Mushrooms and Timber

Managing Commercial Harvesting in the Oregon Cascades

American matsutake *(Tricholoma magnivelare)*, which are harvested from Forest Service lands in the southern Oregon Cascade Range, provide commercial, recreational, subsistence, and cultural opportunities to forest users. The Winema and Deschutes National Forests have used collection permits and educational programs to address concerns about harvesters' activities and resource sustainability. Research on matsutake productivity shows that silvicultural options may reduce fire danger and provide revenue, jobs, and wood while improving forest health and increasing the availability of the mushrooms. Thus forest managers can expand their planning and management activities to enhance the commercial value of forests.

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The dramatic increase in commercial harvesting of nontimber forest products in the Pacific Northwest has coincided with the substantial decline in timber harvesting from federal forests. The harvest of these products involves complex and interrelated social, economic, managerial, and biological issues (see Savage 1995; Molina et al. 1997). Although timber typically exceeds nontimber forest products in value, opportunities exist to manage for both, to the benefit of different groups.

Of nontimber products, the wild mushroom industry in the Pacific Northwest, estimated at $41.1 million in 1992, is second only to the $128.5 million harvest of floral greens (Schlosser and Blatner 1995). Excluding truffles, the American matsutake *(Tricholoma magnivelare)* is the most valuable mushroom harvested in the Pacific Northwest because it is similar to the Japanese matsutake *(T. matsutake)*, a mushroom highly prized and increasingly rare in Japan (Hosford et al. 1997). During the last decade, rapidly increasing numbers of transient mushroom harvesters have collected this mushroom from reliably productive habitats on the eastern slopes of the Cascade Range in southern Oregon.

Managing the Harvest

Harvesters, permits, and education. Local recordkeeping of matsutake harvesting began when the Winema and Deschutes National Forests *(fig. 1)* first issued permits in autumn 1989. Little was known about the matsutake resource, the needs of harvesters, or potential effects on local communities. The two national forests have cooperated closely since 1989 to develop a matsutake program that is responsive to these issues.

A large proportion of matsutake harvesters in this area are recent immigrants from Cambodia, Laos, Thailand, and Vietnam. Agrarian cultural traditions and familiarity with mushroom

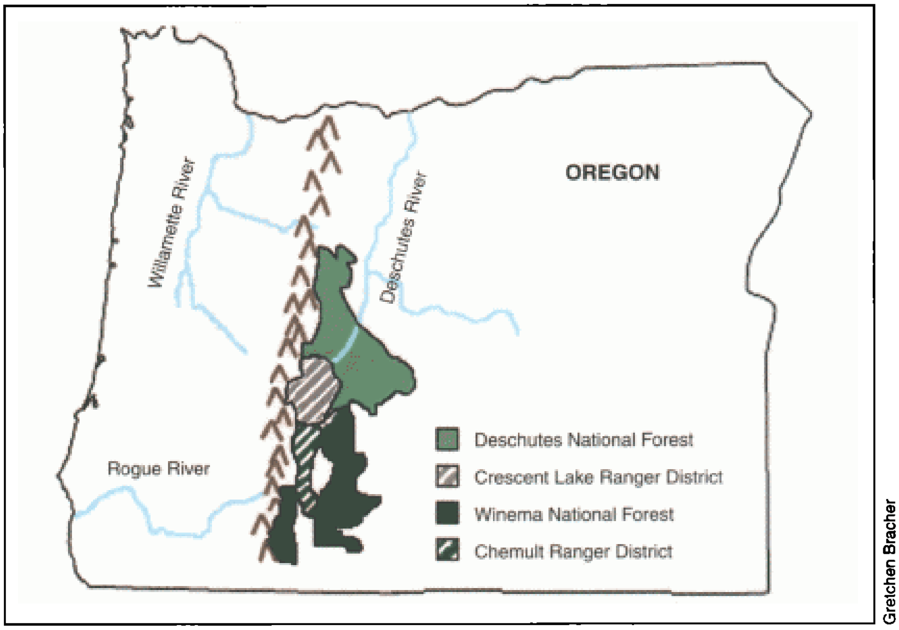

Figure 1. **The Deschutes and Winema National Forests and the Cascade Range, Oregon. The majority of matsutake collected in south-central Oregon are found on the Crescent Lake and the Chemult Ranger Districts.**

Photos by David Pilz

Jerry Smith (left), who administers the matsutake program on the Chemult Ranger District, and Oregon State doctoral candidate Charles Lefevre sample a study plot in a pure lodgepole pine stand. "Buttons," whose veils are still closed, are the most valuable mushrooms by weight.

harvesting draw Asian Americans to this livelihood (Richards and Creasy 1996). Many have limited job prospects because of language barriers, and mushroom harvesting gives families a way to support themselves. The languages, ethnicity, and cultural traditions of the matsutake harvesters are the most salient social issues facing managers.

To educate harvesters, the Chemult Ranger District on the Winema National Forest and the Cresent Lake Ranger District on the Deschutes designed a highly visible program. Topics include harvesting techniques, minimum mushroom sizes, areas off-limits to collection, protection of archaeological sites, camping etiquette, firearms laws, and wildfire danger. The issuance of permits—required by law for removal of any forest product—provides the best opportunity for educating harvesters. Before obtaining a permit, each harvester must view a short educational video featuring Asian actors, demonstrations, and universal symbols. Forest Service personnel identify individuals in the audience willing to translate for non-English speakers as each topic is discussed. Professional interpreters also facilitate cross-cultural communication. The program is considered highly successful by both harvesters and managers.

Frequent contact with harvesters is also deemed essential; Forest Service personnel, law enforcement officers, and researchers all participate. At the program's inception in 1989, 265 permits were sold, yet there were likely 1,600 to 2,000 harvesters. Permit sales and compliance have increased dramatically since the educational program began *(table 1, p. 6)*. The Winema and Deschutes now cooperate with the adjacent Willamette and Umpqua National Forests to issue a permit valid in all four forests. The permit packet includes detailed maps of areas where commercial collection is allowed and a thorough explanation of permit conditions. Although permits are valid in all four participating national forests, most are used in the ranger district where they were purchased.

A permit fee structure has been developed that is responsive to harvesters' incomes and also appropriate for the sale of public resources. In 1997 a commercial permit cost $50 for five days, $200 for the season. Permits for less valuable mushrooms are sold separately. Matsutake permit revenues exceed the cost of managing the harvest and conducting research; income from the sale of permits goes to the US Treasury, however, and does not directly support management and research activities. Funds for managing the mushroom resource come instead from timber sale program budgets. Local ranger districts are seeking authority to retain mushroom permit revenues to fund program administration, education, law enforcement, and resource monitoring.

Impacts on local communities. Chemult and Crescent Lake Junction are the two local communities where mushroom buyers conduct business. Neither community is incorporated and each has a population of less than 300. Weather conditions, annual variation in fruiting levels, and fluctuations in prices influence the number of harvesters. Prices can fluctuate unpredictably because buyers are competitive and harvest levels in other countries can alter prices daily. Surveys of buying stations and campground occupancy indicate that 1,400 to 1,800 harvesters now visit the area annually. Several hundred additional individuals operate the buying stations and are involved in support activities, such as campground management and law enforcement. All these individuals require goods and services during a season that once saw only a few big-game hunters and campers.

Local stores, restaurants, gas stations, and motels enjoy increased sales, but community services—law enforcement, trash disposal, roadways, parking lots, campgrounds, sewage systems, and public telephones—also experience increased use. A local community action team, which includes Forest Service managers, is exploring opportunities to enhance local sales and expand public services. One option is a local mushroom-processing facility to increase economic returns to the community.

Safety and law enforcement. Traffic congestion, firearms, alcohol use, large quantities of cash, ethnic conflicts, and crowded camping facilities increase the workload for local law enforcement agencies. Efforts to address these challenges include the education program, increasing the visibility of agency personnel, employing multilingual law enforcement officers, providing adequate concessionaire campground facilities, matching permit numbers to campground capacities, and setting harvest season dates to help law enforcement agencies plan their workloads.

Resource impacts. The American matsutake is an ectomycorrhizal fungus; it forms a symbiotic association with certain host trees by providing the trees with an extended root system for nutrient and water uptake; in return, it obtains carbohydrates that the tree produces through photosynthesis. Harvesting the fruiting bodies (mushrooms) is analogous to harvesting apples from an apple tree in that the organism is little affected by plucking the fruit. Several concerns exist, however. The most valuable matsutake are the immature "buttons" that remain fresh during shipment to Japan. Prices for immature matsutake are an order of magnitude higher than for mature specimens; hence many mushrooms are harvested before they have the opportunity to disseminate their spores. Also, harvesters occasionally dig or move forest floor litter layers to find buttons that have not yet emerged.

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Matsutake pickers, many of them Asian-Americans, must participate in an educational program as a condition of getting a permit. Program leaders stress harvesting techniques that minimize damage to the mycelium in the soil and promote subsequent fruiting.

Table 1. Total permit sales, value, and percentage of harvesters with permits (compliance), Chemult Ranger District (Winema National Forest) and Crescent Ranger District (Deschutes National Forest).

Year	Permits[1]	Value	Estimated compliance[2]
1989	265	$3,760	3–5%
1990	1,622	37,040	30–40
1991	3,647	85,860	90
1992	2,347	40,792	80–90
1993	11,405[3]	220,585	90
1994	2,157	166,726	90+
1995	4,398	273,730	90+
1996	4,206	334,200	90+
1997[4]	3,733	365,938	90+
1998	1,248	138,330	90

[1]The number of permits sold does not reflect the number of harvesters because tallies include 2-day, 5-day, and seasonal permits.
[2]Compliance was estimated by law enforcement officers and ranger district personnel who inquired about possession of permits when they met harvesters in the forest.
[3]Although 1993 was a typical fruiting year, high matsutake prices attracted many harvesters. Only 2-day or seasonal permits were available that year, and harvesters frequently purchased two 2-day permits on Friday mornings so that they could harvest through the weekend. Starting in 1994 the districts issued 5-day minimum permits that enabled harvesters to check fruiting conditions during a long weekend.
[4]1997 was an exceptionally good year for matsutake fruiting (indeed, all mushrooms in the Pacific Northwest), but matsutake prices were low because of abundant supplies and a depressed Japanese economy. 1998 was a very poor year for matsutake fruiting in the Cascade Range, and this is reflected in the low permit sales. Such wide fluctuations underscore the volatility of international mushroom markets, the uncertain earnings of harvesters, and the difficulties managers face when estimating the value of a mushroom resource.

This may harm the mycelium (body of the fungus) in the soil and reduce subsequent fruiting.

To ameliorate these potential impacts, harvesters are permitted to use only narrow tools (less than 1 inch wide) for prying mushrooms from the ground. They are instructed to cover holes and leave mature specimens to disperse spores. A minimum length of 2.5 inches has been specified in the permits, and in 1998, minimum cap diameters were specified because this dimension can be measured before the mushroom is picked. Local ranger districts have cooperated with mushroom buyers to ensure that undersized mushrooms are not purchased, with the result that the area has a favorable reputation for large buttons. Matsutake that fruit before the first hard frost in late summer or early autumn are typically riddled with insect larvae. To allow this first flush of low-value matsutake to mature and spread spores, the starting date of the commercial harvest season is set for mid-September. No harvesting is permitted in wilderness and research natural areas, and authorized collection areas are rotated annually to allow periodic spore release and recovery.

Research

Study sites and goals. In 1992, recognizing the need to monitor matsutake productivity and better understand its biology and ecology, Chemult Ranger District managers designated three sections (square miles) of the US Rectangular Survey System for matsutake research. The sections are located along a main access road of increasing elevation. A roadside interpretive display explains research objectives and asks harvesters to collect elsewhere. Study areas and research goals also are discussed at the educational presentations when harvesters buy collection permits.

Because annual precipitation in the Chemult Ranger District decreases sharply with decreasing elevation, the three study sections (median elevations of 5,800, 5,500, and 5,100 feet) represent distinct habitats stratified by elevation even though plant species composition overlaps somewhat. Shasta red fir *(Abies magnifica* v. *shastensis)*, white fir *(A. concolor)*, sugar pine *(Pinus lambertiana)*, western white pine *(P. monticola)*, and mountain hemlock *(Tsuga mertensiana)* are more abundant at higher elevations and more mesic sites, whereas ponderosa pine *(P. ponderosa)* is more common at lower elevations and on more xeric sites. Lodgepole pine *(P. contorta)* predominates on flat or concave topography where cold air settles and creates spring "frost pockets" that damage the sensitive new growth on seedlings of other tree species. More detailed habitat descriptions are available in Hosford et al. (1997).

Studies in the Chemult monitoring area have several objectives:

- Describe annual patterns of biological and commercial matsutake productivity in three habitats over several years.
- Examine the extent and type of wildlife consumption.
- Correlate seasonal fruiting patterns with temperatures.
- Evaluate sample plot designs.

Biological productivity is defined here as fresh weight, dry weight, or number of sporocarps produced per unit area during a fruiting season. Commercial productivity is defined as the fresh weight or value of matsutake collected per unit area during a harvest season. Comparisons of biological and commercial productivity provide information about the intensity of commercial harvesting and potential impacts on fungus reproduction or availability as wildlife food. Information about preferred ectomycorrhizal host species and correlations between fruiting and temperature can be used to design silvicultural practices that maintain or enhance matsutake fruiting.

Inventory methods. Inventory plots were used to estimate biological productivity. The sampling design was adapted from fungus diversity studies (Luoma et al. 1996). Three experimental areas were located in each section. Within each experimental area, matsutake production was evaluated within six permanent 6.6- by 164-foot (2- by 50-meter) strip plots located systematically (to avoid overlap) and oriented randomly *(fig. 2)*. From 1993 to 1996, all plots were sampled weekly during the fruiting season (typically September to November). Matsutake were counted when they first appeared and marked so that they would not be recounted during subsequent visits. The cap diameter, stem diameter, and distance from annulus to cap were also measured. To estimate the weight of matsutake left on these plots, matsutake collected nearby were weighed

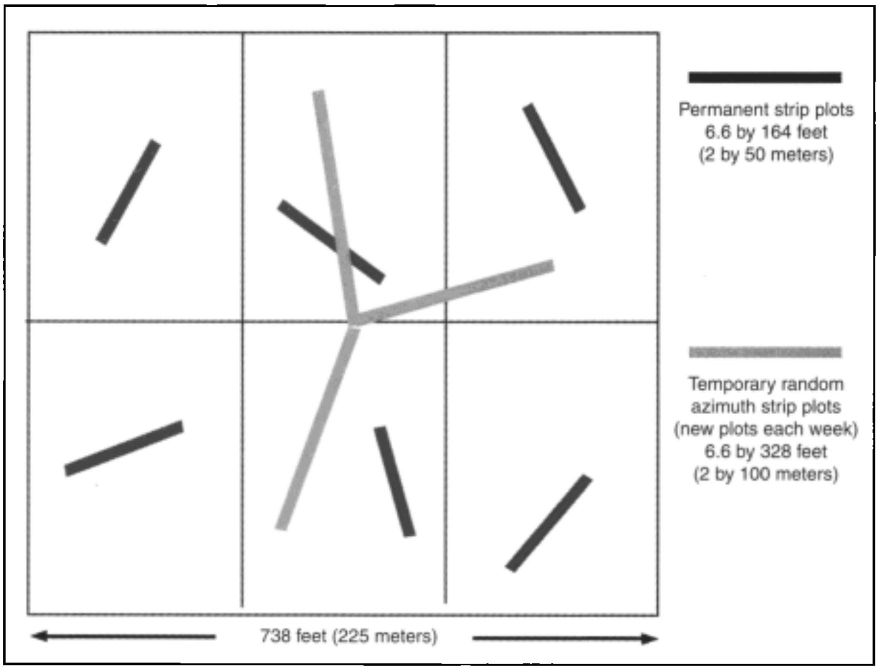

Figure 2. **Example of strip plot layouts within experimental area, Chemult Lake Ranger District.**

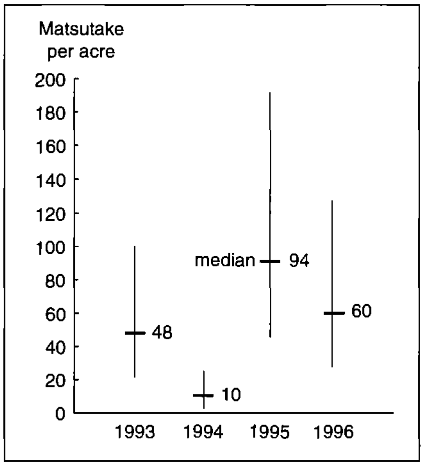

Figure 3. **Number of matsutake per acre (median and 95 percent confidence interval) estimated with samples from the permanent strip plots.**

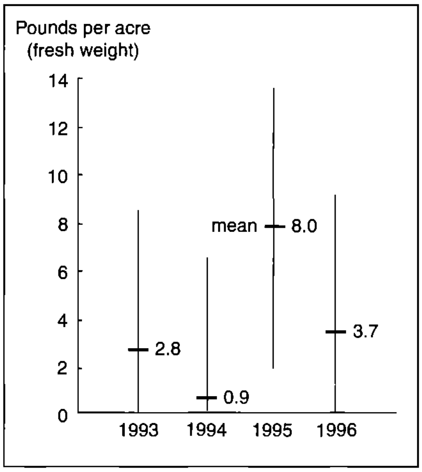

Figure 4. **Pounds of matsutake (fresh weight) per acre (mean and 95 percent confidence interval) estimated with samples from the permanent strip plots.**

(fresh and dried) and measured to develop regression equations relating weight to dimensional parameters. Commercial-quality grades were assigned to each matsutake, and the percentage of each mushroom consumed by animals (excluding those completely eaten) was recorded.

Because matsutake fruit in clusters, the adequacy of our plot size was tested by also sampling temporary strip plots measuring 6.6 by 328 feet (2 by 100 meters). Each week, two or three of the larger strip plots were located along newly selected random azimuths, starting from the center of each experimental area. Matsutake were only counted on these plots, and signs of animal activity (tooth marks, footprints, scat) were identified and tallied.

Measurements of commercial productivity were obtained with harvesters' help. Selected individuals were given exclusive access to the study areas in exchange for compiling data (at the buying stations) on the weights, grades, and prices of matsutake they harvested.

Weekly maximum and minimum soil temperatures at a 2-inch depth were recorded during the 1993 to 1995 seasons, and maximum and minimum air temperatures at 3 feet above ground were recorded during the 1994 and 1995 seasons. Recorders were located in the center of each experimental area.

Results and discussion. No matsutake fruited in 13 of the 54 permanent strip plots (24.1 percent) we sampled, whereas nine strip plots (16.7 percent) had 56.1 percent of all the matsutake found. Although the temporary strip plots were twice as large, they represented one-time samples rather than seasonal sums. Only 72 of the 560 temporary plots (12.8 percent) had any matsutake fruiting in them. The spatially and temporally clustered distribution of matsutake presents sampling design challenges. Sampling over time may reduce the need for large sample areas, but repeated samples of the same plots are not independent and must be analyzed appropriately.

The skewed distribution of matsutake counts was normalized with a $\log_{10}$ (count+1) transformation before the analysis of variance (ANOVA) was conducted. Weekly permanent plot productivity data were summed for each year's fruiting season and analyzed by using a repeated-measures ANOVA, with elevational habitats as the main grouping factor and year sampled as the repeated measure. Confidence limits were calculated for the transformed count means and then back-transformed to median counts with their associated confidence intervals *(fig. 3).* Elevational habitats did not differ significantly and there were no significant interactions among habitats and years, but productivity did vary significantly ($p < 0.0001$) among years.

The dimension that best correlated with mushroom fresh weight was cap diameter. This was a fortunate result for future studies because it is the easiest dimension to measure on a mushroom before it is picked. A regression of the log transformation of fresh weight in grams and cap diameters in millimeters provided the best relation. The formula (with standard errors of the coefficients shown in italics in parentheses) is as follows: log (fresh weight in grams) = −2.624 (*0.4331*) + 2.294 (*0.235*) * log (cap diameter in millimeters). The R^2 of 0.864 for this equation indicates that 86.4 percent of the variation in weight can be explained by measured cap sizes. P values for both coefficients were < 0.0001. We chose not to use dry-weight analyses because the correlation between cap size and dry weight was weaker and dry weight productivity was not comparable to the commercial harvest.

Cap diameter measurements were unreliable in 1995 because field crews used inconsistent units. To compensate, the average estimated weight was calculated for each grade of matsutake from the 1993, 1994, and 1996 data. Average weights by grade were then applied to the matsutake counted in 1995 according to their grade. Yearly estimates of fresh weight productivity are in *figure 4.*

The ANOVA conducted on data from the temporary strip plots showed trends very similar to the permanent plots; that is, no differences were noted among the elevation habitats and there were no significant interactions between habitats and years, but the productivity did vary significantly among the four years we sampled ($p < 0.0263$). Harvesters considered 1993 and 1996 typical years, 1994 a poor year, and 1995 a good year, although commercial harvest occurred in all four years.

In 1995 the weight of matsutake that our cooperating harvesters collected in the three study sections was 22 percent of the biological production we extrapolated from our sample plots; in 1996 it was only 12 percent. These estimates of the proportion of biological production commercially harvested seemed surprisingly low. After reviewing our procedures for measuring the commercial harvest, we still believe humans harvest no more than half the total biological production. Commercial harvesters typically leave overmature or damaged mushrooms, animals eat some, and even the most skilled harvesters do not find them all. These results have somewhat alleviated concerns about reduced spore dispersal and diminished availability of a preferred wildlife food.

Only 7 percent of the matsutake examined within the permanent strip plots were damaged by animals. Matsutake consumed completely could not be counted and may have biased this estimate, but stumps were commonly found, suggesting that animals may avoid eating the pumice that typically clings to the base. No significant differences were noted among habitats or years. Animal signs on the temporary strip plots were 41 percent deer, 38 percent rodent, 8 percent bear, 7 percent elk, and 6 percent other. Of the matsutake individually examined by cooperating commercial harvesters in 1995, 75 percent were not browsed, 23 percent were browsed by deer, elk, or bear, and 2 percent were eaten by rodents. Mammals are able to locate matsutake underground by their spicy odor, and matsutake remnants frequently are found in holes dug by animals. Most mushrooms are nutritious (Fogel and Trappe 1978), and because they are efficient mineral accumulators (Stark 1972), mammals may rely on them for rare minerals otherwise limited in their diets. Human harvesters reduce this food source for animals but certainly do not eliminate it.

Figure 5 illustrates patterns of fruiting during the course of each season. We found no direct correlations of time or abundance of fruiting with soil or air temperatures measured weekly. Daily soil and air temperature readings in immediate proximity to matsutake colonies may prove more useful for predicting fruiting because aspect, canopy cover, and air drainage patterns all produce small-scale temperature variation across the landscape. Commercial harvesters have suggested that a season's potential mushroom productivity is commonly related to summer rainfall. One harvester, Andy Moore, has documented that dropping autumn temperatures, followed by a period of moderate warming, are important for initiating and stimulating mushroom growth. Rainfall can cool pumice soils, which otherwise poorly conduct changes in air temperature. Autumnal showers, therefore, may help initiate fruiting, but matsutake will fruit without rainfall in these habitats. High autumn temperatures can also stunt or destroy maturing flushes of matsutake. Hypotheses about the influence of weather patterns on potential productivity, fruiting initiation, and mushroom growth require testing with more site-specific, prolonged (summer months also), and detailed (daily) records of temperature regimes, precipitation events, and mushroom development.

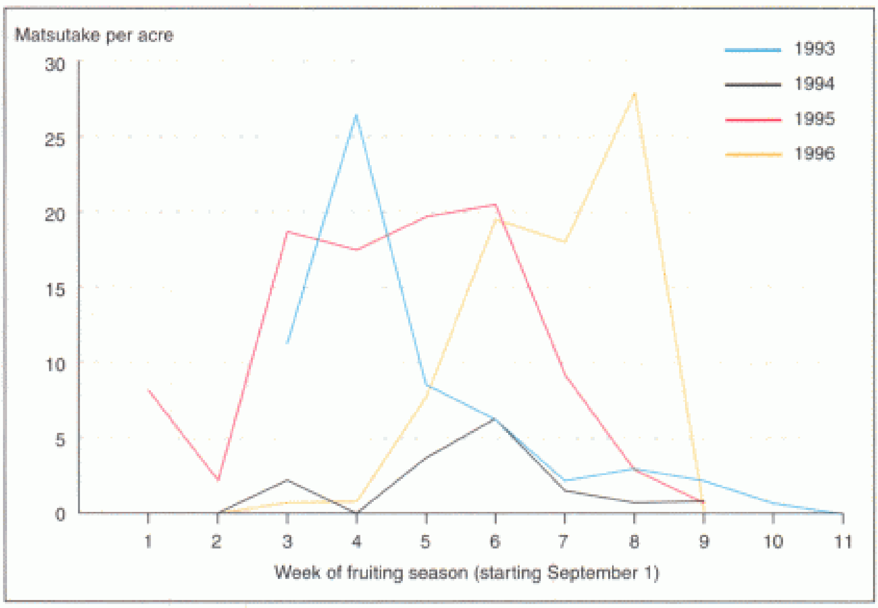

***Figure 5.* Weekly number of matsutake per acre during each fruiting season from 1993 to 1996 (estimated from random azimuth plots).**

Silviculture and Economics

Most information about American matsutake responses to changing forest environments is anecdotal or extrapolated from experiments conducted with the Japanese matsutake (Iwamura et. al. 1966; Ito and Ogawa 1979; Lee 1981; Hosford et al. 1997). Practices used in Japan to enhance production include thinning forest stands, leaving tree species that form abundant matsutake mycorrhizae, clearing understory shrub and forb growth, and removing organic litter from the forest floor. These steps achieve a forest canopy punctuated with light gaps, thin litter and duff layers, sparse vegetative ground cover, and vigorously growing trees. The resulting soil environment may give matsutake a competitive advantage over other soil fungi: higher temperature and light fluctuations, increased soil moisture, and more conifer root growth (sites for mycorrhizal colonization) close to the surface.

Tree species, matsutake species, forest stand structures, fire history, soils, and climate in the southern Cascade Range all differ from their Asian counterparts (Lee 1983; Hosford et al. 1997), but Japanese research serves as a point of departure for management practices to improve American matsutake habitat. Clearcuts are difficult to reforest on the high-elevation pumice and ash soils of the southern Cascades. Desired timber species, such as Shasta red fir or ponderosa pine, are difficult to establish and then grow slowly (Messner 1974; Halverson and Emmingham 1982). Native tree species are susceptible to fungal pathogens, insect attacks, and dwarf mistletoe. Uneven-aged stand structure is typical of natural conditions, especially at high elevations and on north-facing slopes (Cromack et al. 1991). Managing solely for timber production is usually uneconomical because costs of sanitation cuts, site preparation, tree planting, and precommercial thinning usually exceed expected discounted timber revenues. Retaining forest cover and managing for long rotations through selection cutting are the preferred means of timber harvest on these sites, especially when the harvest accomplishes other silvicultural goals, such as fire management.

Before fire suppression began early in the 20th century, frequent light- to moderate-intensity fires removed most understory vegetation and thinned regeneration to densities that a site could support as trees matured (Agee 1993). Currently, many forest stands in the southern Cascades are densely stocked, have accumulated deep duff layers, and have multilayered canopies that create fire fuel ladders. Shasta red firs are considered a preferred host for the American matsutake in this area because most fruiting is observed in close proximity to them; however, the dense tree regeneration in fire-suppressed stands consists predominantly of species other than Shasta red fir. Large-diameter overstory Shasta red firs must compete for moisture and nutrients with these thickets of understory trees, and the deep litter accumulation may impede matsutake fruiting and increase the risk of catastrophic fires. Thinning from below, followed by low-intensity prescribed fires, would retain large overstory Shasta red fir and reduce understory competition, duff layers, and fire hazard. These same silvicultural prescriptions may produce more favorable conditions for matsutake growth and fruiting (Amaranthus et al. 1998).

Economic Calculations

With the help of Ed Brown of the Chemult Ranger District, we developed a theoretical silvicultural treatment for a representative stand to assess the present net worth of managing for timber and American matsutake. The study sites are in a scenic management area not currently scheduled for harvest, but similar nearby areas could produce timber through uneven-aged management. We chose a typical stand with several commercial species of trees, including western white pine, sugar pine, lodgepole pine, ponderosa pine, and Shasta red fir. Our model assumed that selective cuts would retain a canopy cover of 35 percent or more and that sugar pine would constitute 20 to 30 percent of the stand, lodgepole pine 40 to 55 percent, and Shasta red fir 25 to 30 percent. We assumed soil compaction from multiple thinning entries would be minimal (for example, by logging on snow-covered ground) and not detrimental to tree health, mycorrhizal formation, or fungal growth or fruiting.

We assessed three alternatives. In the first two alternatives, the area is selectively harvested to enhance matsutake production with five timber harvests over 90 years. Given that Japanese matsutake productivity has been reported to increase 100 to 400 percent as a result of silvicultural treatments (Weigand 1997), we conservatively assumed (1) a 100 percent increase in matsutake production or (2) no change in matsutake production resulting from timber harvests. Alternative (3) consists of mushroom revenues without timber harvesting. Economic assumptions for calculating the present net worth of each resource and each alternative include a 4 percent rate of return and no change in real prices or costs.

Table 2. Present net worth (1997 dollars) per acre of timber and American matsutake for three management and productivity scenarios.

Products and mushroom harvest cost assumptions	Alternative 1: timber harvest, 100% increase in matsutake productivity	Alternative 2: timber harvest, constant matsutake productivity	Alternative 3 (current management): no timber harvest, constant matsutake productivity
Timber	$ 497	$ 497	$ 0
Matsutake (harvester costs = 50% of mushroom sale value)	580	432	432
Matsutake (harvester costs = 90% of mushroom sale value)	164	135	135

Mushroom and timber revenues are difficult to compare because we have little information on mushroom harvesting costs, and the two resources are sold differently. The price of mushrooms sold to buyers is roughly comparable to the price of logs sold to a mill (delivered log price). Timber harvesting requires large capital investments in equipment and hauling costs, and companies typically provide insurance and pay employees better than minimum wage. Mushroom harvesting is less expensive, wage expectations are lower, and both labor and expenses may be shared by family groups. Timber is sold by bid to one harvester (normally a company), whereas mushrooms are usually sold by permit, with theoretically unlimited numbers of harvesters (individuals) competing for the same resource.

We used return-to-the-resource calculations to compare the present net worth of both timber and mushrooms. The return to the resource for timber can be defined as what the harvester is willing to pay the landowner for rights to harvest the resource (sufficient to cover the costs of harvesting and possibly realize a profit) less the landowner's costs incurred in managing the resource for sustainable production and harvest. In this applied example, return to the resource is the bid price for a timber sale minus Forest Service administrative costs for timber management. All costs to the harvester are taken into account in the bid. We used tree growth models, bid prices (by species), and administrative costs (both direct and indirect) to calculate discounted timber values per acre. Stumpage (bid) prices were actual 1997 Chemult Ranger District selling prices per thousand board feet.

A comparable return-to-the-resource calculation for matsutake included net permit revenues (district permit sales minus administrative costs for the matsutake program) plus net profit to the harvester (sales revenues minus harvesting costs). The Chemult Ranger District collected about $150,000 more from permits than it spent on its matsutake management program in 1996, or $2.50 net per acre of available matsutake habitat. Given our economic assumptions, the present net worth of these permit sales over 90 years was calculated at $60.67 per acre.

Net harvester profit per acre is more difficult to calculate. We weighted matsutake prices by the proportion (fresh weight) of each grade sold by harvesters at three collection areas in Oregon from 1992 to 1996. The weighted price was $15.95 per pound for all grades. The average biological productivity from 1992 to 1996 in the Chemult study area was 3.84 (standard error = 0.77) pounds per acre per year. We assumed that harvesters collected half the biological production in our representative stands. Mushroom harvesting costs included living expenses (food, camping fees, phone calls, etc.), transportation costs, permit fees, and a personal minimum wage sufficient to justify their time (but not necessarily the official state minimum wage). Because harvesting costs are so uncertain, we calculated net harvester profit in two ways, by subtracting 50 percent and 90 percent of sales receipts to buyers. These percentages represent what we believe to be the low and high ends of probable costs to harvesters.

Table 2 shows values calculated as return to the resource over the 90-year period. Income from timber and mushroom harvesting is distributed differently and benefits different sectors of society. Timber in this area grows slowly, and discounted present values per acre are generally less than, for example, Douglas-fir forests west of the Cascades. Trees harvested from federal land must be sold and processed domestically, hence they do not command the higher prices paid for exported logs. The timber market is relatively stable and predictable, especially compared with the highly volatile matsutake market (*table 1,* footnote 4). Calculating the value of mushrooms in our forests is subject to many caveats and uncertainties; more detailed discussions are planned in subsequent articles (Alexander et al., in prep.).

Our study of American matsutake harvesting in the southern Oregon Cascade Range suggests that the commercial value of forests can be enhanced through the harvest of nontimber forest products, such as mushrooms. Well-planned timber removals may provide revenue, jobs, and wood while improving forest health and increasing the availability of other products. Mushrooms and other nontimber forest products also provide recreational and subsistence opportunities to forest users, as well as cultural foods and plants to Native Americans. Maintaining forest health, biological diversity, and noncommercial amenities while broadening the range of forest products is a central challenge for ecosystem management of public lands. This matsutake harvest program illustrates how forest managers can expand their planning and management activities to provide new forest products.

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Funding: USDA Forest Service Winema National Forest and Pacific Northwest Research Station.