21 Special Forest Products: Integrating Social, Economic, and Biological Considerations into Ecosystem Management

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Throughout history, forests have provided a wealth of beneficial and essential products ranging from foods and medicines to building materials. Ancient pharmacopoeias list myriad forest plants and fungi for treating various ailments. Many of these ancient remedies have evolved and continue to evolve into the important drugs of modern medicine. Use of diverse forest species remains commonplace around the world, particularly in cultures with strong rural traditions. Even in the most technologically advanced societies, traditional uses of forest products continue, often as recreational pursuits. For example, the tradition of collecting and consuming wild edible forest mushrooms by Europeans and Asians continues by their descendants in North America.

As societies modernized and depended less on the diversity of wild products from forests, many of these traditional uses diminished, some were forgotten, and others remained useful to only subsistence forest dwellers or native inhabitants. Forest management in the 20th century increasingly emphasized growing and harvesting trees for timber and fiber products as its primary objective. Despite that emphasis, a small entrepreneurial segment in forest-based communities continues to commercialize nontimber products from the forest, including foods, medicinal plants, and floral greens. Forest managers designated these as "minor" forest products, thereby reflecting an attitude that they were less important than timber in the overall scheme of forest management. But the economic impact of this industry and the quantities of products harvested can no longer be viewed as minor. In the Pacific Northwest, special forest products account for over $200 million in revenue (Schlosser et al. 1991). This amount is substantial when compared to the $2.63 billion generated from stumpage receipts to all landowners in Oregon and Washington in 1989 (data derived from Warren 1995). Thousands of tons of biological materials from dozens of species are removed annually from forest ecosystems.

The paradigm shift in forestry from timber management to ecosystem management has heightened public awareness of the importance of the special forest products industry. In addition, managers and the public have increasingly recognized that special forest product species are important components of forest ecosystems. Dramatic declines in revenue to rural forest communities from harvest of federal timber are increasing the importance of special forest products industries in rural economic recovery and development. The two largest public land agencies in the United States, the Bureau of Land Management of the U. S. Department of the Interior and the Forest Service of the U.S. Department of Agriculture, recognize this importance and are developing regional and national strategies for managing special forest products. These strategies emphasize four themes: (1) to incorporate harvesting of special forest products into an ecosystem management framework with guidelines for sustainable harvest, species conservation, and protection of ecosystem functions; (2) to involve the public, including industrial, Native American, and recreational users of these resources, in making decisions about the future of special forest products on public lands; (3) to view the management of and accessibility to special forest products as major factors in assisting rural economic diversification in formerly timber-dependent communities; and (4) to develop and implement inventory, monitoring, and research programs to ensure species protection and ecosystem health.

Blending the management of special forest products into the holistic objectives of ecosystem management will not be easy. The social structure and composition of the industry differ from the typical timber-based community. In the Pacific Northwest, large numbers of migrant harvesters from various ethnic backgrounds are major participants in the industry (Schlosser and Blatner 1995). A thorough understanding of all the groups involved in the special forest products industry is essential to developing effective communication and building common understanding about management directions. The economic structure of the industry is also poorly understood; market dynamics are difficult to track, so that trends in the industry remain clouded. If special forest products are to play a role in rural community development, these economies must be better understood so that investors can assess the risks involved in these enterprises.

The complex biology and lack of information on harvesting of special forest product species also present a significant challenge for integrative ecosystem management. Numerous federal and state laws exist to protect forest resources, including the National Forest Management Act, National Environmental Policy Act, and the Endangered Species Act. Under strong environmental regulations and in a litigious climate, resource managers require substantial data to support management decisions. Unfortunately, baseline data on the effects of harvest, on markets, and on the biology, ecology, and productivity for many special forest product species are either shortterm, incomplete, or nonexistent. Also lacking is information on responses by harvesters to economic incentives and conservation measures set in place by land managers. Many of these species also play important ecosystem roles, such as providing food for wildlife and capturing and cycling nutrients. Yet, we poorly understand these complex dependencies, and the consequences of harvesting special forest products on ecosystem function and integrity are largely unknown. To incorporate sustainable harvests of special forest product species within an ecosystem management context, resource managers and researchers must develop and implement research, inventory, and monitoring protocols for these species and promote transfer of key information to affected and interested publics.

Adaptive strategies for ecosystem management provide for diverse forest stands and landscapes and for a wide range of values and products. Practices are modified as more ecosystem and societal information becomes available. Traditional forest management affects the distribution and abundance of many special forest products by shortening rotations of tree crops and growing only species and genotypes that produce the highest timber yields. Although some special forest product species can thrive in homogenized or intensively managed forests, others cannot. Ecosystem management recognizes that the dozens of genera of plants and mushrooms and assorted other materials collected in the United States as special forest products are products of natural diversity; it therefore adapts practices to help assure their sustainability. We are in the beginning of the adaptive phase of managing for special forest products. Some decisions must be made without sufficient information and adapted or modified as results from inventories, monitoring, and research become available. This chapter develops a conceptual framework for ecosystem management of special forest products and provides a model for future decision support. We draw from familiar examples in the Pacific Northwest, where the special forest products industry is expanding, but the issues, problems, and solutions likely will apply to many other forested regions.

Global Perspectives and History

Over the ages, indigenous peoples acquired an understanding of the basic ecology and usefulness of flora and fauna and explored the various foods and medicinal properties of plants and fungi. Stored in the memories of elders, healers, midwives, farmers, and fishers in the estimated 15,000 remaining indigenous cultures on Earth is broad knowledge about useful products from naturally diverse ecosystems. This knowledge has been passed on through ancient but fragile chains of oral tradition that will be broken when younger members of a society leave the traditional lifestyles. Today, much of the expertise and wisdom of these cultures has already disappeared; our understanding of special forest products gleaned from thousands of years of trial, error, and observation is consequently diminished.

In the course of cultural evolution, other socioeconomic lifestyles have emerged, especially those based on agricultural or industrial production. These agricultural and industrial societies coexist with hunter-gatherer lifestyles, but at the same time change them (Keene 1991). Today, large, single-product timber industries operate side-by-side with smaller-scale cottage industries processing diverse forest products and with individuals who gather special forest products for subsistence, cash income, or recreation. In many rural societies around the world, forested ecosystems continue to be the primary source of products used for food, fodder, fibers, housing, and medicines.

In industrial societies, advances in technology and changes in patterns of economic exchange have altered the scale and type of forest-products consumption and the relative social standing of hunter-gatherers. Over the last two centuries, industrial economies have grown by using capital gained from rapid and effective exploitation of natural resources. Industrial societies will tend to use the few products most efficiently produced from a forest ecosystem. This trend contrasts with that of subsistence societies that tend to have little capital for development and a more geographically restricted access to resources. They may find more products from a single forest, but the products are often less profitable. Almost all countries, including the United States, have substantial populations of harvesters and gatherers that lead subsistence lifestyles.

Industrialized nations such as Russia have never lost their preindustrial cultural ties to diverse forest products. Customs regarding collecting berries and mushrooms remained vital even as industrialization and urbanization proceeded rapidly in the 20th century. Research in Finland, France, India, Italy, Japan, Poland, and Russia and, more recently, in many tropical countries recognizes the importance of special forest products to those national economies. International conferences in Europe and Asia (Akerle et al. 1991, Marocke and Conesa 1981, Vänninen and

Raatikainen 1988) have called attention to the renewed economic role of special forest products in the economy of forested ecosystems.

Industrial and nonindustrial countries alike are beginning to formally recognize the disparity in wealth and material well-being among their peoples, as well as the moral obligation to practice good land stewardship. Out of this recognition, the concept of sustainable development was agreed upon by nations participating in the United Nations Conference on Environment and Development in 1992. Organizations and governments are defining and initiating operational strategies for sustainable development; this process could become a global trend in the 21st century. Special forest products will play an important role in sustainable development and are perceived as essential links to sustaining rural communities and contributing to economic diversification. At the same time, wild species that are special forest products contribute to the diversity and function of forested ecosystems. Thus, strategies must be developed that both supply and conserve these valuable species.

The focus of the biomedicinal or phytopharmaceutical industry on natural products illustrates the global scale of challenges to stewardship and sustainable development issues. Exploring biological diversity as a potential source of new, valuable phytopharmaceuticals is gaining interest and investment from some of the largest pharmaceutical companies in the world (Joyce 1994). In the synthetic drug market, about 25 percent of all prescription drugs still contain natural plant materials as active ingredients (Der Marderosian 1992). Of some 121 prescription drugs currently in use that are derived from higher plants (not including antibiotics from microorganisms), 74 percent were known in folklore (Joyce 1994); about 175 drugs used by native Americans are listed in the U.S. *Pharmacopoeia* (Robinson 1977). Thus, many plants selected for bioactive screening are sampled because ethnobotanical research indicated that the plant had a known medicinal activity or was used by an indigenous group for healing wounds or other disorders (Forlines et al. 1992, Gunther 1973). Today, large investments in drug development, technologically advanced screening capabilities, sophisticated joint ventures, cooperative agreements, and government-supported funding of research raise new issues of resource sovereignty and intellectual property rights Goyce 1994).

Regional Perspectives from the Pacific Northwest

Pacific Northwest forests were essential to the lives of aboriginal people that migrated to North America with the receding glaciers as early as 10,000 years ago. Various forest species were important for food, tools, structures, transportation, and medicine. Large conifers were used for housing, and understory species such as Pacific yew, willows, and red alder were used for many purposes, including hunting tools, bowls, masks, and medicines (Pojar and MacKinnon 1994). Many plants and fungi were part of native traditions and mythology. Medicinal use and spiritual value were linked in medicines derived from trees, forbs, and fungi (Molina et al. 1993, Pojar and MacKinnon 1994, Smith 1983); for example, devil's club was used by Northwest tribes to cure a variety of illnesses and to ward off evil spirits.

Use of plants by indigenous people in the Pacific Northwest for food and aboriginal technology is well documented (see, e.g., Colville 1897, Gunther 1973, Reagan 1935, Turner et al. 1990): Aboriginal people not only gathered species, they also burned and selectively harvested to maintain productivity of important food plants. Use of fire promoted bracken and camas, staples of aboriginal diets, before fire was suppressed by settlers and the land agencies that followed (White 1980). The use of fire to promote berry species and forage is also well documented (Boyd 1986, Gottesfeld 1994, Norton 1979, Robbins and Wolf 1994, Turner 1991). Thus, indigenous people introduced management techniques long before the arrival of other people to the region and may have used over 100 different species (Turner et al. 1983). Indigenous people do not now rely on wildland plants as a primary food source as in the past. However, certain plant products such as berries are harvested extensively, and many traditional uses of plants as herbals, tonics, and medicines are maintained in tribal culture (Turner et al. 1983, 1990).

When settlers came to the Pacific Northwest, they too relied on wild, native species as important supplements to food, medicines, and clothing. Superimposed on wild harvesting were their own traditions and knowledge of plant species harvested or cultivated for herbs, food, and medicine. They applied knowledge from their homelands to related species in the Pacific Northwest. In addition to wild berries, they found forbs such as nettles, thistles, yarrow, and bedstraw that could be used in the same ways as their European equivalents. (Robinson 1977). Whether settlers learned from indigenous people or already knew of certain plant properties, Europeans and Native Americans often had identical uses for plants. Cascara from Rhamnus spp. served as a laxative for both cultures and is still commercially harvested for that purpose. Nettles provided fiber for Northwest Indians, and they were an important fiber source in Europe and Asia (Moore 1993, Robinson 1977). With development of commerce, agriculture, and urban trade centers, dependency on the local forest for its products declined; public lands began to be viewed primarily as an economic cornerstone of industrial development.

Timber, livestock, water, and minerals were the economically important products from public lands in the rapidly ascendant Euro-American economy of the Pacific Northwest. The value, if any, of other plants and fungi continued for subsistence use, largely lacking in any tradable or marketable value. The result was that such goods from public lands were essentially free nonmarket goods. Folk traditions all but disappeared as the commercial development of agriculture and timber harvesting dominated and altered the Pacific Northwest landscape. Traditional folk use of wild plants was relegated primarily to those rural people who, for economic or philosophical reasons, continued to harvest, use, and trade in native plants.

A resurgence of interest in the traditional use of native plants corresponds with increased recognition of the value of traditional healing methods (Krochmal and Krochmal 1984, Moore 1993). This interest is apparent in the growing number of publications on wildcrafting-i.e. foraging for native herbal medicinal edible and otherwise, useful wild plants. As a consequence of the public's demand for natural, unprocessed goods, products that originated in the wild are occupying an increasingly important niche in the marketplace. For example, the leaves of the sword fern, once used for medicine, insulation linings, and sleeping mats (Gunther 1973), are important in today's floral greens industry. The bark of Oregon grape provided a bright yellow dye used by native people in making baskets; its bark and berries were the source of medicinals. The plants continue to be a source of commercial pharmaceutical alkaloids, of which berberine is a primary medicinal constituent. Harvested for the floral greens industry, the plant's foliage also contributes to its current economic importance (Tilford 1993). The rush to capitalize on these markets is altering the traditional relationship between the resources and rural-dwelling harvesters, who have depended on open access to public lands. They are not only finding new markets for their products, but also experiencing increased competition for restricted resources.

Several hundred native plants, including trees, shrubs, forbs, and vascular and non-vascular plants (but excluding those used in the timber industry), are currently harvested for personal and commercial use in the Pacific Northwest (see Table 21.1): The use of these plants is diverse, falling into five general areas: (1) foods, (2) decoratives, including floral greenery and dyes, (3) herbals, (4) medicinals, and (5) specialty products such as aromatic oils and wood products. The Pacific Northwest probably leads all other regions in North America in active use of public lands as a source for diverse floral greens and botanicals (Thomas and Schumann 1993). Commercial harvesting is expanding concurrently with recreational wildcrafting. Gathering plants and plant parts for personal use as ornamentals, foods, or herbals is important to traditional rural wildcrafters, but these activities have widened to include more diverse groups of people. Renewed interest in wildcrafting appears to accompany an emerging ecological ethic. Books such as Tilford (1993) and Moore (1993) include information designed to raise environmental awareness and encourage low-impact harvest of wild plants.

Conifer boughs constitute a constant but highly seasonal market (October to December) in the Pacific Northwest. Schlosser et al. (1991) estimates that 5,000 persons were employed harvesting boughs in the region in 1989 and another 4,000 manufactured wreaths and swags during the short season. Boughs from noble fir provide the greatest volume in the region: in 1989, 9,310 tons were harvested, yielding

Table 21.1 Representative native plants and fungi from the Pacific Northwest currently important as special forest products

Use	Common Name	Scientific Name
Floral greens	Salal	*Gaultheria shallon*
	Sword-fern	*Polystichum munitum*
	Evergreen huckleberry	*Vaccinium ovatum*
	Bear grass	*Xerophyllum tenax*
	Dwarf Oregon grape	*Berberis nervosa*
	Oregon boxwood	*Pachistima myrsinites*
	Mosses	*Isothecium* spp.
		Hypnum spp.
		Neckera spp.
Christmas greens and boughs	Douglas fir	*Pseudotsuga menziesii*
	Noble fir	*Abies procera*
	Western red cedar	*Thuja plicata*
Edibles	Huckleberries	*Vaccinium* spp.
	Berries	*Rubus* spp.
	Fiddlehead	*Pteridium aquilinium*
	Mushrooms:	
	Chanterelle	*Cantharellus cibarius*
	Morel	*Morchella* spp.
	Matsutake	*Tricholoma magnivelare*
	King bolete	*Boletus edulis*
Medicinals and herbs	Pacific yew	*Taxus brevifolia*
	Cascara	*Rhamnus purshiana*
	Devil's club	*Oplopanax horridum*
	Prince's pine	*Chimaphila umbellata*
	Stinging nettle	*Urtica dioica*
Dyes		
	Oregon grape	*Mahonia nervosa*
	Red alder	*Alnus rubra*
	Western red cedar	*Thuja plicata*
Poles and decoratives		
	Lodgepole pine	*Pinus contorta*
	Noble fir	*Abies procera*
	Vine maple	*Acer circinatum*

Note: See USDA Forest Service (1993b) for a broad listing of special forest product species and their use in the United States.

$6.7 million, or roughly half the regional market value (Schlosser and Blatner 1993). Other important species commanding high prices are subalpine fir and incense cedar. The fine commercial quality of Pacific Northwest conifer boughs has not gone unnoticed elsewhere in the world. Little information has been published in North America about methods of commercial bough production in the Pacific Northwest (Murray and Crawford 1982) or elsewhere in North America (Hinesley and Snelling 1992), but Europeans have published numerous studies (e.g., Hvass 1964, Weege 1977) on determining optimal spacing, fertilization, and pruning regimes for bough production, with noble fir as an integral part of mixed-product silviculture.

The medicinal plant market in the Pacific Northwest has typically been associated with native herbs used for alternative therapies. A growing body of manufacturers in herbal and over-the-counter medicines rely on local wildcrafters, but the Pacific Northwest, with its rich biological diversity, has not been ignored by mainstream pharmaceutical industries looking for new, effective compounds. A noteworthy discovery came from the Pacific Northwest in the 1960s and 1970s when the compound taxol, extracted from Pacific yew bark, proved to be an effective agent against ovarian and breast cancer. Taxol was developed by the pharmaceutical company Bristol-Myers Squibb (BMS) under a collaborative research and development agreement with the National Cancer Institute. In 1991 and 1992, about 1.7 million pounds of yew bark were harvested from public lands in the Pacific Northwest under interim guidelines developed by the Forest Service and the Bureau of Land Management. An environmental impact statement (EIS) was issued (USDA Forest Service 1993a) that restricted yew harvest to timber-sale areas and used previously developed harvest guidelines to limit the proportion and size of yew trees taken from any harvest unit. The EIS also required replanting of harvested areas with seedlings or rooted cuttings. In 1993, BMS withdrew from federal lands in the Pacific Northwest because other yew species, harvested primarily in India, provided more cost-effective sources of taxol.

In the United States, federal laws, including the Pacific Yew Act of 1992, and environmental impact statements, such as the federal EIS on management for the northern spotted owl in the national forests, provide a legal framework for limiting harvest of Pacific yew, even though scientific knowledge of the species is lacking. Nevertheless, phytopharmaceutical industries, with their rapid and large-scale development capabilities, could quickly impact a resource when a commercially valuable product is discovered. Such discoveries are relatively rare, but they have widespread environmental and socioeconomic effects whenever they do occur. Future discoveries of phytopharmaceuticals may come from species less common than the Pacific yew. If alternative sources are neither available nor cost effective, conflicts between using native species for treating human diseases and conserving them to protect the species may be difficult to resolve.

As we approach the 21st century, the forests of the Pacific Northwest will become increasingly known for the value of their natural products. Biological diversity, one of the region's greatest ecological assets, could provide abundant opportunities for the development of new commercial products, but this could place more species at risk and increase disturbance of complex ecological relationships. Managing for biodiversity and ecosystem sustainability should provide the special forest product industry with stability and accommodate the tradition of individual collection, use, and enjoyment of native species. To do this we need to have better knowledge not only of the ecosystem but also of the special forest products industry.

Socioeconomic Considerations

Unknown Supplies

A basic gap in knowledge results from the lack of an inventory of the type and amount of existing and potential special forest products in the Pacific Northwest. Such ignorance can have negative economic effects. Without an awareness of changes in stock levels, managers cannot implement adaptive measures to adjust stocks so that a desired and sustainable level of product is available to developing markets. A reliable supply is also essential to wholesalers of special forest products (Handke 1990) and for building enduring commercial relationships that provide steady income to suppliers. For instance, loss of the German market for Washington State chanterelles was the result of a sudden and unpredicted collapse of the supply (Russell 1990). With the growth in worldwide markets for special forest products from the Pacific Northwest and elsewhere, concerns about resource depletion arise even before management of special forest products begins (Foster 1991).

Field inventories are crucial tools for (1) calculating existing stocks of special forest products, (2) identifying existing areas of overharvest, (3) analyzing the possibility of intensified management for expanded commercial production, and (4) providing the scientific database for research on ecological and economic constraints to production (Grochowski and Ostalski 1981). For example, evidence from Europe, where mushroom picking has been intense for much longer than in North America, suggests that environmental changes and increased mushroom collection are leading to declines in mushroom populations (Arnolds 1991, Cherfas 1991, Jansen and de Vries 1988). However, few published articles document the effects of economic harvesting on special forest products (e.g., Benjamin and Anderson 1985, Geldenhuys and van der Merwe 1988, Smirnov et al. 1967). A global information system is needed to register changes in natural populations of special forest product species (Cunningham 1991). Countries such as Bulgaria, Lithuania, and Poland already incorporate national inventories of such species (Budriuniene 1988, Economic Commission for Europe 1993).

Monitoring is especially helpful for short-term prediction of harvest yields. Forecasting crop yields on the basis of weather data and phenological information can help resource managers decide on the intensitrof harvest, the number of permits to issue, the prices to charge, and the allocation of harvesters and handlers in the seasonal workforce. Kujala (1988) has carried out exemplary work in phenological studies of berry and mushroom crops in Finland, but such studies are rare. Information and understanding are lacking for forecasting the productivity of North American species of economic importance, although studies address productivity of prominent commercial species such as Pacific yew (Vance et al. 1994) and chanterelles (Norvel et al. 1994). An inventorying system can provide support to managers so that better decisions can be made about allowable harvest, number of people permitted to harvest, duration of the collection period, and the cost, if any, of licenses to support ecosystem management for resource conservation.

Developing inventory and monitoring programs for special forest products will present new challenges for resource managers. Many special forest product species are irregular in occurrence on the landscape or are present for short duration (e.g., mushrooms). Other considerations include economic and uneconomic concentrations, quality characteristics of commercially valuable stock, importance of access on commercial feasibility, and how to extrapolate inventory results to information about commercial occurrence (R. Fight, Research Forester, Pacific Northwest Research Station, personal communication, 1995). Initial costs to establish new inventory and monitoring programs may be high.

Changing Demands

Tastes and preferences of people constantly change and provide impetus for innovation in special forest products industries. In the early 1960s, for example, bear grass was unknown as a floral green, and edible wild mushrooms were largely unrecognized as a commercial product (USDA Forest Service 1963). Both the evolving definition of special forest products and the reception of products by distributors and end consumers are highly subjective and difficult to know in advance. In central Europe, a market for cut flowers and floral greens endures, but markets for specific plants are subject to rapid changes in fashion (Handke 1990). The accelerating pace of information access often speeds up consumer awareness and demand for innovation. Demand for many special forest products may represent fleeting or erratic markets based on changing tastes and technology.

Cross-cultural comparisons of special forest product species provide sources of information that can lead to innovation in market development. While European countries in the north temperate zone currently use many species of native plants and fungi, closely related species in the Pacific Northwest are often underutilized or unknown for their use as special forest products. Given the receptivity of the American public to innovations in consumption and marketing, the exotic traditions of other countries might provide marketing angles for culinary, medicinal, and horticultural commodities in North America or offer new markets for products abroad. Species such as serviceberry, madrone, dogwood, hawthorn, wild rose, elderberry, mountain ash, and viburnum have relatives native to Europe and temperate Asia (Bounous and Peano 1990, Cherkasov 1988) that already are widely used. Raspberry, native to the Pacific Northwest, is commercially cultivated in forests of

Russia and Lithuania (Budriuniene 1988, Cherkasov 1988). Market niches for these species, whether for subsistence, commercial, or recreational uses, remain to be developed.

New special forest products in the Pacific Northwest might also serve as a substitute for products currently imported to the Pacific Northwest. Ruth et al. (1972) initiated studies concerning development of maple syrup production from bigleaf maple in the Pacific Northwest. Although the study was encouraging, there was no follow-up research and development. Likewise, Oregon white truffles could hold promise as a future market substitute for European sources. On the other hand, substitution for Pacific Northwest special forest products by comparable products from other regions is equally possible.

Labor and Employment

Understanding the special forest products industry and planning for its future requires that planners and managers consider the people employed in the industry. In the Pacific Northwest, the workforce in special forest products has changed rapidly. Schlosser et al. (1991) and Schlosser and Blatner (1995) surveyed processors of floral and Christmas greens and edible wild mushrooms, and Handke (1990) describes the wholesale market for Pacific Northwest floral greens in Germany. But a comprehensive picture of the participants in all sectors of the industry is not yet completed.

A particular gap in information is a thorough profile of harvesters. In the Pacific Northwest, many people consider collecting special forest products as a last resort for employment after other options have failed (McLain et al. 1994). Obtaining information about professional collectors is difficult, because many have nomadic or reclusive lifestyles and work only seasonally. The appearance of unexpected ethnic groups among commercial harvesters has required rapid cultural sensitization and response in the form of new instructional materials and outreach efforts by the Forest Service and the Bureau of Land Management. To date, however, sociologists and anthropologists have not undertaken studies for the Pacific Northwest similar in scope and intent to those in Italy (Farolfi 1990), Finland (Saastimoinen and Lohiniva 1989, Salo 1984,1985), andThailand (Moreno-Black and Price 1993) to characterize populations who harvest special forest products. A basic question in the context of Pacific Northwest society is whether public policy should emphasize development of special forest products within a community or promote efficiency of migratory labor.

Educational programs for harvesters can help both federal land managers and harvesters accomplish mutually beneficial goals. It is often difficult for ecosystem managers to learn about the harvester workforce in their areas. Through cooperatives, extension workshops, or community college courses, exchange of information could help to develop a sense of community and cooperation and provide a forum to address common problems and interests. Education also imparts the values and ethics of ecosystem management and can provide background training in small-business management and finance.

Balancing Management Costs and Benefits

The American public has concerns about both sustainability of special forest product resources and the equitable distribution of benefits derived from special forest products. Rapidly growing public awareness of special forest products as a source of income has been swelling the ranks of product suppliers at all levels of the market supply structure. The growth of Oregon and Washington's population to 7.7 million by 1990 and projections for its continued rapid increase preclude the practicality of open and unrestrained harvesting on public lands. The Pacific Northwest also lacks a locally evolved tradition for regulating harvests.

Private gain from collectively owned resources, such as federal forest land, should require compensation for any deterioration and for subsequent management costs for site restoration or monitoring. Likewise, on private lands, landowners deserve compensation for granting collection rights to other people. Popular perception holds that special forest products industries derived from public lands are largely unregulated, unreported, and untaxed (Molina et al. 1993). Illicit collection and loss of revenue to landowners have not been estimated; however, the rapid development of mushroom markets in the 1980s would indicate that the cost to individuals and to society is considerable. From a policy standpoint, the costs and benefits to society of an unregulated industry must be weighed against the economic costs and benefits of regulation to support sustainability and equity to landowners.

Studies of the economic costs and benefits on returns from investment in special forest products are available from only a few sources in the Pacific Northwest. Managing for a sustainable industry must take into account not just the costs of managing forest vegetation, but also the management of the labor and operations in the harvesting, transportation, grading and sorting, packaging, and distribution networks. Costs for sale of permits or contracts for longterm leases will be incurred as planning staffs prepare and supervise sale operations. Setting fairmarket prices for sales is often difficult when empirical information about the value of permits or leases is unknown or highly variable. Costs also arise from the need for law enforcement, maintenance of campgrounds, and resource monitoring.

Benefits from sustainable management of special forest products should be considered at several scales simultaneously. Revenues to federal land management agencies should cover costs of planning, monitoring, and on-the-ground management. Permit holders and lessees should also benefit from the permit and leasing systems by being assured of a reliable supply. Market dynamics of supply and demand will determine the practicability of harvests by individuals as means to cover federal land management costs.

The Bureau of Land Management and the Forest Service are now exploring a uniform appraisal system for special forest products. Uniformity of legislation, regulations, and enforcement is important to develop coherent market responses from collectors and to increase returns to the land management agencies. There is the chance that regulations will not be effective if their basis and intent are not apparent. Agencies can use regulations to encourage harvest practices consistent with the goals of ecosystem management. One option might be to assign custodial harvest rights in a designated extractive reserve for a single resource for a specified term on the basis of competitive bidding (Fearnside 1989). Ecosystem management would rely on the self-interest of the permitted harvester to ensure the broader societal objectives of sustainable resource use.

There are potentially negative consequences of instituting an obligatory permit or lease system for harvest rights. Possibly the people who might most be in need of income from harvesting special forest products would lose their income source if they had to pay prohibitively high permit fees (Brown 1994). In cases where societal goals include aiding low-income people or diversifying a local rural economy, below-cost sales or sales reserved for small businesses can be effective for developing local capital and creating year-round employment. The relative social and environmental benefits and costs can be assessed as a gauge of the effectiveness of these programs to promote economic opportunities while at the same time protecting the ecosystems being managed.

International policies may provide some guidance for domestic rural development. Chambers (1983) suggests that improving the quality of life of the most economically disadvantaged is a desirable goal of rural development. If federal land management agencies adopted this goal, the economic resiliency of harvesters would be an important consideration. In addition to favorable permit systems, federal or state sources could support the establishment of special forest product cooperatives and processing businesses. Forestry has a long history of cooperatives. Generally, they stimulate entrepreneurship among people previously excluded from product development and marketing (Mater 1993).

The growing awareness of the actual and potential importance of special forest products should lead to changes in land management. Managers strive to meet dual social and ecological objectives-meeting the needs of society for special forest products and conserving the ecosystem function of special forest product species for sustainable interdependent production of all ecosystem goods, services, and conditions desired by society. We propose that adaptive ecosystem management provides the most likely context to assist land managers in meeting the dual goals.

Adaptive Ecosystem Management Considerations for Special Forest Products

Ecosystem management of special forest products on public lands requires integration of knowledge about human and ecosystem behavior. Managers and the public need to understand how factors of biological production and economic activity interact in time and space. Comprehensive knowledge of the roles of people and special forest product species in forest ecosystems will facilitate decisions that conserve, sustain, and enhance each special forest product resource and that meet human needs..

Primary considerations for management of special forest products include: (1) understanding the unique biology and ecology of special forest product species; (2) anticipating the dynamics of forest communities on a landscape level, delineating present and future areas of high production potential, and identifying areas requiring protection; (3) developing silvicultural and vegetation management approaches to sustain and enhance production; (4) integrating human behavior by monitoring and modeling people's responses to management decisions about special forest products; and (5) conducting necessary inventory, evaluation, and research monitoring.

Integrating these considerations into management decisions can appear overwhelming at first glance. Adopting the premise of a continually adapting management system clarifies the process for managers and the public. Activities in special forest products management do not proceed in linear order. Instead, information generated from one activity improves knowledge and refines direction in the other management activities. In this section, we discuss management activities derived from these considerations and how they interact. We conclude by illustrating an example of adaptive strategies for ecosystem management of commercially harvested forest fungi.

Understanding the Unique Biology and Ecology of Special Forest Product Species

The numerous native plant and fungal species of commercial value in the Pacific Northwest perform myriad critical functions in forest ecosystems. Yet, to harvesters, each species has the property of a "product unit." To resource managers each species has the property of a "resource unit." Each individual also functions as a population member, a community member, and an ecosystem member (Allen and Hoekstra 1992). All these properties and values must be considered as we develop models for managing special forest product species. Biological and ecological factors important for modeling the productivity of these species include population dynamics, regenerative ability, life cycle, genetic structure, effects of herbivory and disease, and response to site variables such as overstory canopy conditions.

Plant and fungal species of current economic importance in the Pacific Northwest are described in Molina et al. (1993), Pojar and McKinnon (1994), Schlosser et al. (1992, 1993), and Thomas and Schumann (1993). It is beyond the scope of this chapter to describe each special forest product species, its commercial value, and the biological implications of harvest. Instead we discuss three important groups of special forest product organisms-mosses, understory plants, and fungi-as examples of how the biology and ecology of these species affect their roles as ecosystem components and economic products.

Moss harvest involves the removal of entire communities of bryophytes (moss and liverworts) growing in a harvest area. The most commercially desirable moss grows on trees. A single vine maple stem may carry as many as a dozen moss and several liverwort species (N. Vance unpublished data). Traditional markets for mosses in the Pacific Northwest have increased steadily since the 1980s as demand for commercial-quality moss growing in the Coast Range has risen dramatically. The Siuslaw National Forest, for example, has issued permits for the harvest of 25,000 bushels of moss annually since 1989. Illegal harvest is believed to be at least that much. Harvesters removed an unknown quantity of biomass from public lands before harvest restrictions were imposed and before any program for research and monitoring could provide data for determining sustainable harvest levels. With the imposition of restrictions on moss harvest through permits, quantities requested are exceeding the amount harvested on Bureau of Land Management, Forest Service, and State of Oregon lands (N.Vance unpublished data).

Although research on the ecology of bryophytes in the Pacific Northwest has examined distribution and biomass (Coleman et al. 1956, McCune 1993), it has not addressed human disturbance or population depletion. Species have been well identified taxonomically and have been morphologically characterized (Pojar and MacKinnon 1994, Vitt et al. 1988). At least 30 to 40 bryophyticspecies are commercially harvested for packing material in the horticultural trade and for decoratives in the floral greens industry. The Pacific Northwest coastal region, with moderate temperatures and high precipitation, favors moss growth and diversity. The fog zones of the Coast Ranges support luxuriant moss growth and therefore undergo concentrated harvest. Bryophytes may take 10 or more years to reach preharvest biomass and diversity levels, depending on species, intensity of harvest, and environmental conditions.

The impact of commercial harvest on the functional role of mosses in coastal ecosystems is not well known. Moss species such as *Hylocomium splendens* can be monitored as one measure of change in forest conditions (Wiersma et al. 1987). They serve as important bioindicators of air quality because of their ability to incorporate airborne pollutants such as sulfur dioxide and nitrous oxide (Ferry et al. 1973). A large portion of commercially harvestable moss is in late-successional habitat within the range of the northern spotted owl and the marbled murrelet. One coastal forest species, *Antitrichia curtipendula*, associated with nesting sites for the marbled murrelet and red tree vole, is particularly susceptible to air pollution (USDA Forest Service 1994).

A second group of special forest product species is understory plants whose occurrence and productivity are strongly affected by forest development. For example, three important species-salal, Oregon grape, and sword fern-are common in plant associations within the western hemlock zone where Douglas-fir has been intensively managed for timber production. Foliage from these understory species has been harvested over the past 50 years for use in the floral greens industry (Schlosser et al.1992).

Silvicultural treatments that alter densities of tree canopies may enhance growth and composition of some understory species and diminish that of others. When the overstory canopy is dense, understories are poorly developed. In that case, opening the canopy should increase understory cover and species richness. However, if understory species are established in young stands that have partial canopies, increasing openings in the canopy favors species that respond best to increased sunlight. Salal, bear grass, and Oregon grape require more light than sword fern and should benefit from moderate thinning of the overstory to prevent a dense canopy (Huffman et al. 1994, Schlosser et al. 1992).

Overstory conditions affect the product quality (growth form and appearance) of desired understory species as well as their biomass. Floral markets require that commercially desirable foliage of these species have deep green color and no blemishes. Understory plants with the highest value grow predominantly under a partial canopy (Schlosser et al.1992). Producing plants with these desired qualities is difficult because conditions in young stands change considerably over comparatively short periods. Experienced foragers rely on dependable sources of high-quality product and often prefer to harvest in late -successional forests with more stable canopy structure.

Forest fungi form a third group of special forest product species with unique biological features and ecosystem attributes. The body of most fungi consists of one-cell-wide threads, or hyphae, (collectively know as mycelium) that grow in soil, organic matter, or host organisms, where they are hard to observe without destructive sampling. The mushrooms or truffles (collectively called fruiting bodies or sporocarps) are the reproductive portion of the fungus. Many of the commercially valuable edible fungi depend on and are important to the health of host trees because they are mycorrhizal-that is, they form distinctive fungus-root structures. The fungus transfers water and mineral nutrients to the tree, and the tree provides the fungus with carbohydrates as an energy source produced through photosynthesis. When all trees are harvested, the associated fungi die in the soil and sporocarp production ceases (Amaranthus et al. 1994). Complete removal of all host trees therefore will have immediate impact on commercial harvests of mycorrhizal fungi such as chanterelles and American matsutake.

Fungi usually fruit during a particular and a limited season, and sporocarp production varies greatly from year to year, much like cone crops on forest trees or fruit crops in domestic orchards. Within the season, fruiting often depends on local weather patterns. A given sporocarp may persist for only one to six weeks, changing in size, maturity, and commercial value, and may be eaten by wildlife or collected by humans. Frequent sampling is required to reliably characterize fruiting patterns and commercial value of a mushroom crop. Mushrooms are often clustered and unevenly distributed on all spatial scales, from local sites to drainages, landscapes, and regions. Uneven distributions require large sampling areas to derive statistically sound estimates of abundance. Relative abundance of a species's sporocarps does not necessarily reflect the importance of that fungus to host trees or the ecosystem, but fruiting-body production is the measure of human interest for managing edible fungi as special forest products.

Forest Community Dynamics and Landscape Considerations

Bormann and Likens (1979) describe the eastern U.S. hardwood forests as a shifting mosaic of irregular patches differing in composition and age and directed by processes of disturbance, growth, and decay. This way to envision natural forested landscapes is also relevant to the Pacific Northwest. Most special forest product species are adapted to disturbances that have been a normal part of their evolutionary history. Far from being a negative factor, these natural events tend to renew and diversify populations. As examples, morel mushrooms flourish after fire, and other special forest product understory species, such as salal and Oregon grape, benefit from canopy openings created by tree-root pathogens or windthrow. However, we poorly understand disturbance effects on most special forest product species. Disturbances that differ in type, frequency, or severity from historical patterns may significantly alter the abundance and quality of special forest product species. Adaptive ecosystem management of special forest products identifies the disturbance and recovery processes that sustain these species, examines impacts from timber harvest and other forest management activities, and adjusts activities in response to monitoring information and social goals.

The habitats occupied by special forest product species are characterized at the landscape scale by (1) different major forest types, (2) different successional stages within a given forest type, and (3) distinctive subcommunities such as riparian zones. Species typical of particular habitats often differ from one another in life history characteristics in ways significant to management strategies. Many early successional species are opportunistic generalists that grow rapidly and disperse widely. Compared to early successional communities, a higher proportion of late-successional species have life-cycle characteristics of more stable environments. Landscapes dominated by older forests are generally heterogeneous, or mosaics, with regard to the age classes and species that they contain. This mosaic quality provides habitat for a wide range of special forest product species. The primary objective of a landscape approach for special forest products is to create or maintain a socially desirable and ecologically sustainable mix of habitats and special forest products within an area.

In coniferous forests, most species occur in the early successional, shrub-forb-sapling stage and in the late successional, old-growth stage; the fewest species find suitable habitat in the middle, the closed canopy stages (James and Warner 1982, Meslow 1978, Thomas et al. 1979). Intensive forest management for wood production focuses on the middle, least-diverse stage. Achieving full site occupation by commercial timber species shortens the time in early succession, although. with short rotations the total amount of early successional habitat may actually increase at the landscape scale. Young stands furnish the stocks for the Christmas greens market. Dense canopies of short-rotation forests, however, can hinder development of many understory species harvested as special forest products. Harvesting trees when the mean annual increment culminates eliminates the unique ecological conditions of the old-growth stage. Species such as Pacific yew and mosses occur in greatest .numbers and reach full development under the multiple canopy layers and big trees of old-growth forests.

Riparian zones are especially critical for many special forest product species. Substrate composition, soil moisture, nutrients, depth to water table, temperature, radiation, and disturbance frequency differ from upslope positions. Gravel bars, islands, and flood plains provide a habitat mosaic for a wide array of plant species and often contain distinctive associations-for example, hardwood tree species that contain mosses. Fallen trees in riparian areas contribute to structural complexity, and patches of herbs, shrubs, and deciduous and young coniferous trees produce a multilayered canopy. Openings over streams, lakes, and wetlands provide gaps and breaks in the forest canopy that promote favorable conditions for berry shrubs and ferns. Riparian plant communities also have a higher survival rate than those of nearby hillslope areas during catastrophic wildfire (Michael Amaranthus unpublished data) because higher humidities, cooler temperatures, and damper soils adjacent to streams and lakes help protect the vegetation. Special forest product species in these areas become sources of propagule dispersal for recolonization of upslope areas after fire.

An important first step in considering special forest products at the landscape scale is identifying areas with high commercial production potential or that require protection from harvesting. For example, areas with high production potential and convenient harvester access might be managed for intensive special forest product production to relieve harvesting pressure on sensitive areas. Wetlands or habitats of rare plants or animals may need harvest restrictions. Areas prone to surface erosion or mass failure might need protection. No-harvest areas may be needed to monitor effects of harvesting, and rotated harvest areas could be used to avoid unsustainable harvests and resource depletion. The inventory, monitoring, and research activities discussed below will be essential to identify specific areas for enhanced production or protection.

Silviculture and Vegetation Management Approaches

Stand-level silvicultural objectives can emphasize conditions favoring certain special forest product species. Various approaches may be used to manage for a broad range of products: posts, poles, rails, landscape transplants, shakes, cones, yew bark, boughs, mushrooms, berries, forest greens, and other special forest products. For example, leaving a cover of large trees after timber harvests (green-tree retention) allows two or more canopy layers to develop and provides shade needed by some special forest product species. The numbers of retained trees may differ depending on the needs of the special forest product species, on the ecological adaptations of the particular forest type, and on other management objectives.

Density control is an important tool for providing special forest products and diversifying forest stands (Newton and Cole 1987). Thinning of dense stands can produce posts, poles, rails, and firewood as products. Growing stands at wide spacing allows some special forest product plant species to coexist with specific timber species. Thinnings, coupled with rotation length, can be used to manage the proportion of different seral stage habitats within a landscape. For example, forests can be moved from an early successional structure to an old-growth one without ever passing through a closed-canopy stage. Careful felling and yarding practices and repeated entries are necessary, however, to minimize damage to special forest products.

Other options are available to improve production of special forest products at the stand and landscapes levels. The options might include prescribed fire for habitat rejuvenation for some species; seedbed preparation, direct seeding, and planting of special forest product species; fertilization; and avoiding introduction of exotic or unwanted species.

Integrating Human Behavior

Managers base decisions for adaptive management of special forest products on monitoring present conditions and modeling future alternatives based on best available information. Most discussions of monitoring and modeling ecosystems refer to the behavior of species and processes other than of humans and their actions. Yet, human behavior, perhaps the most complex and difficult to project and predict, plays a key role in the development of most ecosystems. Adaptive management of special forest products must expand to include detailed monitoring of the outcomes of current local human activity on the productivity and structure of ecosystems. Results of different, often innovative, management regimes involving harvesting and culturing of special forest products serve as a record for the knowledge base of the adaptive management system. Monitoring databases (continually supplemented with new data) and data analyses (continually transformed as new infororation is available) enables managers to better decide how to set sustainable harvest amounts and rotation lengths for special forest products.

Conversely, differing harvest levels of special forest products affect individual and community well-being. Here, explicit definition of the interest groups and communities in managerial decision making becomes vital. Management decisions at different scales (local, regional, etc.) also differently affect the well-being of specific segments of the human community. The distribution of effects on people from decisions initiated at a local geographic or ecosystem scale is usually not only local, for example. Many people employed in special forest industries, such as matsutake picking, are not residents in or near the ecosystems where the mushrooms are picked (Richards and Creasy in press). Surprisingly disjunct groups can be simultaneously affected. Managers must anticipate the effect of regulation on harvester behavior and implement regulations that result in behavior most consistent with well-thought-out objectives (R. Fight, personal communication, 1995). Monitoring total effects of management decisions on human responses in harvesting levels and benefits, both individual and collective, can easily become formidable.

Uncertainty about the soundness of management decisions regarding special forest products is great because objective measures of fairness, sustainability, and social or economic health are difficult, if not impossible, to determine. Definitions of human constraints change as society's values change over time. Given the many possibilities for harvesting across different spatial scales and the increasing number of people who participate in or are affected by harvests of special forest products, monitoring actual management practices in the existing landscape cannot cover the entire range of plausible alternatives. In many instances, particularly under conditions where adaptive management encompasses innovative management as an experiment, there may be no precedent with an attendant monitoring database to substantiate desired outcomes. The demand for innovation and new options suggests that managers should invest considerable effort in building forecasting models.

Organization of the best existing information is necessary for creating forecasting models to predict outcomes. Goals of specific scenarios for future management of special forest products should be clear. Traditional as well as new institutional arrangements for resource access and management, harvest levels, product prices, wages, and targeted interest groups are key variables for predicting future outcomes of the soundness of the management decisions. Scenarios offer insights into the distribution of benefits and costs of outcomes, but final decision making remains a singularly human choice, based on professional judgment. The continuous flow of information about current attitudes and values, and likely trends for both, can aid in making the best decision. Investing in information and information organization is costly, and benefits may not be easily linked by cause. The tradeoff is to acquire the least costly amount of information that will satisfy society and reduce dissension among interest groups involved in special forest product industries.

Conducting Necessary Inventory, Evaluation, and Research Monitoring

We are still learning how ecosystems work, and we will be for the indefinite future. Thomas Berry (1988) summed it up succinctly: "What is needed on our part is the capacity for listening to what nature is telling us." It would be a much shorter list to mention aspects of managing special forest products in a sustainable way that do not need monitoring and research rather than those that do. We do not attempt either. Most forestry research during the past decades has focused on forests managed intensively for wood, while most ecological research has focused on pristine forests. Our ability to sustain harvests and populations of special forest product species will require increased research on the ecology of managed forests. Similarly, because socioeconomic research in forestry has focused on timber market forces and timber-dependent communities, new socioeconomic research efforts are needed on specific special forest product markets and publics. Thus, ecological research will determine the role of special forest product species in an ecosystem context, and product market research will define the role of special forest products in society. The final section of this chapter provides a detailed example of integrating research and monitoring approaches for these disciplines.

Adaptive Ecosystem Management of Commercial Mushroom Harvests

Good information and the logical organization of it are the bases for human decisions on complex phenomena. Commercial mushroom harvesting exemplifies how information required for ecosystem management of a special forest product can be obtained in a stepwise, logical manner. This example presents a conceptual framework for (1) identifying concerns of managers and the public about commercial mushroom harvesting, (2) choosing appropriate studies to address those concerns, (3) designing those studies, and (4) adapting information thus obtained to, the needs of management. This approach generally applies to any special forest product. The effort expended should be commensurate with the anticipated harvesting impacts.

The first step in adaptive management of a specific special forest product is estimating whether harvesting activities are sufficiently extensive (widespread) or intensive (concentrated) to be economically or ecologically significant. For example, the demand for wild mushrooms is large and the impact of harvest on ecosystems significant (Molina et al. 1993, Schlosser et al. 1991, Schlosser and Blatner 1993, Schlosser and Blatner in preparation). Many edible species are mycorrhizal, and their symbiotic association with tree roots plays a key role in forest productivity and nutrient cycling. Commercial collection of mushrooms is also socially significant because substantial competition exists among harvesting groups, such as local residents, transient harvesters, Native American tribal members, and recreational pickers (Lipske 1994). Managers must sort out the interests of these competing groups to anticipate problems, reduce conflict, and provide equitable use of the resource.

Educating managers and their constituent interest groups is equally essential. Literature searches (von Hagen et al. in preparation), published summaries of current knowledge, and counsel and opinions from experts are among the avenues for improving and supporting interim decisions when time or fiscal resources do not permit acquisition of high-quality scientific knowledge. Regrettably, political or social pressure often necessitates managerial action in the absence of adequate data. Communication of relative expectations is an important component of public education. Respect for the diversity of opinions about harvesting fungi means that no one interest group is likely to have all their expectations fulfilled.

Only a portion of knowledge about forest fungi applies to managing commercial harvests. Few mycological studies in North America have focused on marketable species. Incorporating monitoring activities into ecosystem management offers one way to ensure that good science feeds rapidly into the decision-making process. Studying harvests of commercial mushroom species informs both users and managers about the impacts of harvests on ecosystems and on economies. Several considerations apply to commercially collected fungi, especially to the predominant commercial species in the Pacific Northwest: American matsutake, morels, chanterelles, Boletus mushrooms, and certain truffles. The following questions confront ecosystem managers as they regulate commercial mushroom harvests.

1. *Production and distribution of mushrooms as special forest products*. How many fruiting bodies are being produced? How are they distributed across the landscape or within certain habitats? How does production differ during a season and from year to year? What is the actual or potential commercial productivity of a given area? What proportion of forest habitat is available and accessible for economically efficient harvesting? What factors determine productivity, and how might they be managed? What managerial actions can alter accessibility of the resource to meet management objectives? How does landscape design promote or impede ecological sustainability of biological production and economic harvest?

2. *Mushroom harvesting by people*. How can the sustainability of mushroom harvesting be assured? What proportion of the crop can be harvested without unacceptable impacts on the fungus itself or other resources? What techniques will mitigate those impacts? Does mushroom harvesting increase or decrease subsequent production? Is spore dispersal reduced by removal of immature mushrooms, and does it impair reproductive

success? Are fungal mycelia and subsequent mushroom production affected by search and harvest techniques such as raking, moving woody debris, or digging? Are mushrooms harmed by numerous harvesters trampling the forest floor? How important as food for wildlife are commercially valuable species, and is human contpetition for the resource significant? What is the demand from various markets for wild mushrooms? How will various management scenarios affect jobs, income, and revenue? How does commercial harvesting affect the relationships (for example, competition and potential conflict) between recreational and commercial harvesters?

3. *Land management decisions*. How do various timber harvesting methods (clearcutting, thinning to various densities, selection of host species) affect subsequent mushroom production over time? How does soil compaction or disturbance from logging activities affect fungal populations? How does the intensity and timing relate to subsequent mushroom production, especially for morels? How do grazing, fertilization, or pesticide application affect production? Can mushroom production be improved through habitat manipulation-for example, planting tree seedlings inoculated with specific fungi, thinning understory brush for sunlight and rainfall penetration, prescribing burns, and irrigating? Can production be increased across the landscape by managing forests to attain tree age class, structure, and composition optimal for fruiting? What types of cost-benefit analyses are needed to help managers decide about managing for special forest products within broad multiple-use objectives? Can ecologic-economic models be developed to support socially acceptable land management decisions?

4. *Biology and ecology of mushrooms as ecosystem components*. What are the important reproductive events in the life cycle of a particular species? How are new colonies or populations established and maintained? What causes them to diminish or perish? How important is spore dispersal to reproductive success, population maintenance, genetic diversity, and adaptability to unique microhabitats? How much genetic diversity exists within and among populations? Are there endemic, narrowly adapted, or unusual populations of otherwise common species? What are the growth rates of fungal colonies in soil and the degree of mycorrhizal development by specific fungi on root systems? To what degree do other mycorrhizal or saprophytic fungi compete with desired fungi for colonization sites on host roots or for space in the forest soil?

Gathering information, analyzing data, and developing adaptive ecosystem models require various investigative methods. Federal land management agencies group these methods into categories of detection, evaluation, and research monitoring.

Detection monitoring addresses the concerns in category one: production and distribution. It encompasses inventories or estimates of production that are repeated periodically to detect trends. Sampling methods may include (1) informal walk-through surveys designed to detect widely scattered populations, (2) weighing commercial collections from defined areas, or (3) systematic sampling regimes using transects or plots. Methods designed for inventories of plants or animals must be modified to meet the constraints of ephemeral, sporadic, and unevenly distributed fungal sporocarps. Some of these considerations are quite pragmatic. For instance, how do personnel frequently sample the same site without causing soil compaction or erosion? At what stage in its development should a mushroom be sampled? Should it be picked to measure weight, and if so, will that influence subsequent fruiting? If size is measured, how should the mushroom be marked for later identification? Forest mycologists are currently developing practical field procedures.

Managers also need to collect baseline social and economic data during this initial monitoring phase to assess the extent of the harvest issues within defined land bases. Variables include the community affiliations of the harvesters and the relative importance of revenue derived from special forest product harvest; the importance of commercial harvesting to local (e.g., rural) and regional economies; price signals and long-term forecasts for market demand; the importance of specific land bases for sustaining the special forest product market; the numbers of harvesters frequenting specific sites and the managerial effort needed to facilitate commercial harvests; and demands from other user groups such as recreational harvesters. Such information can be collected by managers as part of the regulation and permit system, by interviewing and surveying distributors, and by holding meetings of involved publics.

Evaluation monitoring assesses the impact of management practices and scrutinizes trends in detection monitoring; it applies to the second and third categories of concern: mushroom harvesting and land management. Examining the ecological impact of mushroom harvesting involves comparing experimental treatments. Researchers delineate recurring patches or constellations of mushrooms and then randomly assign replicated treatments, such as picking, not picking, raking duff, digging, trampling, or irrigation. The increase or decrease in sporocarp production from the treatments is compared. Similar experimental designs can be used for determining the influence of land management activities on mushroom or truffle production, but adequate replication requires expensive, stand- or landscape-level research projects. These are most cost-effective if they integrate numerous related studies.

Examining the sociological and economic impacts of management decisions requires analysis of changes in human economic behaviors, particularly how quantities harvested and accessibility to the resource affect personal, community, and market economies. Whether management objectives were achieved and considered fair by the involved publics must be considered along with the management efforts (e.g., costs) deemed commensurate with benefits to the public. Managers can develop large-scale commercial harvest experiments to evaluate effects of trial harvest contracts and techniques on ecosystem and market sustainabihty.

Research monitoring examines the basic biological and ecological concerns listed in the fourth category. Studies of this nature usually involve establishing secure, longterm field study sites. These sites undergo intensive scrutiny and serve as a representative sample of conditions believed to occur within the region. Investigative methods may use a wide variety of specialized equipment and techniques. Examples include trenches to observe underground mycelium; weather stations to correlate fruiting with local precipitation patterns, temperature, or humidity; vacuums or slides for spore collection; laboratory culture of fungi and mycorrhizal compatibility trials with selected host seedlings; microscopic examination and descriptions of mycorrhiza form, structure, and development; and various recently developed molecular techniques for genetic analysis.

Access to inventory and monitoring data is essential for timely and cost-effective decision support. Managers now have access to new technologies that facilitate the use of large amounts of information for analyzing ecosystem interactions and processes. Published information is available from library databases through Internet access. Mushroom distributions and abundance can be added as data layers to already sophisticated geographic information system databases. Precise field locations can be determined with global-positioning-system satellite receivers. Systems-modeling software allows managers to create contingency scenarios from matrices of alternative management options (Bormann et al.1994). On-line expert systems can lead users to appropriate information or suggest pertinent considerations. These technologies are in various stages of development, but all are likely to become increasingly important to managers who need to consider the ecosystem ramifications of harvesting special forest products like mushrooms. The information these tools provide will help managers justify their decisions and implement adaptive modifications when new information becomes available. This thoroughness and flexibility is especially useful when managers need to balance the interests of competing or conflicting user groups. Although the task of managing special forest products in an ecosystem context is daunting, the means are becoming increasingly available. Successful integration of special forest products into ecosystem management will succeed only if managers, policy makers, and the public are committed to that goal.

Acknowledgments

We appreciate the sharing of ideas and critique of the manuscript from Keith Blatner, David Brooks, Beverly Brown, Roger Fight, Jeff Gordon, Karen Esterholdt, Richard Haynes, Leon Leigel, Les McConnell, Mike Rassbach, Mark Savage, James Trappe, Nancy Turner, and Nancy Wogen. Support from the Cascade Center for Ecosystem Management is likewise appreciated.

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