies such as the Long-Term Ecological Research program funded by the National Science Foundation and Long-Term Ecosystem Productivity program of the Pacific Northwest Research Station, USDA Forest Service.

The forests of the Pacific Northwest are created and maintained by disturbance events. Hence, disturbing the forest to remove commodities such as wild edible mushrooms does not necessarily conflict with maintaining forest resources. After natural disturbance such as fire, biological remnants of the previous forest remain and provide the basis for the recovery (Amaranthus and others 1990, Hansen and others 1991). These remnants, called "biological legacies," include large live trees and a wealth of dead standing and fallen trees that provide continuing habitat for mycorrhizal fungi (Amaranthus and others 1989). Research is needed to determine how these biological legacies may be influencing mushroom production over time.

Research has shown that mycorrhizal fungi, such as chanterelles, matsutake, and boletes, depend on living trees for photosynthate to fuel their activities. But research has not identified those factors that initiate fruiting body production and how they may vary in time and space and with changes in the physical and biotic environment. Research also is lacking on the role of edible mycorrhizal fungi in maintaining forest health and productivity or plant responses to unpredictable or varying environments.

Diversity in an ecosystem provides resilience in times of stress, as is particularly true of the soil fungi with their strong response to microenvironmental changes. Different mycorrhizal fungi have different "specialties": some are most active in the cool, wet periods; others are adapted to warm, dry times. Succession of mycorrhizal fungi in the forest environment goes on over the course of a year, many years, or decades. In a changing environment, forest productivity may rely on a succession of mycorrhizal fungi for uptake of nutrients and water. The occurrence and fruiting of edible fungi may depend on attainment of these conditions. Research monitoring is necessary to understand these relations.

The Forest Service, Bureau of Land Management, and other stewards of the land are charged with maintaining forest productivity for current and future generations. The sustained production of wild edible mushrooms can be included within the definition of forest productivity and must be viewed in terms of generations of human beings and of trees. Research monitoring of edible mushrooms should be included in other long-term studies of forest health and productivity.

Conclusions

The yields of wild edible fungi are the product of diverse and complex interactions within natural systems whose relations have coevolved over millennia. Managers cannot consider mushroom production in isolation from the community and ecosystem to which the mushrooms are ecologically adapted. Our approach to the harvest of wild edible mushrooms considers plants, the soil community, the larger ecosystem, and human uses and needs as a coherent and dynamic partnership. The sustainability of the wild edible mushroom resource ultimately is understood in terms of patterns arising from the connections within the partnership.

Just as the forest invests tremendous capital in the form of photosynthates to fuel the production of wild edible mushrooms, we must invest in the effort to understand and conserve this ephemeral and poorly understood resource. Monitoring is essential and three kinds are recommended: detection, evaluation, and research monitoring of the mushroom resource are necessary to assess abundance and distribution, the effects of management, and the role of these fungi in long-term forest health. Our biological research must be done in conjunction with socioeconomic questions relating to effects on rural communities, interactions between mushroom-user groups, and sustainability of a commercial industry. Sharpening our knowledge will be a good investment and is an essential part of maintaining continuous production of wild edible mushrooms for future generations.

Acknowledgments

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Metric to English Conversion Table

Metric quantity	English equivalent
Hectare	2.471 acres
Centimeter	0.3937 inch
Meter	3.28 feet
Gram	0.03527 ounce
Kilogram	2.2 pounds
Metric ton	1.102 tons

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Appendix 1
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Smith, Alexander H.; Weber, N.S. 1980. The mushroom hunter's field guide. Revised. Ann Arbor: The University of Michigan Press. 303 p.

Appendix 2

Pacific Northwest mushroom clubs, compiled from the North American Mycological Association membership list, 1990.

Florence Mushroom Club, Siltcoos Station, Westlake, OR 97493

Fungus Federation of Santa Cruz, 1305 E. Cliff Dr. (Museum), Santa Cruz, CA 95062

Humboldt Bay Mycological Society, P.O. Box 4419, Arcata, CA 95521-1419

Kitsap Peninsula Mycological Society, P.O. Box 265, Bremerton, WA 98310-0054

Lincoln County Mycological Society, 207 Hudson Loop, Toledo,OR 97391-9608

Mendocino County Mycological Society, P.O. Box 87, Philo, CA 95466-0087

Mount Mazama Mushroom Association, 417 Garfield St., Medford, OR 97501-4028

Mycological Society of San Francisco, P.O. Box 11321, San Francisco, CA 94101-7321

North American Truffling Society, P.O. Box 296, Corvallis, OR 97339-0296

Northern Idaho Mycological Association, 5936 N. Mount Carrol St., Coeur d'Alene, ID 83814-9609

Northwest Mushroomers Association, 831 Mason Street, Bellingham, WA 98225

Olympic Mountain Mycological Society, P.O. Box 270, Forks, WA 98331-0720

Oregon Coast Mycological Society, P.O. Box 1590, Florence, OR 97439-0103

Oregon Mycological Society, 2781 SW Sherwood Dr., Portland, OR 97201-2250

Pacific Northwest Key Council, 124 Panorama Dr., Chehalis, WA 98532-8628

Puget Sound Mycological Society, U of WA Urban Hort. GF-15, Seattle, WA 98195-0001

Snohomish County Mycological Society, P.O. Box 2822, Everett, WA 98203-0822

South Sound Mushroom Club, 6439 32d Ave. NW, Olympia, WA 98502-9519

Southern Idaho Mycological Association, P.O. Box 843, Boise, ID 83701-0843

Spokane Mushroom Club, P.O. Box 2791, Spokane, WA 99220-2791

Tacoma Mushroom Society, P.O. Box 99577, Tacoma, WA 98499-0577

Tri Cities Mycological Society, RR 1 Box 5250, Richland, WA 99352-9765

Vancouver Mycological Society, 403 Third St., New Westminster, BC V3L 2S1

Wenatchee Valley Mushroom Society, 287 N. Iowa Ave., East Wenatchee, WA 98802-5205

Willamette Valley Mushroom Society, 2610 E. Nob Hill St. SE, Salem, OR 97302-4429

Molina, Randy; O'Dell, Thomas; Luoma, Daniel; Amaranthus, Michael; Castellano, Michael; Russell, Kenelm. 1993. Biology, ecology, and social aspects of wild edible mushrooms in the forests of the Pacific Northwest: a preface to managing commercial harvest. Gen. Tech. Rep. PNW-GTR-309. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 42 p.

The commercial harvest of edible forest fungi has mushroomed into a multimillion dollar industry with several thousand tons harvested annually. The development of this special forest product industry has raised considerable controversy about how this resource should be managed, especially on public lands. Concerns center around destruction of forest habitat by repeated entry and harvest, gradual loss of the mushroom resource by potential overharvest, conflict between recreational users and commercial harvesters, and regulation and monitoring of future harvests. A key to wisely managing the edible mushroom resource is common understanding among resource managers, the mushroom industry, and the concerned public about the biology of these unique forest organisms, their ecological importance in forest ecosystems, and effects of forest disturbance on their survival. The primary objectives of this overview paper are to provide information on the biology of forest fungi, describe the major edible fungi harvested in the Pacific Northwest, integrate a perspective on the social aspects of the mushroom harvest issue, summarize the development of the commercial mushroom industry, and suggest research and monitoring protocols for developing management guidelines.

Keywords: Fungi, mushrooms, mycorrhizae, monitoring, forest ecology, forest management, special forest products, recreation.

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