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Mushrooms, Trees, and Money: Value Estimates of Commercial Mushrooms and Timber in the Pacific Northwest

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ABSTRACT / Wild edible mushrooms are harvested in the forests of the Pacific Northwest, where both trees and mushrooms grow in the same landscape. Although there has been some discussion about the value of trees and mushrooms individually, little information exists about the joint production of, and value for, these two forest products. Through four case studies, the information needed to determine production and value for three wild mushroom species in different forests of the Pacific Northwest is described, and present values for several different forest management scenarios are presented. The values for timber and for mushrooms are site- and species-specific. On the Olympic Peninsula in Washington, timber is highly valued and chanterelles are a low-value product by weight; timber has a soil expectation value (SEV) 12 to 200 times higher than chanterelles. In south-central Oregon, timber and American matsutake mushrooms have the potential to have about the same SEV. In eastern Oregon, timber is worth 20 to 110 times as much as the morels that grow in the forest. Production economics is concerned with choices about how much and what to produce with what resources. The choices are influenced by changes in technical and economic circumstances. Through our description and analysis of the necessary definitions and assumptions to assess value in joint production of timber and wild mushrooms, we found that values are sensitive to assumptions about changes in forest management, yields for mushrooms and trees, and costs.

Forests are the source of many products and the center of many activities. When we talk about the value of forest products such as trees or mushrooms, we often think of them as separate. However, when one product is harvested from the forest, most noticeably trees, other resources are affected in many ways. In different forests, and with different mushroom species, this interaction can have different implications for the joint production of trees and wild edible mushrooms over the landscape.

Few studies examine joint production of forest resources. Calish and others (1978) examined how nontimber resources, such as water quantity, elk (*Cervus canadensis*), deer (*Odocoileus* species), trout (*Oncorhynchus* species), and mass soil movement, affect Douglas fir (*Pseudotsuga menziesii*) rotation lengths. They assigned different values to nontimber goods and examined how adding the value of particular resources changes the optimal economic rotation length. Some of the resources they examined, such as deer, shorten the rotation, whereas others, such as mass soil movement, lengthen it. What is important is that including nonwood resources in forest management planning alters analysis results, and managing for multiple resources simultaneously requires trade-offs. As might be expected, adding an aggregate value for several nontimber resources, such as elk and amenities, to the timber value, increased the total per-acre value of the land.

KEY WORDS: Joint production; Resource value; Economics; Mushrooms; Nontimber forest products

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There are three general economic concepts used to value goods or actions: economic impact analysis, distribution analysis, and efficiency analysis. Economic impact analysis looks at the flow of money through an economy or region, and the effects of that flow. For example, economic impact analysis might address issues of employment. Economic impact analysis is not particularly helpful at the scale of small areas, such as single forest stands. Distribution analysis addresses issues about the rights to, and distribution of, goods, services, and property. Distribution analysis can be conducted across generations, across geographic areas, across income levels, or between racial or ethnic groups, for example. Efficiency analysis is used to contrast, for example, the market price of two goods at the same level of production. Efficiency analysis does not address issues about employment or equity.

The revenues from, and value of, nontimber forest products such as mushrooms have often been discussed in these different contexts (e.g., Allen 1950, Meyer Resources Inc. 1995, Russell 1990, Schlosser and others 1991). Some studies have assessed economic impact in terms of total economic contributions of industries in the nontimber forest product market on a regional basis (e.g., Acker 1986, Cronemiller and others 1950, Schlosser and others 1991, Schlosser and Blatner 1995, Shaw 1949). Others have looked at wages and employment in nontimber forest product industries (e.g., Acker 1986, Heckman 1951, Meyer Resources Inc. 1995, Obst and Brown 2000, Schlosser and others 1991, Tedder and others 2000). Many assessments of nontimber forest products discuss rural impacts and distributional issues such as ownership and access (e.g., Arora 1999, Dyke and Newton 1999). Little work exists on the value of nontimber forest products on a per-acre or per-hectare basis (an efficiency type assessment), as the biology of nontimber forest products is not understood well enough in most cases to create yield functions. Pilz and others (1998a, 1999) provide two examples of efficiency assessments of the value of nontimber forest products. Pilz and others (1998a) discussed the value of chanterelles (*Cantharellus* species) and timber in Washington's Olympic National Forest. They found that the trees are worth considerably more than the mushrooms. Pilz and others (1999) briefly examined the value of timber and American matsutake (*Tricholoma magnivelare*) in south-central Oregon. The relative value of timber and mushrooms is dependent on the assumptions made about mushroom harvester costs.

In this paper, we explain in more detail the necessary assumptions to evaluate joint production of trees and mushrooms in four case studies. We modify and expand on the analysis of chanterelles and timber in the Olympic Peninsula outlined in Pilz and others (1998a), and of American matsutake and timber in the Winema National Forest in southern Oregon, described in Pilz and others (1999). We add an assessment of American matsutake in the Dunes National Recreational Area on the coast of Oregon and an analysis of morels (*Morchella* species) and timber in the Wallowa-Whitman National Forest in eastern Oregon. In this paper, we use growth and yield models (Curtis and others 1981, Wykoff and others 1982) to predict timber yields through time given our management assumptions. Our yield projections for wild edible mushrooms are based on several mushroom studies in different areas of the Pacific Northwest. We calculate the soil expectation value (SEV) for mushrooms and for timber. The SEV is the present net value of an infinite series of rotations over time. By using SEVs, values for different products harvested in different ways can be directly compared.

Of the many nontimber forest products collected commercially in the Pacific Northwest, wild mushrooms are one of the most economically significant. Mushroom yields are more difficult to estimate than timber yields, even with years of data, because mushroom abundance differs greatly from year to year. American matsutake, chanterelles, and morels are three of the major commercial wild mushroom groups in the Pacific Northwest. Of these three mushroom groups, American matsutake generally commands the highest price, followed by morels and then chanterelles. In many years, the weight of morels and chanterelles harvested are each greater than that of American matsutake. In 1992, a fresh weight of 1.3 million lb (590,000 kg) of morels, 1.1 million lb (500,000 kg) of chanterelles, and 825,000 lb (374,140 kg) of American matsutake were harvested in Idaho, Oregon, and Washington (Schlosser and Blatner 1995). In any given year, however, the amounts harvested can change considerably (Keith Blatner, Washington State University Department of Natural Resource Sciences, personal communication). Trees and mushrooms in forests are interdependent; because of mycorrhizal associations, one cannot exist without the other. Chanterelles and American matsutake are mycorrhizal. Morels are still being examined for possible mycorrhizal associations.

Three of the four forests we examine are producing timber and mushrooms as commercial products simultaneously; hence, the two products we are examining are produced jointly. The trees in one of the four case studies, the Dunes National Recreation Area, are not sold and generally have no commercial value. Since production economics is concerned with choice, how much and what to produce, along with the optimal combination of resources, are key issues. Production economics also examines how choices are influenced by changes in technical and economic circumstances. No real world production process operates in an environment of certainty. Entrepreneurs do not know the exact price they will receive for their timber or mushrooms, the price they will have to pay for inputs purchased, or the success they will have in converting products they have bought into products they can sell. The complexities of a dynamic and uncertain world pose important problems and suggest that we should proceed one step at a time. In this paper, we describe the necessary definitions and assumptions in four case studies of joint production of mushrooms and timber.

Analytical Methods

In three of our four case studies (the Winema and Wallowa-Whitman national forests in Oregon and the Olympic Peninsula in Washington), we estimated a per-hectare value for mushrooms and a per-hectare value of a representative timber type for commercial timber production under stated constraints. In the Oregon Dunes National Recreation Area, trees have virtually no timber value and are not commercially harvested, so we only calculated mushroom values.

A frequently used method to assess the value of a resource is the Faustman formula, also called the soil expectation value (SEV). The SEV is the present net worth of a continuing set of rotations or cutting cycles, taking all revenues and costs into account. The SEV is:

$$\mathrm{SEV} = \frac{a}{(1+i)^{w}-1} \qquad (1)$$

where a is net periodic income (or net return in each cutting cycle), i is the discount rate, and w is the length of the cutting cycle in years.

The SEV value is a reflection of the management assumptions used and the discount rate (Davis and others 2001). The SEV of an annual harvest, as is the case for mushrooms, simplifies to:

$$\mathrm{SEV} = \frac{a}{i} \qquad (2)$$

Because the annual harvest, a, for mushrooms varies significantly from year to year, we made assumptions based on several years of yield information, on an average annual production for each species assessed. An SEV can be thought of as an expected value for the potential of bare land to produce marketable products, such as mushrooms and trees, in perpetuity. Assuming the product grows and is harvested forever, with a certain value and discount rate, the SEV indicates the current value of the potential production of that product for all time. The SEV allows value calculations to be comparable for products with different growing cycles, such as mushrooms and trees.

Even with information about mushroom production and prices, mushroom and timber revenues are difficult to compare. The methods by which timber is measured, marketed, and sold makes SEV calculations for timber rather straightforward. The way mushrooms are marketed and sold makes SEV calculations dependent on assumptions about unknown values. For trees, the delivered log price minus the harvest cost, wages and transportation costs, and other costs associated with harvesting and transporting the trees, equals the stumpage price, or the bid price in government timber sales. The landowner captures all the return to the resource because property rights and markets are well defined. The stumpage price minus the landowner's cost of administering the sale is the return to the resource. The return to the resource after each cutting cycle for all time, discounted back to the present, equals the SEV.

Yield functions for timber allow the conversion of dollars per cubic meter to dollars per hectare. In timber sales, there is generally one buyer and one seller (the landowner). The amount sold and the price timber is sold for are clearly defined, and harvest costs are well known. As an example, an SEV calculation for Douglas fir on a 50-year clear-cut rotation with a regeneration cost of \$988/ha, a precommercial thinning at age 10 that costs \$247/ha, no commercial thinning, a real interest rate of 4%, and a yield of 318.6 m^3/ha at age 50 (McArdle and others 1982) with a current net value of \$84.75/m^3, is represented in equation 3.

$$\frac{-(\$988/\mathrm{ha})(1.04)^{50} - (\$247/\mathrm{ha})(1.04)^{40} + [(318.6\ \mathrm{m}^3/\mathrm{ha})(\$84.75/\mathrm{m}^3)]}{(1.04)^{50}-1} = \$3078/\mathrm{ha} \qquad (3)$$

This is not a value per year. The SEV is sometimes referred to as a bare-land value because it is a way of assigning a monetary value to land used for particular purposes, such as growing trees or mushrooms, with stated assumptions. This example shows how the SEV for Douglas fir was calculated for one of the management scenarios in our chanterelle discussion. The SEV is what the representative hectare is worth if you incur the costs and revenues at the times you plan for; in this case, to let each rotation of timber grow 50 years without commercial thinning. The SEV calculation is entirely dependent on the assumptions about how the resource will grow, how it will be managed, and what the dollar value is of the resource after costs are accounted for. These calculations are less precise for resources that have little economic, market or yield information, such as commercially harvested wild edible mushrooms.

For wild edible mushrooms, the return to the resource is the net return to the landowner along with the net return to the harvester. This is different than the return to the resource calculation for timber. As mentioned previously, the owner of trees captures all the return to the resource, because property rights and markets are well defined. Return to the resource for wild edible mushrooms, as with many other nontimber forest products, is harder to calculate in part because the landowner usually captures little to none of the value. Permit prices, if a permit is granted, are usually fixed and low and may or may not cover the cost to the landowner. Property rights are not clearly defined, and markets and prices are not publicly documented for these resources as they are for timber markets. The harvest of wild edible mushrooms is labor intensive, the unit value is often low, the season is short, and the economic risk is high. The harvester captures much of what little return to the resource there might be by doing the labor and taking the risk, and often makes little money. The market is imperfect. Because the landowner captures little or none of the return to the resource through administratively set permit prices, or no permit at all, the return to the resource for wild edible mushrooms is the sum of net return to the landowner through permit sales, along with net return to the harvester.

The net return to the landowner is usually permit fees minus administrative cost; in most cases, the harvester is not the landowner. The net return to the harvester includes subtracting both an estimate of personal costs (gas, food, etc.) and an estimated personal minimum wage from mushroom revenues, realized by selling mushrooms daily at buying sheds. Each of these cost and revenue estimates must be converted to costs and revenue per hectare, as for timber calculations. These calculations depend on information that ranges from good to nonexistent.

Several assumptions based on existing studies and observational evidence must be made to calculate the return to the resource for commercially harvested mushrooms. For return to the landowner, the landowner frequently sells permits to many individuals. The permit generally does not give the individual exclusive rights to harvest in a particular area, and the landowner generally does not know how much product is harvested or from where. We do know, however, the total area permits cover for our case studies, and land managers were able to estimate the number of hectares within those areas that would support the commercial wild mushroom in question. They also know their administrative costs. Revenue minus costs divided by hectares equals net revenue per hectare; equation 1 was used to estimate that revenue in perpetuity.

Calculating net return to harvesters involves more uncertainty. First, mushroom yields per hectare must be estimated. We have estimates of total biological production (fresh weight per hectare per year) in each of our four case studies. There are always some mushrooms missed, regardless of who is picking, and some are eaten by animals and insects. Mushrooms with blemishes or imperfections are not marketable as high-grade mushrooms and are less likely to be picked. We made assumptions about what percentage of biological production is actually harvested, ranging from half to three quarters, for each species and location we examined. Second, costs incurred by mushroom harvesters must be estimated. Costs to harvesters include out-of-pocket expenses, such as permit fees, gas, and food, and a personal minimum wage. A personal minimum wage is not the official minimum wage but rather the minimum wage the harvester feels he or she must make to participate in the activity. That personal minimum wage is not reported and has not been estimated for mushroom harvesters. The price of mushrooms sold by harvesters to buyers includes harvester profits (if any) and costs to the harvester. In production terms, the price of mushrooms sold to buyers is equivalent to the price of logs sold to the mill (delivered log price).

Some conjecture about total cost of harvesting to the individual mushroom harvester must be made to calculate profit to harvesters or the return to the resource. Two estimates of net harvester profit were calculated by subtracting 50% and 90%; respectively, of sales receipts to buyers. Our estimates mean that the net return to harvesters was calculated as 50% and 10%, respectively, of delivered price. These percentages represent what we believe to be the high and low ends of costs to American matsutake harvesters (Pilz and others 1999). There is support for this assumption in reports of personal harvesting costs by Guin (1997). Guin picked American matsutake in southern Oregon and northern California in 1993, the first year he commercially harvested American matsutake. He also worked as a mushroom buyer; the income he made buying mushrooms is not included. Guin picked for 73 days, for an average of about 6.5 hours per day, making an average of \$8.50/h after expenses. The net does not include a personal minimum wage, which must be considered as part of his cost, or the days spent scouting potential sites, or traveling. The personal minimum wage of a harvester could take up part or all of the \$8.50/h average. Guin was relatively inexperienced and so may represent the 90% cost assumption for harvesters.

We used mushroom price, estimated average mushroom yield per hectare, and estimated percentage of biological productivity actually harvested to estimate gross revenue to harvesters. We subtracted an estimate of harvest cost plus wages (that is, either 50% or 90% of mushroom sales revenue) to estimate net revenue to harvesters. Equations 4 and 5 illustrate an example of how SEV for chanterelles was calculated in the 50-year Douglas fir rotation scenario on the Olympic Peninsula with an assumed biological production of 17 kg/ha, no mushroom production for the first 20 years of a timber rotation, the assumption that 75% of the biological production of mushrooms was harvested, an average mushroom price of \$4.40/kg, a 4% discount rate, and a 90% harvester cost.

$$(17\ \text{kg/ha})(0.75)(\$4.40/\text{kg})(0.10) = \$5.60/\text{ha/yr} \quad (4)$$

$$\text{Future value} = \frac{\$5.60(1.04)^{30} - 1)}{0.04} = \$314.07/\text{ha} \quad (5)$$

$$\text{SEV} = \frac{\$314.07}{(1.04)^{50} - 1} = \$51/\text{ha} \quad (6)$$

In equation 4, the annual return from mushrooms is calculated for those years that mushroom harvests are assumed to occur (at current prices). Equation 5 estimates the future value of 30 years of mushroom production. The annual return from mushrooms, in this case, is assumed to happen every year for the last 30 years of a 50-year timber rotation, with no return for the first 20 years. In equation 6, the future values of that first rotation and all subsequent rotations are discounted to the present to see how much that future mushroom income is worth presently. For chanterelles in the Olympic Peninsula, the return to the landowner is zero, because we assumed permit revenue equals administrative cost (Craig Marbet, Simpson Timber Co., personal communication).

The discount rate for all the examples is 4% with no real increase in prices or costs. We used 1997 prices for timber and administrative costs. Mushroom prices are generally a 5-year average for the region (1992–1996). Mushroom prices are highly volatile, both within a season and from one season to another. We selected the 5-year average as a current value that might be expected for the given area over the long run, under the same real price and cost assumptions we used for timber prices and administrative costs. We assume that there will be no major changes in weather that would affect timber or mushroom production in the next 200 years; discounted values after that are negligible. Assumptions specific to each case study are discussed in the appropriate section.

Case Studies

We illustrate the site- and species-specific nature of our assumptions and calculations with four case studies of wild edible mushroom harvesting in the Pacific Northwest. For each case study, we present one or more management alternatives. The first case study outlines American matsutake and timber values for two timber management alternatives in the Winema National Forest in southern Oregon. The second case study assesses American matsutake values in the Dunes National Recreation Area on the Oregon coast and is the only case study in an area where there is no timber harvested. The third case study outlines values for chanterelles and Douglas fir timber in the Olympic Peninsula in Washington. This case study did not assume the land is in public ownership, and the two management alternatives outlined could be on public or private land. The last case study describes values for morels and timber on the Wallowa-Whitman National Forest in eastern Oregon. These four case studies were chosen because they represent a cross section of the variable timber types and mushroom species harvested for the commercial market in the Pacific Northwest.

Case 1: American Matsutake in Winema National Forest

In 1993, the Chemult Ranger District of the Winema National Forest designated three sections (square miles) of the US Rectangular Survey System for American matsutake studies. Measurements of biological production and commercial productivity were obtained, and daily information about weights, grades, and prices of American matsutake were collected (Pilz and others 1999). The price for American matsutake was calculated by weighting mushroom prices by the proportion of total weight attributed to each grade sold by harvesters at three sites in Oregon from 1992 through 1996. The weighted price was \$35.17/kg for all

Table 1. Timber prices and modeled harvest volumes in Chemult, Oregon, for current management criteria

Tree species	1997 price ($/m^3)	Volume removed (m^3/ha/entry) 1998 harvest	2018 harvest	2048 harvest	2068 harvest
Pinus moniticola	80.59	0.3058	0.0451	0.6640	0.6791
Pinus lambertiana	63.56	6.9896	7.6896	10.2803	14.0978
Pinus contorta	56.87	0.9023	3.0628	6.4047	9.8620
Abies magnifica var. *shastensis*	41.65	9.6024	10.0000	10.4745	10.1129
Pinus ponderosa	68.31	0.3105	0.3465	0.4674	0.4418

grades. The average biological productivity from 1992 through 1996 in the study area that the representative stand was modeled after was 4.3 kg/ha/yr (Pilz and others 1999). In 1995, commercial harvesters collected 22% of the estimated biological production in the study area, and in 1996, only 12%. The researchers had expected higher percentages, based on personal observation in the commercially harvested areas open to the public. There are several reasons why the recorded percentage harvested might be lower than that believed by forest managers to be the actual percentage harvested: there were far fewer people looking for mushrooms in the study area than in a comparable area in the public access commercial area, some of the cooperators were not skilled pickers, and the study area was marked but may have been subject to trespass. We decided that an assumption of commercial harvest at 50% of the biological productivity was a reasonable estimate and representative of the intensity of picking in the public access commercial area of the Chemult Ranger District.

The representative stand in the Chemult Ranger District is in a high-elevation mixed-species site; commercial trees include western white pine (*Pinus monticola*), sugar pine (*Pinus lambertiana*), lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosa*), and Shasta red fir (*Abies magnifica* var. *shastensis*). Timber prices were species- and region-specific 1997 stumpage values minus an administrative cost of $18/m^3 for each entry. We examined two timber management alternatives. The first alternative emphasizes current management for visual quality and development of large-diameter trees. The representative stand is in a high-elevation scenic management area, so the timber prescription was designed to meet current management goals. We began with an uneven-aged forest representative of an existing stand. After 80 years with four commercial thinnings at intervals of 20 or 30 years, the growing-stock species mix stabilizes so that an entry can be made every 20 years. The harvest volumes for each entry are detailed in Table 1. This serves as an example, as the species and volumes are entirely dependent on the location chosen for the case study. The prices in this case study are the prices paid in timber sales in that US Forest Service district in 1997.

The second silvicultural management alternative emphasizes management for American matsutake habitat and visual quality. American matsutake is a mycorrhizal fungus; that is, it grows in a symbiotic association with tree roots. Although American matsutake has a broad range of host trees (Hosford and others 1997), it is often found fruiting near lodgepole pine and Shasta red fir in the Chemult area. In our second forest management alternative, we assumed that canopy cover should be 35% or more, and that sugar pine, lodgepole pine, and Shasta red fir will dominate the target stand. Beginning with the same initial stand as the first alternative, this mushroom-emphasis prescription stabilizes after 90 years and five entries; timber harvests thereafter also were scheduled every 20 years. This alternative looks quite similar to the first in terms of volumes removed until 2048, when it begins to remove less volume of every species than the slightly more aggressive visual quality alternative. Trees in this region grow somewhat slowly. In both alternatives, reproduction is indefinitely sustainable in the model, and we assumed soil compaction to be negligible. Timber yield enhancing treatments are provided periodically and progressively across the landscape.

Japanese matsutake (*Tricholoma matsutake*) productivity has been reported or predicted to increase by 100%–400% in response to silvicultural management activities, such as host tree selection and understory thinning (Weigand 1997). Koo and Bilek (1998) examined production studies and found that results were mixed, but *Tricholoma matsutake* did respond to vegetation control with an increase in fruiting. The studies differed as to whether the response was short- or long-term, and the degree of response differed. Although the effect of vegetation control or host manipulation has not been studied for American matsutake, we assumed it would result in an increase in American matsutake fruiting in the long run. In our mushroom-

Table 2. American matsutake and timber soil expectation value[a]

	Value (1997 US $/ha)	
	Matsutake productivity constant; visual management	Matsutake productivity doubles; mushroom and visual management
American matsutake		
50% harvest cost	1100	1492
90% harvest cost	343	423
Timber value	1161	1265

[a]Chemult Ranger District; two timber management scenarios and two mushroom harvester cost assumptions.

emphasis prescription, productivity of American matsutake was assumed to increase by 100% over a 90-year period before stabilizing. In the management prescription with a more diverse mix of tree species (the first alternative), production of American matsutake was assumed to remain constant

Table 2 shows that the SEV for timber in the prescription emphasizing visual amenities and timber value is $1161/ha. The SEV for timber in the prescription emphasizing mushroom production and visual quality is $1265/ha. At first glance, it seems surprising that the SEV for timber in the mushroom-emphasis prescription is higher than that of the current management prescription, as the current management prescription is designed not only to choose trees to meet visual quality constraints, but also to emphasize market value. The present net worth of the first three timber harvests for both prescriptions, in 1998, 2018, and 2048, was virtually the same. Because of the different species mix goals, however, the scenarios diverged after 2048. The mushroom-emphasis scenario stabilized with a timber harvest worth a little more than the timber-emphasis scenario. The differences between the timber harvest values of the two alternatives occur only after more than 70 years; hence little difference in net present timber value exists between the two management alternatives.

The mushroom emphasis prescription was designed to encourage the fruiting of American matsutake. The SEV for American matsutake ranges from $343/ha to $1492/ha (Table 2). The landowner portion of the mushroom values is the net return from permit sales on the Chemult Ranger District, estimated at $6.18/ha/yr; with an SEV of $154.50/ha. The mushroom harvester portion of return to the resource differs with our assumptions.

Case 2: American Matsutake in the Oregon Dunes National Recreation Area

In the Oregon Dunes National Recreation Area and in the Mapleton Ranger District of the Siuslaw National Forest, American matsutake is found primarily in association with shore pine, a variety of lodgepole pine (*Pinus contorta* var. *contorta*). Mushroom productivity in the coastal study areas averages 11.8 kg/ha, as compared to 4.3 kg/ha in the Chemult study areas. There are few commercially valuable trees in the Oregon Dunes National Recreation Area, and timber is not harvested in the area. The habitat is similar to areas in British Columbia with lodgepole pine stands of low timber value but productive for American matsutake. Similar nearby undeveloped private land has a high conversion value for housing and development; much of the nearby private land has been developed for residential and recreational use.

In the Oregon Dunes National Recreation Area, there were no data collected on the proportion of biological productivity harvested by commercial pickers as there was on the Chemult study. Although one manager in the Oregon Dunes National Recreation Area estimated that as much as 80% of the biological productivity is harvested, we assumed a 50% harvest. Our estimate of the percentage harvested, administrative costs, and permit revenues is based on all matsutake-producing lands in the Oregon Dunes National Recreation Area and the Mapleton Ranger District, the area covered by the commercial permits. We again used the weighted regional price of $35.17/kg for American matsutake.

For several years, the Oregon Dunes National Recreation Area and the Mapleton Ranger District have been trying different methods of distributing commercial permits for American matsutake. In 1996 and 1997, 100 commercial permits were offered by sealed bid for the Dunes National Recreation Area and Mapleton Ranger District. In 1997, 87 permits were sold for a total revenue of about $43,700. We assumed gross revenues will remain about the same, and administrative costs will remain at about $33,500 (Dan Segotta, USDA Forest Service, Oregon Dunes National Recreation Area, personal communication). The SEV for the landowner portion of return to the resource is $157/ha. Table 3 outlines the discounted present value in perpetuity (SEV) of American matsutake in the Oregon Dunes National Recreation Area and the Mapleton Ranger District. The SEV estimates for American matsutake in this habitat with the same assumptions about harvester cost are higher than the projections for the Chemult Ranger District, even assuming forest manipulation can

Table 3. American matsutake soil expectation value[a]

Harvester cost assumption	American matsutake SEV (1997 US $/ha)
50% harvester cost	2478
90% harvester cost	675

[a]Oregon Dunes National Recreation Area and Mapleton Ranger District.

double production on the Chemult Ranger District. The coastal area has a more benign climate, and the season is longer; the higher value is due to higher American matsutake productivity in coastal sites.

Case 3: Chanterelles in the Olympic Peninsula

Chanterelles are also mycorrhizal and associate primarily with Douglas fir, western hemlock (*Tsuga heterophylla*), and Sitka spruce (*Picea sitchensis*) in this region of the United States. In Douglas fir stands west of the Cascade Range, chanterelles generally do not fruit in commercial quantities until the stand is at least 20 years old, and if they do, slash from precommercial thinning can make walking through the stand difficult. Chanterelles grow throughout the Pacific coastal region and are abundant on the Olympic Peninsula. They are exported to Europe and consumed domestically. Chanterelles keep and ship well and are becoming increasingly common in grocery produce sections.

On the Olympic Peninsula, Douglas fir stands where most chanterelles are harvested are commonly site index 130 lands (McArdle and others 1982), highly productive for both mushrooms and Douglas fir. Pilz and others (1998a) developed harvest regimes for the study area and calculated SEV values for chanterelles and Douglas fir on the Olympic Peninsula. We included a modification of that work here, and elaborate on the assumptions that were used. We outline two timber harvest alternatives. The first assumes clear-cutting on a 50-year rotation and was developed by using DFSIM (Curtis and others 1981). Precommercial thinning occurs at age 10, and there is no commercial thinning. The second timber harvest alternative consists of a 100-year rotation with commercial thinnings at 35 and 50 years, and a clear-cut final harvest. Regeneration and site preparation costs were assumed to be $988/ha, and precommercial thinning costs were $247/ha. Price premiums were included for older trees in the longer rotation.

Chanterelle productivity likely is influenced by factors such as stand age, stand density, and tree growth rates, but we must assume constant productivity because there is not yet enough information about *Cantharellus* yields in relation to stand characteristics to assume otherwise. The mean price for chanterelles from 1993 to 1996 for Idaho, Oregon, and Washington was $6.50 per kilogram (Blatner and Alexander 1998). This price includes all the *Cantharellus* species sold, including what is referred to in the trade as white chanterelles (*Cantharellus subalbidus*), and Pacific golden (yellow) chanterelles (*C. formosus*) (Redhead and others 1997). White chanterelles generally sell for the lowest price ($1.10–$2.20/kg) and constitute about 15%–20% of the harvest in the Olympic Peninsula (Bettina Von Hagen, Ecotrust, personal communication). Yellow chanterelles make up the bulk of the chanterelle harvest in the Pacific Northwest (about 80% in the Olympic Peninsula) and sell for anywhere from $1.00 to $13.00/kg, depending on the grade, supply, and markets. More recently, yellow-foot or winter chanterelles (*Craterellus tubaeformis*) are also being harvested from the same forest type, but we lack information on their commercial value. This analysis is for yellow chanterelles. They are common on the Olympic Peninsula, so the average price is often lower than the three-state average cited previously. We assume an average price at buying stands of $4.40/kg. Yellow chanterelle productivity on commercial sites in the Olympic Peninsula ranges from <1 to 25 kg/ha/yr (Pilz and others 1998b). Commercial harvesters are not likely to search areas with a productivity of 2 kg or less per hectare per year, but they might visit patches they already know about. Harvesters would be more likely to visit sites with productivities of about 5 kg/ha/yr or more. We use 5 and 17 kg/ha/yr as low and high estimates of commercial chanterelle productivity for our alternatives. We assume that for chanterelles, permit and lease revenues pay for administrative costs for the landowner with no net profit (Joe Simpson and Craig Marbet, Simpson Timber Co., personal communication). We assume that commercial harvesters collect 75% of the biological production (higher than the 50% harvest of American matsutake), because in comparison to American matsutake, chanterelles persist longer, are less likely to be consumed by animals or insects, and are easier to find. The SEVs for chanterelles under a range of productivity and harvester cost assumptions are summarized in Table 4, as are the SEVs for Douglas fir on a 50- and 100-year rotation. Examples in the Analytical Methods section above illustrated calculations for the Douglas fir timber SEV in the 50-year rotation scenario (equation 3) and for chanterelles in an area that produces 17 kg/ha/yr with a 90% harvester cost (equations 4 and 5). The discounted present value in perpetuity, or SEV, of chanterelles is considerably lower than the SEV of the timber in this high-site area for every scenario modeled. Douglas fir in productive sites, as in this

Table 4. Douglas fir timber and chanterelle soil expectation value[a]

	Value (1997 US $/ha)	
Chanterelles	50-year rotation, no commercial thinning	100-year rotation with commercial thinning
5 kg/ha/yr		
50% harvester cost	84	104
90% harvester cost	17	20
17 kg/ha/yr		
50% harvester cost	254	309
90% harvester cost	51	62
Douglas fir timber	3078	4087

[a]Site index 130 lands, two timber harvest scenarios in the Olympic Peninsula, Washington.

example, command high stumpage values relative to many other tree species in the United States, and yellow chanterelles sell for less by weight than most edible mushrooms collected in the Pacific Northwest.

Case 4: Morels in Wallowa-Whitman National Forest

Although members of the genus *Morchella*, the true morels, produce common and popular edible fruiting bodies, the biology of most members of the group is poorly understood (Weber 1995). Some species seem to fruit in response to human or natural disturbances such as recent fires, logging, soil disturbance, windfalls, or tree stress and mortality from insects or disease. These species likely complete their life-cycle as saprobes (Ower 1982, Ower and others 1986, Stamets 1993). Other species regularly fruit in undisturbed forests, and likely these species form mycorrhizal associations with certain tree species (Buscot 1992a, b, 1994, Buscot and Kottke 1990, Dahlstrom and others 2000, Harbin and Volk 1999, Wipf and others 1997). Based on ongoing studies in Oregon east of the Cascade Range, we made several assumptions about morel productivity and response to disturbance. We did not attempt to differentiate among species of morels, but considered the genus as a whole. We assume the species mix of trees will not influence morel productivity. We assume morel productivity in a stand differs from 1 to 3.5 kg/ha/yr, depending on the type of disturbance, when it occurs, and stand age (i.e., >40 years). Morel production assumptions, outlined in Table 5, are based on recent yield studies of morels in eastern Oregon and reflect the types of disturbance anticipated from our timber management prescriptions.

We modeled a managed, uneven-aged stand within a grand fir/big huckleberry (*Abies grandis/Vaccinium membranaceum*) plant association, using the forest vegetation simulator (FVS) growth and yield model (previously known as the stand PROGNOSIS model) (Wycoff and others 1982). Douglas fir, western larch (*Larix occidentalis*), grand fir, lodgepole pine, Engelmann spruce (*Picea engelmannii*), and ponderosa pine occur in this plant association. In the absence of fires, grand fir eventually would out-compete Douglas fir and western larch, two of the more desirable species favored in this plant association to maintain long-term resiliency and sustainability. Historically, such stands were subject to moderate to severe fires every 50–100 years. These partial stand-replacement fires resulted in a mosaic of forest stand ages across the landscape. Private industry does both selective cutting and clear-cutting in high-elevation grand fir types. East of the Cascade Range in Oregon and Washington, clear-cutting is not a frequently used silvicultural prescription. In 1999, of the approximately 70,000 ha harvested east of the Cascade Range in Oregon, only 3000 ha were clear-cut. When clear-cutting is used in grand fir/Douglas-fir mixed-species sites, rotations can range from 60 to 80 years on high-quality sites at lower elevations to 110 years at higher elevations (Dennis Parent, Inland Paper Co., personal communication).

Many high-elevation forests east of the Cascade Range are being managed to move the forest from single-aged stands to uneven-aged forests. Our modeled stand is 40 years old at the beginning of the simulation, a result of either a stand replacement fire or previous clear-cutting. By using plant-association-specific stocking-level goals suggested by Cochran and others (1994) throughout the simulation, a schedule of harvest thinnings and periodic underburns are prescribed and implemented to achieve desired future conditions, to maintain stand health, and to produce timber products; that is, standard USDA Forest Service management for such stands east of the Cascade Range in this type of high-elevation habitat. The plant association-specific stocking-level goals suggested by Cochran and others (1994) were achieved in our model with thinning and prescribed underburning. Harvest thinnings and underburning were used to achieve desired future conditions, maintain stand health, and produce timber products. We assumed there would be no cumulative soil compaction that would diminish tree or mushroom growth. The modeled scenario emphasizes forest and watershed health and development of large-diameter trees over long rotations. Stumpage prices were taken from Table 94, "Average stumpage prices for sawtimber sold on National Forests for selected species," in Warren (2000).

Harvest and economic assumptions are similar to those for chanterelles and American matsutake. We

Table 5. Productivity assumptions for morel species in Blue Mountains of Oregon

Condition/activity	Amount (kg/ha/yr)	Duration	Type of morel
Young stand development	0	Even-aged stands less than 40 years old	No measurable production
Slash pile burn	1	1 year	Burn species[a]
Stand development	1.5	Stands more than 40 years old	Naturals[b]
Tree thinning	2.5	1 year	Naturals
Prescribed burn without soil disturbance	3	1 year	Burn species
Broadcast burn with timber thinning	3.5	1 year	Burn species

[a]"Burn morels" refers to species that fruit in the first to second year after a fire. The sharp increase in production after a fire was assumed to last just one season. We assumed broadcast burning associated with commercial timber thinning to be the most productive for morels because the activity is associated with tree or root death and soil disturbance; broadcast burning without tree thinning to be less productive; and slash pile burning to be the least productive for morels because less area is covered.

[b]"Naturals" refers to a group of morels that fruit in forests where no recent fire has occurred; they do respond to soil disturbance such as caterpillar tractor roads or skidding with a brief increase in fruiting. Naturals resume annual fruiting the second year after fires.

Table 6. Timber and morel soil expectation value in Wallowa-Whitman National Forest, Oregon

	Managed stand (1997 US $/ha)
Morels	
50% harvester cost	52
90% harvester cost	10
Timber	1105

assume an average price of $7.70/kg for all morels. We assume harvesters find 50% of disturbance-related morels (e.g., in burns, near insect killed trees, and in thinnings), and 35% of "natural" morels, the ones that appear when there is no disturbance. Although commercial harvesters do buy permits, the cost is low ($70 for 100 days), so we made the simplifying assumption that permit revenue equals administrative costs. In Table 6, the per-hectare SEV of morels and trees for the modeled selectively harvested stand is presented. The timber value is similar to that for the Chemult Ranger District in southern Oregon, also managed as an uneven-aged stand (Table 2). Douglas fir values on the Olympic Peninsula (Table 4) are far higher than either the Wallowa-Whitman or Chemult example because yields and productivity of timber in the Douglas fir coastal zone is high.

Discussion

Differences in value for timber and mushrooms from the various landscapes follow trends that might be intuitively obvious. On the Olympic Peninsula, where timber is worth a lot and chanterelles are a low-value product by weight, timber has an SEV 12 to 200 times higher than that of chanterelles. On the Winema National Forest, where the timber is not worth as much as Olympic Peninsula Douglas fir and American matsutake is one of the most valuable mushrooms by weight, the mushrooms and timber have the potential to be worth about the same. In eastern Oregon, timber is worth 20 to 110 times as much as the morels.

In each case study, however, assumptions about wages and mushroom yields and harvest have significant impacts on the estimated mushroom value. Chanterelles in the Olympic Peninsula have an SEV that ranges from $17 to $309/ha depending on assumptions regarding yields per hectare, mushroom response to timber management, mushroom harvester wages and profit, and so on. It should be kept in mind that these are projections of what happens in a joint production framework. Over the whole landscape, through time, both are produced.

In the context of our joint production approach, we have discussed choices in production and how changes in various circumstances influence production. We have outlined what information is needed to assess production choices and consequences for timber and mushrooms. There are many issues that make this type of assessment difficult. Trees are an easily identified and measured product with specific property rights. They are stationary in space and time and have a relatively predictable and highly visible market. Mushroom production is extremely variable, yields are difficult to predict through space and time, and the market is a high-risk one. Because price series are unpublished and costs are not documented, it is difficult for buyers or harvesters to predict revenues. The market does, however, behave as a competitive market, responsive to international supply and demand, inventories, tastes, and preference, for example. The major barrier to entry for participants in any nontimber forest product market is information.

Harvester costs can be affected by several factors. As the number of harvesters goes up, the costs increase, because people are searching the same areas. Many areas are open to both commercial- and personal-use harvesters, thereby increasing competition. In an open access resource such as mushrooms, a lack of coordinated effort and competition for the product increase costs. Three examples of increased costs caused by open access are: (1) people spend time concealing their activities, (2) they search areas that may already have been harvested, and (3) the product is harvested as soon as it becomes marketable, not when it has grown to optimal size. Allowing commercial mushroom harvesting to remain open to anyone willing to buy a permit is a distributional or equity decision, as well as an efficiency decision. From an efficiency standpoint, limiting the number of harvesters in a particular area would decrease the cost to individual harvesters if their efforts were coordinated and might improve the quality of the product, thereby increasing the return to the land or the net return to the resource. Restricting access also would lessen impacts on the resource. Access restrictions, such as leases or limited permits, affect employment and have distributional and equity effects on both those still allowed to harvest an area and on those excluded from an area. People who have access to the area would be affected by how the harvest restrictions were implemented. Forest managers who consider access restrictions or bid policies must consider both the benefits to the resource and the benefits and costs to the harvesters affected by such policies, and understand that efficiency analyses alone do not address equity or distributional issues.

Our timber management assumption that merits greatest consideration relative to long-term mushroom productivity is the lack of soil compaction from multiple thinning entries. Soil compaction has a detrimental effect on the growth of mycorhizal fungi and the formation of ectomycorrhizal root tips (Amaranthus and others 1996), hence cumulative soil compaction impacts from multiple stand thinning entries have the potential to progressively diminish the fruiting of ectomycorrhizal species of edible mushrooms such as chanterelles and American matsutake. We know of no studies directly addressing this topic, but the degree of soil compaction and the percentage of the soil surface of a stand affected by compaction is likely to be negatively correlated with productivity of ectomycorrhizal mushrooms, as they are with soil fertility and tree growth. Logging systems that minimize soil compaction will preserve site fertility for both trees and edible ectomycorrhizal mushrooms. Nonectomycorrhizal morel species that fruit in big crops after forest disturbances might constitute an exception to this generalization. Some morel species fruit abundantly in disturbed or compacted soils. Harvesters often follow skid trails to find morels in thinned or salvage-logged stands. Indeed, morels are known to fruit in footprints. Large crops of morels in disturbed soils are ephemeral, occurring for only the first season or two after the disturbance. Whether repeated soil disturbances will perpetually produce large morel crops is not known. Alternatively, large flushes of morels in response to soil disturbance might derive only, or predominantly, from the initial disruption of soil structure.

All our case studies were analyzed at the stand level. The fruiting patterns of ectomycorrhizal mushrooms [such as American matsutakes, chanterelles, and King boletes (*Boletus edulis*)] are often spatially clustered within a stand; that is, mushrooms tend to fruit in discrete patches where the mycelial colonies exist in the soil. Per-unit-area productivity of mushrooms in these discrete patches is likely to be considerably higher than average mushroom productivity for a stand as a whole because stand-level mushroom productivity also includes areas of the stand lacking the mycelial colonies and fruiting of edible mushrooms. On the small scale of an ectomycorrhizal mushroom colony and its surrounding host trees, mushrooms may be worth more than the trees (over time) even if this is not true of the stand as a whole. If silvicultural prescriptions already stipulate, or can accommodate, small areas with nonharvested trees, then timber sale planners might consider locating the unharvested tree patches to coincide with mushroom patches, thereby avoiding potential immediate declines or disruption in the fruiting of edible mushrooms resulting from soil compaction or removal of ectomycorrhizal host trees. Mushroom harvesters (commercial and recreational) are often intimately familiar with the precise location of these mushroom patches and frequently resent their loss or damage from logging operations. Cooperating with local harvesters to minimize disturbance of productive mushroom patches could lessen resentment on the part of mushroom harvesters, given that they are willing to reveal their precise harvest locations and have those locations subsequently disclosed by clumps of leave trees. How mushrooms will respond over time in small areas with unharvested trees has not yet been investigated, but in areas that are otherwise clear-cut, conserved mushroom patches could conceivably act as an inoculum source for new colonies of edible mushrooms in the regenerating stand.

Our selection of case studies for comparing timber and mushroom values illustrates the largely site- and species-specific nature of such value calculations. We have provided a framework for the assessment of joint production of different forest products. Net harvester wages for nontimber forest products are not documented and have received little attention, but our range of assumptions about wages and costs can provide guidance. The estimated mushroom yields we present are based on several biological yield studies and should prove useful to forest managers. By critically analyzing our assumptions, productivity values, and prices in the context of the forest types being considered, forest management goals, mushroom species harvested, and typical mushroom prices and harvest expenses, our analyses can be adapted to local circumstances. Economic comparisons of the value of timber and mushrooms are sometimes used as arguments for whether or not forests should be logged. Rarely is the answer obvious from simple comparisons of these two forest products. A more comprehensive analysis would include several silvicultural regimes that provide alternate harvest levels for both mushrooms and timber, the inclusion of the value of other nontimber forest products, and the value of other forest amenities such as recreation, water quality, biodiversity, and scenery, for example. As more information becomes available about wild mushroom and other nontimber forest product markets and species biology, landowners will be better able to understand how management decisions influence local and regional economic impacts and distributional issues.

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Literature Cited

Acker, R. 1986. Harvesting wild edible mushrooms in Washington: An issue paper. Washington Department of Natural Resources, Olympia, Washington, 44 pp.

Allen, J. W. 1950. Marketing woodlot products in the State of Washington. Bulletin 1. Washington Department of Conservation and Development, Institute of Forest Products, Olympia, Washington, 61 pp.

Amaranthus, M. P., D. Page-Dumroese, A. Harvey, E. Cazares, and L. F. Bednar. 1996. Soil compaction and organic matter affect conifer seedling nonmycorrhizal and ectomycorrhizal root tip abundance and diversity. Research paper PNW-RP-494. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, 12 pp.

Arora, D. 1999. The way of the wild mushroom. *California Wild* 54(4):8–19.

Blatner, K. A., and S. Alexander. 1998. Recent price trends for non-timber forest products in the Pacific Northwest. *Forest Products Journal* 48(10):28–34.

Buscot, F. 1992a. Stratégies écologiques et biologiques des morilles. *Cryptogamie-Mycologie* 13:171–179.

Buscot, F. 1992b. Synthesis of two types of association between *Morchella esculenta* and *Picea abies* under controlled culture conditions. *Journal of Plant Physiology* 141:12–17.

Buscot, F. 1994. Ectomycorrhizal types and endobacteria associated with ectomycorrhizas of *Morchella elata* (Fr.) Boudier with *Picea abies* (L.) Karst. *Mycorrhiza* 4:223–232.

Buscot, F., and I. Kottke. 1990. The association of *Morchella rotunda* (Pers.) Boudier with roots of *Picea abies* (L.) Karst. *New Phytologist* 116:425–430.

Calish, S., R. D. Fight, and D. E. Teeguarden. 1978. How do nontimber values affect Douglas-fir rotations? *Journal of Forestry* 76:217–221.

Cochran, P. H., J. M. Geist, D. L. Clemens, R. R. Clausnitzer, and D. C. Powell. 1994. Suggested stocking levels for forest stands in northeastern Oregon and southeastern Washington. Research note PNW-RN-513. USDA Forest Service Pacific Northwest Research Station, Portland, Oregon, 21 pp.

Cronemiller, L. F., J. B. Woods, C. H. Ladd, and others. 1950. Secret treasures in the forest. Bulletin 14. Oregon State Board of Forestry, Salem Oregon, 47 pp.

Curtis, R. O., G. W. Clendenen, and D. J. Demars. 1981. A new stand simulator for coast Douglas-fir: DFSIM users guide. General technical report PNW-128. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, 79 pp.

Dahlstrom, J. L., J. E. Smith, and N. S. Weber. 2000. Mycorrhiza-like interaction by *Morchella* with species of the Pinaceae in pure culture synthesis. *Mycorrhiza* 9:279–285.

Davis, L. S., K. N. Johnson, P. S. Bettinger, and T. E. Howard. 2001. Forest management. McGraw-Hill, New York, 804 pp.

Dyke, A. J., and A. C. Newton. 1999. Commercial harvesting of wild mushrooms in Scottish forests: Is it sustainable? *Scottish Forestry* 53(2):77–85.

Guin, J. 1997. Matsutake mushroom: The white goldrush of the 1990s. Naturegraph Publishers, Happy Camp, California, 95 pp.

Harbin, M., and T. J. Volk. 1999. The relationship of *Morchella* with plant roots. Abstract. XVI International Botanical Congress, St. Louis, Missouri, p. 59.

Heckman, H. 1951. The happy brush pickers of the high Cascades. *Saturday Evening Post* 4:35–40 (October 6).

Hosford, D., D. Pilz, R. Molina, and M. P. Amaranthus. 1997. Ecology and management of the commercially harvested

American matsutake mushroom. General technical report PNW-GTR-412. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Koo, C. D., and. E. M. Bilek. 1998. Financial analysis of vegetation control for sustainable production of Songyi (*Tricholoma matsutake*) in Korea. *Journal of Korean Forestry Society* 87(4):519–527.

McArdle, R. E., W. H. Meyer, and D. Bruce. 1982. The yield of Douglas-fir in the Pacific Northwest. Technical bulletin 201. USDA, Washington, DC. Reprinted by OSU Bookstores, Corvallis, Oregon.

Meyer Resources Inc. 1995. A preliminary analysis of the economic importance of the 1994 pine mushroom industry of the Nass Valley area, British Columbia. Victoria, British Columbia.

Obst, J., and W. Brown. 2000. Feasibility of a morel mushroom harvest in the Northwest Territories. Report developed in cooperation with the Government of the Northwest Territories by Arctic Ecology & Development Consulting and Deton'cho Corporation. Arctic Ecology and Development Consulting, P.O. Box 1888, Yellowknife, Northern Territories, Canada X1A 24P.

Ower, R. 1982. Notes on the development of the morel ascocarp: *Morchella esculenta*. *Mycologia* 74:142–144.

Ower, R. D., G. L. Mills, and J. A. Malachowski, Neogen Corporation Assignee. 1986. Cultivation of *Morchella*. US Patent 4,594,809.

Pilz, D., F. D. Brodie, S. Alexander, and R. Molina. 1998a. Relative value of chanterelles and timber as commercial forest products. Pages 14–16, *in* L. H. Liegal (compiler). Mushrooms in the mist: The biological, socioeconomic, and managerial concerns of chanterelle mushroom harvesting on the Olympic Peninsula, Washington State. *Ambio* special report No. 9.

Pilz, D., R. Molina, and L. Liegel. 1998b. Biological productivity of chanterelle mushrooms in and near the Olympic Peninsula Biosphere Reserve. Pages 8–13, *in* L. H. Liegal (compiler). Mushrooms in the mist: The biological, socioeconomic, and managerial concerns of chanterelle mushroom harvesting on the Olympic Peninsula, Washington State. *Ambio* special report No. 9.

Pilz, D., J. Smith, M. P. Amaranthus, S. Alexander, R. Molina, and D. Luoma. 1999. Managing the commercial harvest of the American matsutake and timber in the southern Oregon Cascade Range. *Journal of Forestry* 97(3):4–11.

Redhead, S. A., L. L. Norvell, and E. Danell. 1997. *Cantharellus formosus* and the Pacific golden chanterelle harvest in western North America. *Mycotayon* 65:285–322.

Russell, K. 1990. Manufacturing, marketing, and regulatory considerations: Forest fungi. Remarks presented at the Special Forest Products workshop, 8–10 February 1990. Portland, Oregon, Washington Department of Natural Resources, Olympia, Washington.

Schlosser, W., K. Blatner, and R. Chapman. 1991. Economic and marketing implications of special forest products harvest in the coastal Pacific Northwest. *Western Journal of Applied Forestry* 6(3):67–72.

Schlosser, W. E., and K. A. Blatner. 1995. The wild mushroom industry of Washington, Oregon and Idaho: A 1992 survey of processors. *Journal of Forestry* 93(3):31–36.

Shaw, E. W. 1949. Minor forest products of the Pacific Northwest. Research note 59. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland Oregon, 10 pp.

Stamets, P. 1993. Growing gourmet and medicinal mushrooms. TenSpeed Press, Olympia, Washington, xvi + 552 pp.

Tedder, S., D. Mitchell, and R. Farran. 2000. Seeing the forest beneath the trees: the social and economic potential of non-timber forest products and services in the Queen Charlotte Islands/Haida Gwaii. Mitchell Consulting and the BC Ministry of Forests, Victoria, British Columbia, 136 pp.

Warren, D. D. 2000. Production, prices, employment and trade in Northwest forest industries, all quarters 1998. Resource bulletin PNW-RB-231. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Weber, N. S. 1995. A morel hunter's companion. Reprint of 1988 edition by Two Peninsula Press. Thunder Bay Press, Lansing, Michigan, 209 pp.

Weigand, J. F. 1997. Forest management of the North American pine mushroom [*Tricholoma magnivelare* (Peck) Redhead] in the southern Cascade Range. PhD thesis. Oregon State University, Corvallis, Oregon. 500 pp.

Wipf, D., S. Koschinsky, P. Clowez, J. C. Munch, B. Botton, and F. Buscot. 1997. Recent advances in ecology and systematics of morels. *Cryptogamie-Mycologie* 19:95–109.

Wykoff, W. R., N. L. Crookston, and A. R. Stage. 1982. User's guide to stand prognosis model. General technical report INT-133. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.