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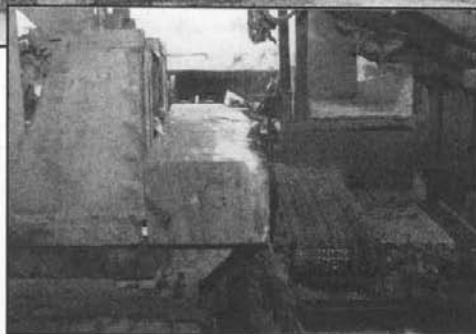
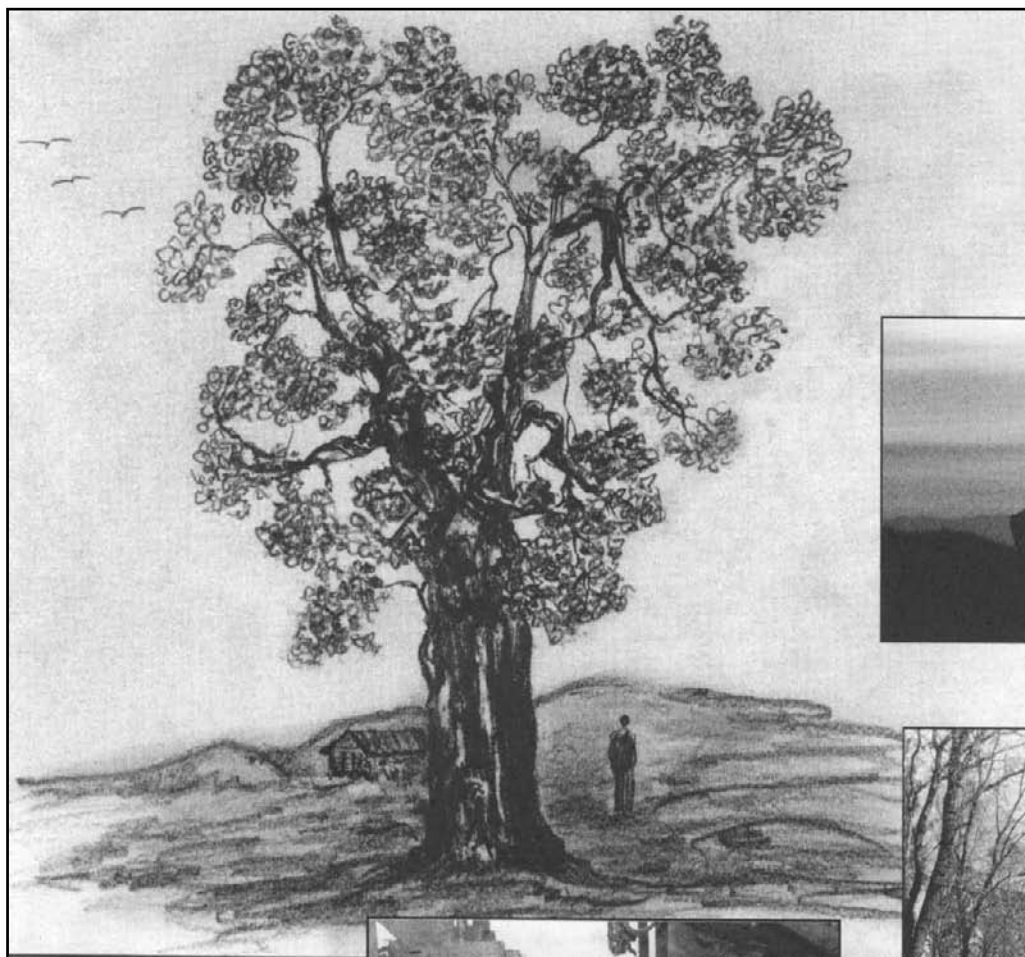
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California's Hardwood Resource: Managing for Wildlife, Water, Pleasing Scenery, and Wood Products

Philip M. McDonald Dean W. Huber



Abstract:

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A new management perspective that emphasizes a variety of amenities and commodities is needed for California's forest-zone hardwoods. For the near future and perhaps more on public than on private land, these "yields" are wildlife, water, esthetics, and wood products. Each is presented first as an individual yield and then as part of a combined yield. As an individual yield, water, for example, might have great utility for a power and light company desirous of filling its reservoirs; as a combined yield, the worth of water for wildlife, tree growth, and esthetics also is high. Managing the hardwood forest for these yields requires some special considerations. Foremost is to consider all of the yields in an ecosystem setting with special regard to managing larger areas for longer timeframes. Within this setting are several factors central to a new perspective for managing hardwoods. These include the need for a well developed hardwood processing industry and the expanded role of silviculture. Teamwork, scheduling, social considerations, and total yield also are included and then incorporated into the special management situations of agroforestry and the urban interface. Some guidelines and recommendations are then presented to further management of forest-zone hardwoods in California in the 21st century.

Retrieval Terms: California forest-zone hardwoods, esthetics, management, water, wildlife, wood products

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Cover: California's forest hardwood ecosystems provide amenities and commodities to many people. In descending order, the water represents the lifeblood of the land and the biologically rich and diverse riparian zone (Frank Kratofil photo); the elk, the wild and the free (Frank Kratofil photo); the leaf-lined road, the peace and beauty of the fall landscape; and the hardwood cant, the security of stable jobs in rural America (Cal Oak Company photo). Line drawing by Connie R. Gill, public affairs specialist, Pacific Southwest Research Station, Redding, California.

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California's economically promising forest-zone hardwoods can be found from the Oregon state line almost to the Mexican border, and from near the Pacific Ocean to the Nevada state line. Within California, they grow well to an elevation of about 7,500 feet and form many ecological types as pure hardwood stands, as components of mixed hardwood and conifer stands, and as occasional trees, clumps, and groves within the conifer forest. Stands of hardwoods are usually scattered across the landscape and seldom occupy extensive areas. As broad sclerophylls, the hardwoods have developed a host of physiological and morphological adaptations that have allowed them to compete, prosper, and reproduce their kind for millennia.

As a resource, the inventory of hardwood trees is huge, contains every size class and structure possible, and currently has a net increase as burgeoning hardwood sprouts capture cut-over land formerly occupied by conifers. There is even a high proportion of old-growth trees. More than 300 species of birds and animals call the hardwood ecosystems "home," many people enjoy the contrast and beauty of the hardwoods in spring and fall, and many acre-feet of water come from the hardwood forest. In terms of the total potential worth of amenities and commodities on public land, the near-term value of hardwoods is manifest in wildlife, water, pleasing scenery, and wood products. On private land, the need to supply an ever-increasing amount of wood products could mandate that wood fiber be the primary yield. Water could well be a commodity of great worth in California in the near future on both ownerships. For public and private land, management is not limited by gaps in the resource base; rather it is challenged by the enormity of it all.

The forest-zone hardwood ecosystems in California are variable, widespread, and highly complex. Managing these ecosystems for sustainable yields and values brings concerns for the land and for human beings together. People and their effect on the land are an integral part of ecosystem management.

The art of silviculture has a bright future on both public and private land. Ecological types, or habitats in the case of

wildlife, will need to be maintained, prolonged, and created. It will be silviculturists who will do this over a broad range of space/time scales. To achieve both ecological diversity and rural community stability, silviculturists will manipulate individual species on small plots of land for a short time and sustain complex plant and animal communities over 100,000-or-more-acre landscapes in perpetuity. They also will intensively manipulate hardwood stands to achieve spacing and density levels that will yield optimum levels of wood fiber and water. The wood has value that is maximized when processed into useful products. A stable and dynamic wood products industry is a critical adjunct to silviculture, which in turn is a critical part of ecosystem management.

Each yield has value individually. For wildlife, the greatest value of the hardwoods is the acorns and berries that they produce. The frequency and magnitude of acorn crops, for example, is critical to fawn survival rates and ultimately to the size of the deer population. For water, deciduous hardwoods use 20 to 30 percent less water than evergreen conifers, and manipulating hardwoods to enhance streamflow has much promise. For pleasing scenery, the vivid and contrasting spring and fall color of hardwoods is without peer. For timber and wood products, the potential uses are numerous. With proper treatment, hardwoods can be manufactured into specialized and traditional products such as toy blocks and odor-free food storage cabinets as well as into classic lumber products and veneers.

For multiple yields, hardwoods can achieve their true potential as producers when some key factors, such as teamwork, scheduling, social aspects, and total yield, are addressed. Future management of the vast hardwood resource is too much for one person, and innovative teams of scientists, managers, and other stakeholders must be formed to formulate policy and solve problems. Ecological risk taking and flexibility will be keys. Scheduling is extremely important for managing the hardwoods, because it permits field jobs, raw materials, manufacturing and service jobs, and products and amenities to flow from the land in a predictable manner for the benefit of all. The variable nature and extent of the hardwood resource allows it to serve people as individuals and in towns and small cities in rural America. Special "forests" in urbanized and agricultural settings can serve America as well. Once all the goods and services that come from the hardwood resource are given a realistic value, below-cost timber sales and most amenity enhancements, which also rarely pay their way, will be a thing of the past.

Opportunities abound for managing hardwoods for multiple yields. In general, good wildlife management is good timber management as well as good management for esthetics and water. It cannot be emphasized enough that the total worth of carefully grown forest hardwoods, particularly if deciduous, is maximized with large trees.

Introduction

Native hardwoods in the forest zone of California and southwest Oregon constitute a huge natural resource that is scarcely used for lumber and wood products and inadequately managed for other valuable resources such as wildlife, water, and esthetics. Huber and McDonald (1992) presented 22 reasons for failure of a sustained hardwood industry to develop. McDonald and Huber (1994) addressed each of these and noted progress on many of them over the past 18 years. Based on this progress, it is likely that a viable hardwood industry will develop in California and Oregon in the near future. This is important, because a well developed, sustainable wood products industry is vital for future silvicultural manipulation, which in turn is critical for future ecosystem management.

Of special note in the publications by Huber and McDonald (1992) and McDonald and Huber (1994) was the acknowledgment of some realities--the most striking of which was that California hardwoods and hardwood ecosystems never really had a management philosophy, let alone some guidelines. It was not that no ideas or management possibilities had been put forth. Edwards (1957) and Roy (1962) produced articles that sketched what little was known on the silviculture-ecology of California hardwoods and made a few tentative management recommendations. In 1978, McDonald presented silvicultural and ecological results from an extensive study on a high site in the northern Sierra Nevada. He also noted, "studies involving other disciplines [wildlife and water] show great promise," and suggested that many benefits could be realized by silviculturists, hydrologists, and wildlife biologists working together. Later, Tappeiner and McDonald (1980), Plumb and McDonald (1981), and McDonald and Tappeiner (1987) put forth more detailed management recommendations based on an increasing amount of new ecological and silvicultural information. Although they acknowledged that wildlife and esthetic considerations were important, the emphasis of hardwood management was primarily for timber and wood products. This changed in the early 1990's with wide recognition that the widespread and complex hardwood ecosystems had value far beyond wood products. Wildlife, water, esthetics, and wood products were where the total value in amenities and commodities from forest-zone hardwoods was manifest (McDonald and Huber 1994), at least on public land. Wood fiber and water production rated high as potential yields from private land.

On nearly all forest land in California, regardless of ownership, some daunting problems need to be addressed, perhaps in concert with ecosystem management. These are the large amount of fuels and fuel ladders that have built up from decades of fire suppression, California's burgeoning human population, and pressure on all natural resources by these people and their recreational needs. The odds of catastrophic fire have increased to the point that large

investments in natural resources are being questioned. California's 30 million people need not only commodities, but "a place to get away from it all." As ecosystem management progresses, consideration of these problems will need to be in the forefront of work to be done.

Managing hardwoods for the benefit of wildlife also has long been advocated, but particulars are sketchy. Early authors (Leopold and others 1951, Robinson 1931) stressed the need for sound principles for developing the wildlife resource, but not until recently have strategies for actually managing habitats for wildlife been presented. Probably the most comprehensive of these is the California Wildlife-Habitat Relationships (WHR) System, as described by Mayer and Laudenslayer (1988). Although not specific to hardwoods, Ohmann and Mayer (1987) and Verner (1987) also noted the need for identifying, inventorying, and assessing wildlife habitats in California. Verner (1987) lists six critical research needs that include studying wildlife habitats, monitoring wildlife trends, and developing more and better models for determining wildlife suitability, habitat relationships, plant succession, and the effect of fragmentation. These suggest some of the components that should be incorporated in managing hardwoods for wildlife.

Guidelines for managing California forest-zone hardwoods for esthetics scarcely exist. Although hardwoods generally are acknowledged as contributing to the variability and contrast of the forested landscape, rarely are they given special emphasis.

Of the four major uses of California's forest-zone hardwood resource, the one currently with the least emphasis is water. In fact, it is scarcely recognized that more water in the form of streamflow comes from a deciduous hardwood forest than from an evergreen forest, be it hardwood or conifer (Swank and Douglass 1974, Urie 1977).

Plainly, the four major uses envisioned for forest-zone California hardwoods have no comprehensive management perspective and few guidelines. Although the need has been stated many times, only the most tentative recommendations are available. What is needed is a unifying management philosophy that emphasizes a variety of yields and the management perspective and guidelines that support it (McDonald and Huber 1994).

This paper presents that philosophy, which of necessity is forward looking and not always based on tangible literature, to all people who have an interest in native California hardwoods and who need assurance that the near future will not be chaos. This paper also discusses the factors making up the management perspective (McDonald and Huber 1994), adds new factors, and presents guidelines and recommendations for managing California's forest-zone hardwood ecosystems for wildlife, water, esthetics, and wood products. Each of the above yields¹

¹In this paper, "yield" is used in the broadest sense--broader than "use." It includes valuable intangibles such as the feeling one gets when walking among fallen leaves, seeing a deer, or feeling the moisture and coolness from a hardwood-lined stream.

is presented, alone and in many combinations, in a biological and social setting. New concepts of teamwork and social emphasis enlarge this setting and, together with the special applications of agroforestry and the urban interface, suggest that the complex hardwood ecosystems have great value in their own right.

The Hardwood Forest

Species and Distribution

California's indigenous hardwood resources can be divided into two basic groups: those that grow in the foothills and woodlands at lower elevations, and those that grow in the forest-zones at higher elevations. Only forest-zone hardwoods and, within this category, only those that are the most abundant and have a fairly large natural range are discussed in this paper. These include tanoak (*Lithocarpus densiflorus* [Hook. & Arn.] Rehd.), California black oak (*Quercus kelloggii* Newb.), giant chinkapin (*Castanopsis chrysophylla* (Dougl.) A. DC., Pacific madrone (*Arbutus menziesii* Pursh), California-laurel (*Umbellularia californica* [Hook. & Arn.] Nutt.), canyon live oak (*Quercus chrysolepis* Liebm.), and red alder (*Alnus rubra* Bong.). All of these species have an established history of utilization for wood products and other yields (Economic Development

Administration 1968), and as food and raw material for Native Americans (Baumhoff 1963) and for modern society (Wolf 1945).

Seldom do these hardwood species, alone or together, occupy entire mountain sides. Most often they are found as single trees, in clumps or groves, or occupying a given aspect in areas of up to 100 acres (*fig. 1*). Exceptions can occur, however, where extensive cutting and burning of conifer associates has allowed hardwood species to dominate over much larger areas. Seldom do each of these species grow in pure stands; rarely are all of them found growing together. In the Coast Ranges and Klamath Mountains, tanoak, Pacific madrone, giant chinkapin, and California-laurel often are associated with each other and with conifers, but only on the drier fringes are canyon live oak or California black oak found. Red alder tends to grow best in cool, moist environments, particularly as a colonizer of bare mineral soil after disturbance. In the northern Sierra Nevada, tanoak, Pacific madrone, and California black oak are associates, sometimes with scattered canyon live oak on poorer sites. On the east-facing slopes of the Coast Ranges, in northeastern California, in the central and southern Sierra Nevada, and the Transverse and Peninsular Ranges of southern California, California black oak and canyon live oak may intermix, but usually grow alone.

Arborescent forms of these species range from southern Coos and Douglas Counties, Oregon, southward through the Klamath Mountains and Coast Range to Monterey County, California. With the exception of red alder and California-

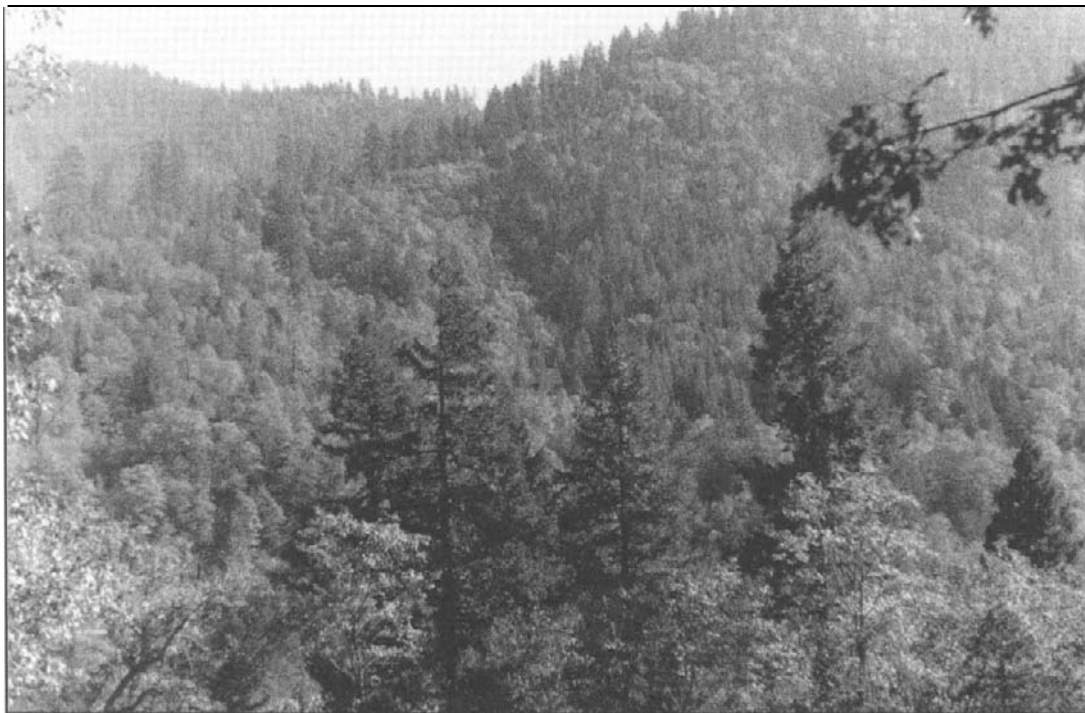


Figure 1—This landscape on a southwest aspect in northern California is clothed with hardwoods and scattered softwoods. It supports a high diversity of plants and animals.

laurel, they also extend southward through the Cascade Range and Sierra Nevada at least to Calaveras County. Canyon live oak and California black oak extend further south throughout the Transverse and Peninsular Ranges almost to the Mexican border (Griffin and Critchfield 1972). All of the hardwood species except Pacific madrone and red alder have a shrub form. In most instances, the shrub forms grow on poor or extremely poor sites and, in general, extend the species' natural range to higher elevations. Shrub tanoak (*Lithocarpus densiflorus* var. *echinoides*) does this also, but is found on good sites.

Just as the hardwood species seldom grow alone, rarely are they found without conifer associates. In the Coast Ranges, the most common conifer associates are Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) and redwood (*Sequoia sempervirens* [D. Don] Endl.); in the interior mountain ranges ponderosa pine (*Pinus ponderosa* Dougl. ex Laws var. *ponderosa*) is the most common with California white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.), incense-cedar (*Libocedrus decurrens* Torr.), sugar pine (*Pinus lambertiana* Dougl.), and Jeffrey pine (*P. jeffreyi* Grev. & Balf.) less abundant.

Woody shrubs that associate with the hardwoods discussed in this paper can be both few and numerous, depending on tree size, stand density, and seed availability. In general, high stand densities limit the diversity and abundance of shrubs, and beneath some stands shrub density and diversity approach zero. Some of the most abundant shrubs in the Coast Ranges include species in the genera *Rubus*, *Gaultheria*, *Rhododendron*, *Vaccinium*, and *Ceanothus*. In the interior mountain ranges, major shrub genera include *Arctostaphylos*, *Ceanothus*, *Rhamnus*, *Prunus*, *Castanopsis*, and *Adenostoma*.

Forbs and grasses, like the shrubs, vary tremendously beneath the hardwoods. They can be almost totally absent in the shade beneath dense stands or quite diverse and abundant in more open stands. In the Coast Range south of San Francisco Bay, an average of 36 species per site, mostly perennials, was found under the California-laurel canopy (Stein 1990). In the northern Sierra Nevada, five species, all perennials, were noted beneath dense California black oak stands. Density of two of these species, poison oak (*Rhus diversiloba*) and wood rose (*Rosa gymnocarpa*), was quite high in places. Together they ranged from 2,000 to 8,000 plants per acre.²

Inventory of Wood, Wildlife, Esthetics, and Water

A key to effective management is knowing how much inventory one has to work with, and its size, location, worth, and future prospects. In California, this information has been lacking for forest-zone hardwoods other than in local areas (Huber and McDonald 1992).

Recently (in 1985), an extensive and detailed inventory of hardwoods in California was produced (Bolsinger 1988), which is the source of the information on arborescent hardwoods in this section. And although far from complete, much better information also is available on the birds and animals that call California hardwoods home. Very little information is available on the inventory of pleasing scenery and water for forest-zone hardwoods.

In California's forest zone, hardwood types (where one or more hardwood species predominate) occupy 2.25 million acres; 0.4 million acres on public land and more than 1.8 million acres on private land. Almost all hardwoods are of sprout origin following fire or cutting. Hence, the hardwood forest of today consists of a mosaic of even-aged stands. Since 1945, the total area occupied by hardwood types has increased by about 760,000 acres (fig. 2). Tanoak and Pacific madrone are the species that make up most of this increase. They sprout from stumps of cut or burned trees and capture areas formerly occupied by conifers. In addition, individual trees, clumps, groves, and stringers of hardwoods occur in conifer types on about 4.5 million acres in many parts of the State.

Total growing stock volume of the principal forest-zone hardwood species in California in trees 5.0 inches in breast height diameter and larger in 1985 was almost 8.7 billion cubic feet with California black oak, canyon live oak, tanoak, and Pacific madrone constituting 92 percent of the total (table 1). Total sawtimber volume of the principal forest-zone hardwood species in California in trees 11.0 inches in breast height diameter and larger in 1985 was more than 5.0 billion cubic feet (table 1).

In hardwood types, and conifer types with hardwoods, the hardwood volume has increased substantially since the early 1950's, again as a direct result of logging practices and poor restocking by conifers. Hardwood growth rates have been higher than those for conifers, and mortality rates have been lower as well. Another reason for the increase in hardwood timber volume is that cutting has been but a fraction of total volume and growth.

A major attribute of California hardwoods is that much of the sawtimber volume is in trees greater than 29 inches at breast height. This is in strong contrast to hardwoods in the rest of the Nation where almost all trees in this size class have been harvested.

Implicit in the volume data is the fact that forest-zone hardwoods constitute a large, variable, and complex resource. Of extreme importance is that it is largely intact—unlike the current status of softwoods, every age and size class is present including large numbers of big, old-growth trees. Every structure is present as well, and individual stands, particularly if conifers are present, range from one to many stories. Tree density also exhibits a wide range—from one or two per acre to more than 700 per acre. The wide variety of sizes, structures, and densities gives managers virtually unlimited opportunities to maintain, create, or sustain every habitat or ecological type that they could possibly need. And when the conifer-hardwood

²Unpublished data on file, Pacific Southwest Research Station, Redding, California.



Figure 2—This sugar pine stump on cutover land is surrounded by young California black oak seedling-sprouts.

Table 1—*Growing stock and sawtimber volume by principal forest-zone hardwood species in California in 1985 (Bolsinger 1988)*

Species	Growing Stock		Sawtimber	
	Volume	Percent of total	Volume	Percent of total
	<i>billion ft³</i>		<i>billion ft³</i>	
California black oak	2.53	29	1.69	34
Canyon live oak	2.03	23	0.81	16
Tanoak	1.94	22	1.38	27
Pacific madrone	1.52	18	0.84	17
California-laurel	0.43	5	0.18	3
Alder	0.17	2	0.10	2
Giant chinkapin	0.05	1	0.04	1
Total	8.67	100	5.04	100

mixtures are included, and they too are numerous and varied, the total number of habitats is huge and their variety and potential for management is unlimited.

California's tremendous wildland diversity creates desirable habitats for more than 600 species of terrestrial vertebrates native to the State (Laudenslayer and Grenfell 1983). More than 300 wildlife species find hardwood-dominated habitats optimum or suitable for reproduction

(Ohmann and Mayer 1987). It is one thing to name the species, however, and quite another to state their numbers, to define their habitat, or to denote where that habitat is located. And given that habitats change on a seasonal basis and from year to year, the job becomes even more difficult. For wide-ranging species like birds and migratory species, defining and locating habitats is particularly daunting.

A major data base has been created and is being constantly updated by the California Department of Fish and Game's Wildlife-Habitat Relationships (WHR) System. Although not yet complete, an inventory of the State's wildlife habitats is well underway. Describing them in a manner useful to a wide range of planning and management objectives is an enormous challenge. Information must be provided for a great diversity of vegetative species and vegetation types. That many gaps characterize the vegetation data base does not help. A good start at generalized habitat descriptions tied to broad vegetation classes is provided by Verner and Boss (1980), who list individual wildlife species and put them into broadly described vegetation classes, and by Mayer and Laudenslayer (1988), who describe a wide variety of habitats and place specific wildlife species in them. Both present information that can assist the land manager in assessing potential impacts of land management activities.

How does one inventory the amount of pleasing scenery and catalog its worth? Various techniques have been attempted, mostly since 1965, to inventory forest landscapes by such means as high-altitude imagery, conventional air

stereophotography, low-level air reconnaissance photography with ground checking, and even simple sketches and field notes. From these inventories, descriptions have been derived that are used as a basis for judging landscape values and predicting visual impacts (Litton 1968, Litton and Tetlow 1978). Placing a monetary value on pleasing scenery has proven to be especially difficult as noted in *Searching for the Value of a View* by Magill and Schwarz (1989).

An inventory of the amount of water yielded from hardwood types in the forest zone is not known. What is known is that the citizens of California use about 42 million acre-feet of water annually (California Department of Forestry and Fire Protection 1988), with a predicted increase of 3.5 million acre-feet by the year 2010, primarily for domestic and industrial use, and to satisfy in-stream flow requirements.

Physical Environment

The climate of southern Oregon and California is best described as Mediterranean with long, hot, dry summers and cool, moist winters. For forest-zone hardwoods in the central Sierra Nevada, average January temperatures range from 33° to 41° F and average July temperatures from 62° to 75° F. Average annual precipitation varies between 30 and 68 inches, with little or no rain falling between mid-May and mid-September. The number of frost-free days ranges from 116 to 240 (McDonald and others 1983).

The moderate climate of the coastal mountains in southwestern Oregon and coastal California is characterized by more evenly distributed rainfall and fewer extremes of temperature than inland areas. Temperatures average from 41° to 50° F in January and from 57° to 73° in July. Average annual precipitation varies between 34 and 83 inches with the summer rainless period seldom lasting more than 30 days. Fog often is a moderating influence. Number of days free of killing frost ranges from 204 to 338.

Elevational ranges vary greatly. In the Coast Ranges of Oregon and California, the forest-zone hardwood species can be found from near sea level to 5,000 feet. In the interior mountains, the species grow in an elevational range of 600 feet in western Shasta County to about 7,800 feet in the southern Sierra Nevada. Geology of the area where these species are found is complex with volcanic, sedimentary, and metamorphosed rocks. All aspects are represented in topography that often is steep, rugged, and dissected by streams, canyons, and draws. The hardwood species are especially prevalent on the warmer and drier south and west aspects in the northern and central portions of the interior mountains, grading to north and east aspects in the mountain ranges of southern California.

Soils within the mountains where these species grow reflect a wide range of local climate, geology, parent material, and topography interacting over a long timespan. They range from deep, moist, fertile alluvium to shallow skeletal soils characterized by coarse texture, excessive drainage, and relative infertility. Most species, however, grow best on

medium to coarse-textured, deep, and well-drained soils. Canyon live oak grows on an extremely wide range of soils from the very best to the very worst, the latter consisting of rocks with a little soil between them.

Adaptation and Ecology

The forest-zone hardwoods described in this paper, with the exception of California black oak and red alder, belong to a worldwide class of vegetation known as broad sclerophylls. "Broad" refers to the typically wide leaves, and "sclerophyll," derived from the Greek language, means "hard leaves." It refers to specialized tissues in the leaves that reduce water loss. By definition, broad sclerophylls are evergreen and contain a large amount of sclerophyllous tissue (Cooper 1922). California black oak would qualify as a broad sclerophyll except that it is deciduous.

Broad sclerophylls and California black oak, because of millions of years of adaptation through natural selection (Chaney 1925), are extremely well adapted to a broad range of biotic agents and abiotic events (Cooper 1922, Keeley 1977, Kummerow 1973, Mooney and Dunn 1970). And the harsher the site, the better adapted they are. The adaptations are both morphological and physiological. Morphological features include special structures and coatings on leaves and stems to inhibit moisture loss, smooth upper-stem bark to facilitate the transport of water to the base of the tree, an extensive deep-thrusting root system, and capability to form a burl at or near groundline. The burl has at least two important functions: as a reproductive platform by virtue of its many dormant buds (from which sprouts arise) and as a food-storage organ. Physiological processes involve photosynthesis, transpiration, respiration, and water wasting, which govern plant metabolism, energy intake, water losses, and dominance potential (McDonald 1982).

A major limitation of hardwoods is tree height—sclerophyllous hardwoods do not grow as tall as conifer associates. Consequently, the hardwoods have developed at least five evolutionary strategies via specific adaptations that have allowed them to persist as species for millions of years (Chaney 1925). These are (1) ability to minimize water loss and to tolerate moisture stress, (2) capability to produce sprouts at a young age, (3) production of huge amounts of seed, (4) ability to protect plant organs and processes through physiological and morphological means, and (5) capability to waste water without serious consequences.

The first and perhaps the most important physiological adaptation of these species is their ability to regulate water loss at levels nonlethal to themselves and to tolerate drought at levels lethal to potential competitors. Leaves, stems, twigs, and roots all contain adaptations that facilitate this accomplishment, and physiological processes are geared to function efficiently at low moisture levels when necessary. The sclerophylls become physiologically active within hours or even minutes of the onset of favorable conditions. They have the capability to shift from a stressed condition with

essentially no photosynthesis to that of positive net photosynthesis soon after a moisture pulse.

Formation of a rudimentary burl at the root crown and capability to produce sprouts at a young age constitutes the second major adaptation by facilitating the species' capability to regenerate quickly after disturbance. The sprouts grow very fast and those of tanoak and Pacific madrone often exceed 5 feet in height after one growing season. After 10 years, sprouts of tanoak on a good site in the northern Sierra Nevada averaged 19 feet tall and 10 feet wide; those of Pacific madrone were 22 feet tall and 10 feet wide (McDonald 1978). Such robust growth almost guarantees reoccupation of the site after disturbance from fire or logging and gives the inherently shorter hardwoods the means to compete with the taller conifers.

All of the hardwoods discussed in this report sprout, and all produce seed. Both sprouts and seeds are valuable to wildlife as foodstuffs. Production of huge amounts of seed is the third major adaptation that serves the species well. After fire or logging kills the taller conifers, the hardwoods sprout quickly and reoccupy the original site. Seeds, through the action of disseminators, enable the species to occupy new areas. "It is not extravagance, but good investment for the oaks to provide subsistence for a continuing population of animal associates" (Grinnell 1936). Although area-wide estimates of seed production for hardwoods are hard to find, some local estimates serve to illustrate the fecundity of the species. On a good site in the northern Sierra Nevada, for example, tanoak had four bumper, six medium, and three light seed crops in 24 years. Thus, at least some seed was produced every other year. A 16-inch d.b.h. tree had the equivalent of 1.1 million acorns per acre beneath it in a bumper seed year. The acorns were 79 percent sound (McDonald 1978). On the same site in a light seed year, a 15.7-inch d.b.h. Pacific madrone tree produced 107,640 berries or about 2.1 million seeds (McDonald 1978).

The fourth broad-based adaptation concerns the species' capability to protect plant organs and processes through physiological and morphological means. Normally, plants respire excessively when internal moisture levels are low and internal temperatures become high. But sclerophylls have a built-in "fail-safe" mechanism that lowers respiration, even though temperatures may become quite high (Mooney and Dunn 1970). This keeps the plant from using all its energy reserves during the hot windy days of late summer. Related adaptations are that internal tissues tolerate high levels of moisture stress, and external tissues do not wilt or collapse. Bad-tasting, dull-colored, and prickly leaves discourage consumption by herbivores and safeguard the evergreen habit.

The fifth major adaptation, water wasting, is unique because it utilizes the advantages gained in adaptations one and four to give the species a competitive advantage. The sclerophyllous hardwood species discourage competition by using all the water in the rooting zone without paying the price of high internal moisture stress, high respiration, and

eventual death. Competitive species, lacking these adaptations, succumb, because no water is left to support life functions.

The best source of specific ecological information for the various hardwood species in this study is contained in their silvical descriptions (Burns and Honkala 1990) and in a description of southwestern Oregon—northern California hardwoods (McDonald and others 1983). At present there is no ecological classification system for forest-zone hardwoods on USDA Forest Service land in California (Diaz 1992). However, some very general classifications of California vegetation, including hardwoods, have been produced. These include the Forest Cover Types (Eyre 1980), the University of California Natural Land and Water Reserves System (Cheatham and Haller 1975), and Calveg (Parker and Matyas 1980).

Because of the importance of succession in hardwood ecosystems, the discussion that follows will include the role of disturbance and the climax status of each hardwood species. As the potential of California's hardwood forests to produce increased amounts of amenities and commodities becomes apparent, more disturbance will result, and more active management is going to be necessary. Where sprouting is the primary reproductive mode, the amount of time and available space for a diversity of plant species is limited because of the burgeoning sprouts. Where the stand is less dense and at least some of the reproduction is from seeds, the window for increased plant diversity is more open. As Atzet and Martin (1992) noted, "Disturbance brings change that helps maintain compositional, structural, and functional diversity, helps to select adapted, resilient individuals, and helps to dampen the effects of minor environmental oscillations and extremes. Change is an essential ingredient of healthy ecosystems." Furthermore, change through disturbance is critical over most of the hardwood species' natural range, especially where they intermix with conifers. Continued absence of disturbance allows the inherently taller conifers to overtop and eventually eliminate the hardwoods.

The following information on the successional status of forest-zone hardwoods represents a consensus of several ecologists and silviculturists in Oregon and California. Tanoak and Pacific madrone and, to a lesser extent, California-laurel and giant chinkapin are part of a multiple-species, conifer-hardwood mix, usually with Douglas-fir as dominant and the hardwood species in the secondary canopy. This association is considered to be climax. Pacific madrone also grows on the drier edges of this mix, and here it is regarded more as a subclimax than a climax. California-laurel is considered by most ecologists to be a climax species. Giant chinkapin has such wide ecological amplitude and both a shrub and tree form that it is almost impossible to classify. The tree form rarely is dominant, is tolerant of shade, and needs disturbance, particularly fire, to become established by sprouts from the root crown. Most ecologists regard giant chinkapin more as a persistent subclimax than as a climax species.

Growing abundantly in disturbed areas along the Pacific Coast and often in riparian areas, red alder is classified as an early successional species. It is subject to replacement in the

drier parts of its range by taller, longer-lived conifers. Canyon live oak has the widest latitudinal and elevational distribution of any California oak species, and hence is found in a wide range of habitats. On better sites, it is shorter than its associates, and here it is a persistent member of the stand for scores of years. On steep, rocky sites, it grows better than its associates and is best classified as an edaphic climax. California black oak also is widely distributed, but rarely is it excused from displacement by taller, more shade-tolerant associates. However, on drier aspects throughout its range the species perseveres and hence is regarded as a persistent subclimax.

Expanded Role of Silviculture

For the four major uses of forest-zone hardwoods, identified as those having the most value, it is inescapable that guidelines and recommendations, including those that are silvicultural, must key to ecosystems and to a large-area, long-timeframe basis. It is ecosystems with all of their environments, all of their species, and all of their values that need to be sustained. A landscape perspective is important because many species of wildlife need large territories, pleasing scenery often is manifest in a long view, raw material for a wood-processing facility comes from miles away, and water flows from watersheds that embrace many hundreds if not

thousands of acres. And because the landscape and its plants and animals are dynamic and constantly changing, the need for a long timeframe is equally inescapable. Plainly, the role of silviculture must be expanded to include a large variety of space/time configurations that range from manipulating individual organisms in small plots of land for a short time to sustaining complex plant and animal communities on 100,000-acre-or-larger landscapes in perpetuity.

Because wildlife has been identified as the most important user of forest-zone hardwoods on public land in the near future (McDonald and Huber 1994), it is the *habitat* that will become the fundamental management unit.³ Whether large or small, simple or complex—the habitat will be that which is strived for. Silviculture will be the mechanism for maintaining, creating, and sustaining the habitats deemed necessary by society. When a young stand is needed, silviculturists will create it; when an old stand is to be prolonged beyond its normal time, silviculturists will keep it healthy by maintaining stocking at optimum levels for stand health. When a special situation arises like increasing the population of an animal that needs a particular cover, silviculturists can do it (*fig. 3*).

³Because “habitat” is currently used almost universally by wildlife biologists, it is applied here. However, the term “ecological type” also is used in this paper to classify specific areas of bedrock, landform, soils, and potential vegetation (U.S. Department of Agriculture 1993). Ultimately, mapping, record keeping, and related work will probably be keyed to ecological types, which in turn may incorporate existing stand and compartment records.



Figure 3—Thinning this hardwood stand and piling the slash resulted in ideal habitat for wood rats for several years.

When shelter is needed in the area between disjunct habitats, silviculturists will plant trees to create it; when more open habitats with early seral species are needed, silviculturists will designate harvest areas; when a winter range or travel corridors need more acorn-bearing trees to sustain animals, silviculturists will see to it that they are there (Potter and Johnston 1980).

The art of silviculture will need to become broader in the future. A closer tie to wildlife biology will be a must, and applying silvicultural practices on larger areas with longer timeframes will be a challenge. New tools like geographic information systems (GIS), which project vegetation over all or pieces of the landscape over time, will help. A closer tie to ecology, especially to understanding the autecology of individual plant species and the plant and animal community in general, will be critical to successful practice. Perhaps the greatest challenge of all will be to create future ecological types that have the species composition, density, and structure that the manager desires (*fig. 4*).

The Hardwood Timber Industry of the Future

An important yield from the silvicultural manipulations will be the wood from the stand-tending and harvesting

operations. Because early control of species composition and stand structure is key to desired stand condition, the wood will be characterized by being from several species and mostly from smaller trees. Large volumes are likely from initial entries into existing unmanaged stands.

This wood needs to be processed because it has value and can subsidize other stand-tending practices. Furthermore, the mills that are supported by it create jobs and ultimately contribute to the stability of rural communities. A dynamic and stable processing industry is critical to future management of forest-zone hardwood ecosystems—removal of excessive and unhealthy trees is one way of keeping the ecosystem healthy. In spite of a difficult past denoted by frustration and failure (Huber and McDonald 1992), prospects for the California hardwood industry have improved since the mid 1980's (McDonald and Huber 1994). Painful lessons on the uniqueness of hardwood harvesting, drying, and marketing have been learned and, on the basis of knowledge gained from past experience, Hall (1993) believes that “the stage is set and California is poised for the hardwood industry to develop.” A combination of research studies, technical assessment, industrial testing, and practical experience have contributed to this belief.

Although the belief is there and the stage is set, the development of a sustained hardwood industry needs direction to fill gaps and speed the process. In the following sections, two avenues of direction are provided: (1) the future processing industry and (2) a blueprint for getting started.



Figure 4—Through a series of thinnings, silviculturists can manipulate the density of this stand to produce large crops of acorns on well-formed trees in the near future.

The Future Processing Industry

In the future, the wood obtained from silvicultural manipulation within the ecosystem management framework will have three types of primary processors: (1) concentrated high volume, (2) dispersed low volume, and (3) specialized.

Concentrated High-Volume Processors

This form of processing will be concentrated in a few large sawmills capable of sawing in excess of 40,000 board feet of lumber per shift. The processing sites will be vertically integrated with sawmills, green chains, air-drying yards, dry kilns, planing facilities, dry sorting areas, sorting and shipping facilities, and an internal sales organization. Such mills will be the ones that fill the volume markets of commodity type lumber and wood products. Because of their high-volume capacity, they will need a large and steady supply of logs, which presupposes coordinated scheduling of silvicultural operations over large areas (one or more managed landscapes).

Although some primary hardwood processors of this size existed for a short time in the past, several technological changes make them more promising in the future. For example, fixed-speed band mills can be replaced or upgraded with variable-speed systems to accommodate differences in wood density; variable-speed carriages also can be installed.

Dispersed Low-Volume Processors

Dispersed, low-volume processing will be by numerous small mills capable of sawing less than 5,000 board feet of lumber per shift. These smaller processors may be stationary, but more likely will be portable, and mounted on trailers that are pulled to new sites. Although designed to be portable, most operators currently set them up for semipermanent processing at a given site.

Because of their lower production capacity, these mills will not be vertically integrated. In order to amass enough lumber volume to vertically integrate, these processors may form cooperatives with other mills. Through cooperative ventures, they can provide centralized concentration yards for log storage as well as air-drying yards, dry kilns, planing mills, and a sales organization much like the larger high-volume mills. This type of small dispersed business format is similar to the well established hardwood industry model of the eastern United States, the only difference being the cooperative organization.

Like their larger counterparts, these smaller mills may contribute to the supply of commodity lumber sizes and species. However, their lower production capacity will allow them to be more flexible in sawing a wider variety of species, adjusting to changes in the market, filling niche markets, and developing specialized markets. Processing logs with character or figured wood to maximize value-added opportunities for crafted fine-wood furniture is an example. Because their volume is lower, this type of processor will require a smaller supply of logs. And because of their portable

nature and flexibility in the marketplace, they will fit well into most silvicultural operations.

Over time, this processing component may increase its production capacity to the 15,000-board-feet-per-shift range. Several reasons, both mechanical and mental, will contribute: continued improvements will be made in the mechanical design of equipment. Thin-kerf saws, for example, will allow for an overall increase in production and recovery. Headrigs will grade-saw the outer portion of the log, but mass-produce the lower-quality inner portion into cants. The cants would then be production-sawn on the resaws. Mental changes also will lead to increased production. According to Burton (1993), operating a small low-volume sawmill is like a narcotic; once you get started, you want to have more.

Producers of less than 1,000 board feet per shift will also be present in the hardwood processing industry. These low-volume producers will be an integral component of the craft trade and niche markets and will produce enough high-value product to offset lower quality wood. Of all the processors, they have the greatest flexibility in locating a supply of logs. However, they may find the supply deficient if the high-value end product that they manufacture requires a special type of characteristic (burl, crotch grain, curly figure) that is difficult to find.

Specialized Processors

Specialized processing will be more on a market “need” than on a shift basis. It will tie to high-value burlwood, quality veneer, and logs with unique character or figure. Although these processors will be few, they will provide a vital component of the hardwood processing mix. Material for specialized processors will come from the large and small processors and consist of identifying and separating suitable logs from hundreds of ordinary logs. These logs will be costly, but the cost will be more than offset by the high return of the end products. Some logs may also be harvested directly from the forest, as is the current practice.

The future for this segment of processor is both bright and gloomy. It is bright because the demand for products made from decorative burl and high-quality veneer is predicted to increase. Improvements for recovering more veneer from each valuable log also are being developed through use of micro-veneer (Klein 1991) and thirding-saw (three-cut) technology (Franklin 1993). The outlook for this type of processor is also gloomy because the supply is scarce and probably will be more scarce in the future. Trees that have quality decorative burl or clear veneer most often are large, old trees—those least likely to be available in the near future.

A Blueprint for Getting Started

Financing, training, seasoning, and marketing are the four keys needed for starting a sustainable hardwood industry in California. Money is needed to buy the land and construct the mill facilities, purchase the equipment, and buy the raw material. Start-up capital, probably from public and private

sources, must be available. A California state tax incentive program that promotes forest health through removal of excessive fuels and fuel ladders (thereby reducing the potential for catastrophic wildfires) will be much more effective if it also supports utilization of the massive amounts of raw material that will be forthcoming. And because a program of fuel removal can enhance forest productivity, it can be linked to the existing and well received Department of Forestry's California Forest Improvement Program (CFIP). Private capital in the form of a revolving loan fund also has merit. The money is loaned for the above uses, production is begun, and the money is repaid as sales increase.

The uniqueness of hardwood trees, logs, products, and values mandates that loggers, millers, and marketers be given the specialized training necessary to further their utilization. Recent legislation on "economic adjustment and community assistance" provides the means for delivering economic assistance and diversification opportunities for the rural forest-dependent regions that have been affected by the decline in public timber supply. Training is a large part of this package; training for hardwood production can be included. Using the knowledge developed in the established hardwood industries in the south and northeastern parts of the United States is recommended.

Seasoning the wood so that product shapes and sizes are stable must be done. Special equipment, some of it in hand and some that needs to be invented, is needed. Until a better solution is found, installing steam spray systems to recondition lumber after drying seems a good idea. Another idea comes from the food processing industry. A recent process uses a combination of microwave heating and vacuum drying. The principle is that warm moisture can be removed rapidly and with little or no harm from that being dried. Reducing the traditional "low and slow" air-dry and kiln drying cycle for hardwoods can provide large savings. Drying time is lowered, amount of manufactured product awaiting processing is reduced, and kiln size can be smaller because frequent small loads equal or exceed a few large ones in terms of volume dried in a given period of time.

The payoff for innovative hardwood harvesting and processing is sales. Hardwood products must be appealing to consumers and sold at a price that recovers production costs and yields a profit. But because of the uniqueness of hardwoods (Huber and McDonald 1992, McDonald and Huber 1994) and the large amount of relatively small and low-grade material, a new way of evaluating worth and manufacturing to maximize that worth is needed. Grading to reflect the percent "clear" wood in 1-foot increments in an 8-foot log makes sense. Above all, manufacturing value-added products needs to be done. More specifically, the value needs to come from small and short material such as made-to-order hardwood flooring, bobbins and spools, and toy blocks. A world of opportunity awaits those who can manufacture products from reconstituted wood material (fiber, particles) that are both functional and appealing (U.S. Department of Agriculture 1991). A whole new market also awaits those who can sell

their products in the international arena and meet its special needs. In more local situations, opportunity exists by accessing urban landfills and development sites for a broad range of woody raw materials and integrating them into the customer's complete "solution," which, for example, provides not only doors, but the moulding and trim that go with them (Economic Development Administration 1994).

Finally, and perhaps most important of all, the key to sustaining the hardwood industry—not just for wood products, but for all the inherent uses and values discussed in this report—is to form a partnership with the landowner. In this partnership, the landowner shares in the profits (Jungwirth 1994). This virtually guarantees sound and continuous management of the forest, which in turn provides a steady supply of raw material, probably of increasing quality.

Managing for Individual Yields

The four major uses envisioned for forest-zone hardwoods (wildlife, water, pleasing scenery, wood products) have appeal because they have both an individual and a combined form. Although it is almost impossible not to enhance more than one yield for at least a period of time, single yields have appeal. A large public utility, for example, might want to manage its hardwood forests to maximize streamflow for its reservoirs. Some state and federal agencies likely would want to establish optimum habitats for some species of wildlife. The best yield along roadways may well be pleasing scenery. Ecosystem management, accomplished by innovative silvicultural prescriptions, will be the mechanism through which raw material for commerce and industry is formed. This "harvesting" or vegetation manipulation will be practiced to enhance wildlife, water, esthetics, and timber and wood products.

Wildlife

The management perspective involving wildlife addresses two critical items: (1) the importance of hardwood seed crops and (2) the need to expand planning and management to the landscape level.

Acorns from oaks and berries from Pacific madrone serve as valuable foodstuffs because of the large amounts produced, their high nutrient content, and their being available at critical times (*fig. 5*). Acorns, for example, are eaten by nearly 100 species of animals, ranging from valley quail and wild turkeys to deer, wild pigs, and bears (Clark 1992). Deer are prodigious consumers of acorns. They eat them in the fall and root about in the fallen leaves and snow for them in the winter. Acorns are also avidly searched for in the spring by does and fawns, particularly in areas just exposed by melting snowbanks. The size and well-being of the fawn crop often is determined by the availability of acorns and their high



Figure 5—Tanoak acorns (above) and Pacific madrone berries (below) are vital foodstuffs for many species of birds and other animals.

nutritional value (Dixon 1934) (*fig. 6*). Indeed, “some oak stands and perhaps extensive forests should be managed primarily for acorn production” in oak-dominated forests in the central and eastern United States (Johnson 1993).

Much of our existing knowledge on wildlife management has come from research that emphasized single species, small spatial scales, and short timeframes. This is rapidly changing as the need to manipulate components of eco-

systems over large landscapes is recognized. Landscapes may cross several vegetation types, many mountain-valley configurations, and several property lines. Consequently with landscape management, the scale for potential manipulation is much broader, and more opportunities for more effective and better resource management are present. Migrating animals, most birds, and animals that require large territories will especially benefit, but many other species



Figure 6—Viewing wildlife, as exemplified by this young deer, brings pleasure to many people and perhaps reminds them of freedom and room to roam. (Photo by Frank Kratofil)

will benefit as well. Larger areas and longer timeframes should ensure that important patterns of mate selection, male-female ratios, and movement to favorable areas for reproduction are maintained.

Habitats, based on their future condition and sustained over the landscape in perpetuity, are needed. Equally important is that enough of each habitat be present to maintain each wildlife species on the level at which it will perform its normal ecological role (Conner 1988).

Once the species are known and the characteristics of their habitat have been defined, the next step is to bring them together. De Becker and Sweet (1988) match the wildlife habitats defined in Mayer and Laudenslayer (1988) to nine vegetation classification systems used in California today. Moreover, their cross-referencing system is user-friendly and can be easily augmented in the future. Ohmann and Mayer (1987) suggest that future wildlife assessments incorporate a “value ranking” in the evaluation process. This ranking will be used to adjust habitat units upward or downward according to their perceived value. Loss of a vegetation type or successional stage that is uncommon or used by a large number of wildlife species is likely to be perceived as more critical than loss of more common or less used habitats.

Special habitats of major worth to wildlife are those of the riparian and travel zones. The riparian habitat, because of its proximity to water, is rich in plant and animal diversity and critical for resident and migratory animal species. It should be managed carefully and gently. Special care in

removing specific trees, fuels, and undesirable plant species will be required.

The travel-zone habitat also is important, and it too should provide food, shelter, and cover for transitory animals. A dependable supply of nutritious foodstuffs is particularly important because the animals need extra energy to sustain their migration. Management in this zone will be complicated because of its corridor-like configuration, its need to be more free of impediments to travel (large areas of blown-down trees for example), and in some areas, its ridgetop location. In the latter areas, oaks may need to be planted below the ridgetop (where enough soil is present for them to grow well) to provide adequate acorns and browse.

Much needs to be learned about managing hardwood habitats. As noted earlier, hardwoods need disturbance to maximize their propensity for sprouting. But how much disturbance can specific wildlife species endure before being negatively affected? Concomitantly, how much human activity can they tolerate? Another concern is that of interspersions (the way various pieces of a landscape fit together, or the way that habitat components fit together over the landscape). For many species, especially birds, the effect of interspersions on their life patterns and processes is thought to be important, but it is scarcely mentioned in the literature. The worth of “edge” or that brought about by the juxtaposition of two different vegetation types is high for many species, but virtually worthless for species that call the interior of the forest “home.” Similarly, the interior habitat is nearly worthless for edge species.

Water

When describing the relationships of forest-zone hardwoods to water, three aspects of water need to be addressed. These are quantity, quality, and timing of delivery. Plentiful amounts of water, of high quality, delivered late in the spring when plants, including irrigated crops, need it are desirable. Having adequate water for animals throughout the year is ideal (fig. 7).

Deciduous hardwoods have greater utility than evergreen hardwoods or conifers when water quantity is considered. This is because leafless crowns of deciduous trees allow rain and snow to fall to the ground where evaporation is much lower than if lodged on evergreen leaves exposed to wind and sun. The thick carpet of leaves readily absorbs the water and further minimizes evaporation from the soil.

Water yield is lowered significantly when deciduous hardwoods are converted to conifers. Fifteen years after two experimental watersheds in the southern Appalachians had been converted from a mature deciduous hardwood cover to eastern white pine (*Pinus strobus* L.), annual streamflow was reduced about 20 percent below that expected if the hardwoods had remained (Swank and Douglass 1974). In a related study, two southern Appalachian experimental watersheds were cleared of mixed hardwoods and then planted with eastern white pine. Once the pine crowns began to close, streamflow steadily declined from 1 to 2 inches per year. After 10 years, water yield was 3.7 inches less from the pine stand than that expected from the hardwood forest (Swank and Miner 1968). In northwestern Michigan, jack pine (*Pinus banksiana* Lamb.) and red pine (*P. resinosa* Ait.) plantations replaced native hardwood forests. On well drained sites, 18 percent less water was yielded after 10 years; on imperfectly drained sites, yield declined 32 percent relative to deciduous forests on similar sites (Urie 1977).

Other studies have shown that manipulation of the forest is possible without deleterious effects on water quality or timing. Singer and others (1990) noted that oak removal from 14 percent of a 250-acre watershed in central California showed no change in nutrient or sediment removal. Furthermore, "selective oak removal appeared to have no harmful effect on water quality." Hewlett and Hibbert (1961) noted that, in North Carolina, "increases in annual [water] yield the first year after cutting mature hardwood forest in several ways, were roughly proportional to the percent of the stand that was cut. Increases tended to diminish in the years following the initial treatment, whether cutting was repeated or not, but a certain proportion of the increases can be maintained indefinitely by annual recutting. In general, increases are greatest during those months when normal streamflow is lowest, but water yield can be increased during all seasons of the year."

Esthetics

Pleasant scenery, fall colors, and the contrast and variability added to the landscape have been recognized as a

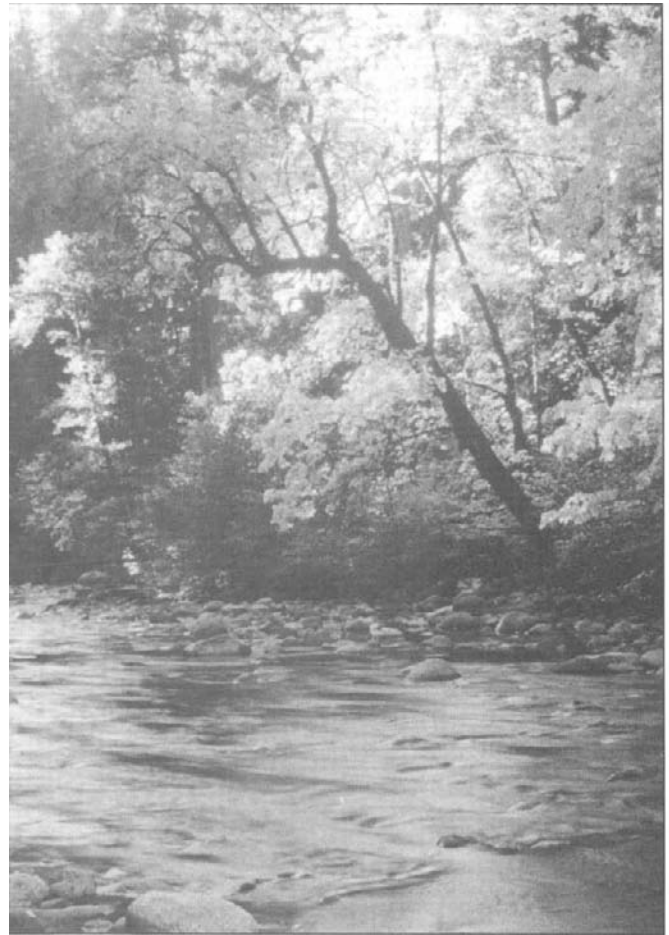


Figure 7—Not only is water vital to all species of plants and animals, the riparian zone of which it is a part is rich in species diversity and forms a pleasing view. (Photo by Wayne Steffes)

valuable yield from California hardwoods for many years (Heady and Zinke 1978, Litton and McDonald 1980, McDonald and Whiteley 1972, Plumb and McDonald 1981). This amenity value adds material wealth to rural economies. Motel owners in Quincy, California, for example, have their best season in the fall when travelers come to see the colorful dogwoods, maples, oaks, and willows.

Only one study is known in which the hardwoods, or the conifers above and around them, were manipulated to foster scenic beauty. In a study in the northern Sierra Nevada, where the objective was to enhance the roadside view, one treatment was to cut the middle stratum of conifer trees to feature the understory of nearly pure Pacific dogwood (*Cornus nuttallii* Audubon) (McDonald and Litton 1987). Elsewhere in the study area, "Pacific dogwood and California black oak are specifically emphasized where they congregate and can be well displayed—they are of special value providing spring-fall seasonal accents which are scarce in western forests" (Litton and McDonald 1980).

Hardwoods of the forest zone have beauty as single trees, as pure stands, and intermixed with conifers, both in

the short and long view. They have seasonal beauty, especially in the spring and fall by virtue of their colorful leaves and blossoms. Deciduous trees have winter value as their stark form has its own particular kind of beauty (*fig. 8*). And whatever the season, hardwoods of all shapes, sizes, and agglomerations provide exceptional framing around landscape “features” such as waterfalls, streams, cliffs, and sunsets. Another strong trend of hardwoods is that their appeal increases with size. Large trees, regardless of season or setting in the landscape, are more appreciated than smaller trees.

Timber and Wood Products

Forest-zone hardwoods, as noted earlier, are almost all of sprout origin following fire and cutting, and consequently often consist of a mosaic of even-aged stands (McDonald and others 1983). These stands tend to be too dense, grow too slow, and are too homogeneous (McDonald 1980) to provide suitable habitats for the many species of wildlife that depend on them for shelter and sustenance. More stands

with wider tree spacing are needed, not only for wildlife but also for enhancement of esthetic, timber, and water yields.

In general, artificial regeneration of most hardwood species is unreliable, and other than for red alder, a new stand is best achieved by manipulating clumps of root-crown sprouts. Cutting a low stump, less than 8 inches, is important because it promotes healthy root-crown sprouts, rather than unhealthy stool sprouts (McDonald 1978). The key to a healthy sprout clump is that as much as possible of the parent-tree root system be captured by the sprouts. This is accomplished by having sprouts well spaced around the entire circumference of the clump, not clustered in one portion of it.

Early manipulation of clumps and of the number of stems per clump is biologically effective and promotes a healthy forest. A light thinning at age 20 will begin to concentrate growth on selected stems in desired clumps. Care must be taken, however, not to open up the stand too much. Keeping selected stems in a *codominant* position is best because relatively close spacing promotes the development of straight stems and minimizes forking.



Figure 8—The architecture of this deciduous oak canopy is revealed in a winter sunset. (Photo by Connie Gill)

Successive light thinnings will continue to concentrate growth on desired stems, lessen clump and stand density, and further the development of increasingly wide crowns. Thinned material will serve as a source of fuel, fiber, and raw material for local industries. Later harvests of larger trees will provide quality logs for manufacture into high-value lumber and wood products. The goal is to grow straight, tall trees as fast as possible by controlling spacing and tree density.

In mixed hardwood and conifer stands, new and different management strategies are suggested, including mixing traditional with nontraditional species. O'Hara and others (1994) point out that "mixtures of species can potentially meet many nontimber objectives with only a small sacrifice (or even an enhancement) of timber production." Where mixed tanoak and Douglas-fir stands are present, they should be managed together. Each has a different and valuable yield: tanoak for lumber and pulp chips; Douglas-fir for traditional wood products. Either species could be harvested earlier in the rotation if larger specimens of the other are desired later (McDonald and Tappeiner 1987). Where California black oak and conifer trees are present, the conifers will shade the oaks and reduce the number of short "water sprouts" or epicormic branches, as they are better called, along the tree boles. Bole and eventually log quality will benefit. In both instances, the cost of controlling one species is eliminated, and staggered harvests give the landowner more frequent monetary returns. Total yield should be enhanced.

Managing for Combined Yields

Philosophy and Management Perspective

It is increasingly recognized that hardwood ecosystems in California's forest zone have value far beyond timber and wood products (McDonald and Huber 1994). Thus an overriding management philosophy is that these ecosystems are unique and needed, they have great total value, and they should be retained in total. Conversion to pines and firs is not desirable. This also fits into the broader philosophy that the management of natural resources in California is changing. More and more people realize that population growth and commodity needs are fast approaching the limit that natural systems can provide and sustain. A broader, more value-oriented and more people-oriented way of managing forest land is needed. Ecosystem management has been suggested, but too often only the environment and its vegetation and animals are noted, with people scarcely mentioned. The material that follows embraces the philosophy that all plants and all animals and all humans are important, and that all must interact together if California's hardwood resource is to achieve its full potential for yielding commodities and amenities. A related philosophy is that the rural way of life is an important part of this

Nation's heritage and that people and small towns in rural America can benefit from stable markets supplied by a stable hardwood industry (fig. 9).

The need for management of forest-zone hardwoods is *urgent* and, in some instances, the knowledge needed to do the job is *coming*. Total preservation of forest-zone hardwoods or not managing them at all are not viable options. Ecological risks will have to be taken. They can be mitigated, however, by leaving room for options. Decisions must incorporate as many future options as possible. Lack of basic knowledge about ecosystem processes, along with probable changes in society's outlook on the forest and its expectation of goods and services from it, mandates a management philosophy with built-in long-term flexibility.

Embodied in this philosophy of inclusion, interaction, and urgency are several factors that form part of an expanded management perspective that includes teamwork, scheduling, social aspects, and total yield.

Teamwork

If forest-zone hardwoods are ever to have effective large-scale management, the "team" concept must be present at all levels. Landscapes in many instances have private, county, state, and federal jurisdiction, and within each are large and small projects with different constituencies of interested people. Thus, the team will need to range from politicians and advocacy groups at the "buy-in" or agreement level to land managers and scientists at the operational level. Regional coalitions that are project oriented and national advocacy groups that are issue oriented must reach at least some level of agreement on a management plan.

To complement the high degree of biological complexity that is likely to be encountered as progress toward managing forest-zone hardwood ecosystems is made, a high level of cooperation and collaboration for scientists and forest-land managers will be needed. Teams of scientists that cross traditional disciplinary lines will study complex problems and recommend solutions; management teams will decide complex issues and employ far-reaching strategies that require expertise beyond the capacity of a single individual. Also, teams of scientists and managers will be working together toward achieving science-based knowledge with high applicability toward operational problems. And because much of the land containing hardwoods is owned by small nonindustrial landowners, a special effort must be made to bring management to their land.

As never before, teamwork will be needed to manage the hardwood resource. Such teamwork will need to take place at all levels within an organization (managers and workers), among divisions in an organization (planning, budget, research, programs), among disciplines in a large organization (genetics, silviculture, fisheries, etc.), and among landowners in a landscape (small private, large private, government). This teamwork will take skilled managers, much coordination, and a spirit of cooperation. Many new links in the way of doing things will have to be forged,



Figure 9—Small logs from 60-year-old tanoak trees (above) and larger logs from 120-year-old California black oak trees (below) provide opportunity for manufacturing many valuable wood products.

training and technology transfer will be required, and innovation will be at a premium.

Scheduling

A key to managing hardwood ecosystems and achieving a future condition that sustains basic values is scheduling. “Yields,” such as habitat for a bird or animal, exceptional

scenery, several million cubic feet of timber, or many thousand acre-feet of water, need to be accomplished in a predictable manner. Scheduling promotes efficiency in getting the needed job done, benefits the specific resource on the right area at the right time, and stabilizes the various industries that depend on the yields. As an example, let us begin with a piece of ground that was covered with undesirable tree species. Their

removal would increase water yield and provide an early seral stage of vegetation for wildlife and the contrast needed for a pleasing view. Hardwood root-crown sprouts, augmented by natural or planted seedlings, would provide the basis for a new forest. Browse from some of these sprouts would be available to wildlife for the next few years. At age 20, the new stand would be thinned to decrease the number of hardwood stems, concentrate growth on desired trees, and provide habitat for different birds and animals. At this stage, water yield would be decreasing, but pleasing scenery (perhaps contrasting to the more somber conifers in adjacent areas) would be provided. The thinned trees would be raw material for fuelwood and pulpwood or perhaps for an industry that would make toys or bobbins and spools from small-sized material.

At age 50, thinning would provide similar yields (*fig. 9*), but with higher volumes of timber, and allow the remaining trees in the stand to develop tall straight boles and full crowns. After age 80, an increasing yield of acorns (McDonald 1969) and berries would provide sustenance to more and different species of wildlife. Crown expansion would mandate a light harvest of mature trees around age 120, and logs from these trees would provide a timely addition to the raw material needed by a sawmill (*fig. 9*). In turn, the sawmill's product might be sent to another mill where it would be manufactured into fine furniture. For the next century or longer, this stand could be counted on to provide a known habitat for wildlife, a known yield of water, and scenery characterized by old and stately hardwoods, but little or no timber.

Adjacent areas, also with scheduled vegetative manipulations, would provide similar or different yields. Timeframes and area sizes could be adjusted to enhance a particular animal population or yield of wood and water, as desired. Eventually various areas in an entire watershed would be managed according to a master schedule, and a predictable flow of specific amenities and commodities would be provided at a known time. Several watersheds making up a drainage would ensure that ecosystems large and small would be maintained. All values would be enhanced because a predictable amount of value and product could be counted on.

Social Aspects

The rural way of life is part of our national heritage. Consequently, forest management strategies that furnish jobs and income to rural communities are important. This fact, plus the idea that scheduling to provide desired ecological types will mean a constant need for tree and stand-tending operations, will create a win-win situation. The mosaic of habitats and structures will add stability—work will need to be done and material will need to be removed each and every year. Trees and other vegetation will need to be planted and protected, stands will need to be thinned, and at some future date, some large trees will need to be harvested. The landscape will provide the jobs, the people will sustain the landscape. And products from managing the habitats will be the raw

material for small local “cottage” industries and for larger processing and manufacturing plants, which in turn will provide jobs for people in towns and small cities in rural America. Stable jobs and stable communities will result.

Total Yield

A major change in forest management planning is proposed—it is to employ the concept of “total yield.” Value will be the cornerstone of yield and its units will be the dollar worth of wildlife, water, pleasing scenery, and timber and wood products, in the broadest sense. Determining value will be a major challenge, but it must be done. The worth of pleasing scenery, for example, will be difficult to ascertain. “We need valid value comparisons” for forest environmental values (Minckler 1989). We also need to assess the cost of producing and maintaining amenity values (McDonald and Litton 1987). Recently, economists have been developing techniques for evaluating the worth of nonconsumptive and nonuse values (Langner 1991, McCollum 1991).

The long-term effect of recognizing the worth of individual yields and combining them to form a total yield will have an enormous effect on management in terms of what can be done and in reporting accomplishments. A new vista of accomplishments might happen. In areas where timber values were low, for example, the justification for cutting would not be based solely on the timber value, but also on the increased yields of pleasing scenery, increased browse and berries, and perhaps the betterment of the habitat for wildlife. Indeed, many water, dispersed recreation, and wildlife enhancement projects would not be valued below cost if related resource values were valued fully. The limitation of “below-cost timber sales” could be overcome in many instances because cost would be relative to gains from wildlife, water, and pleasing scenery, as well as wood. And in the broadest sense, the worth of the forest-zone hardwoods could be calculated and realistically compared to other vegetation types, especially softwoods.

Areas of Special Application

Because native hardwoods in general lend themselves particularly well to special kinds of management such as that in agroforestry and at the urban interface, each is discussed in the material that follows.

Agroforestry

This special kind of forestry has the general connotation of combining the growing of trees with an agricultural crop for the mutual benefit of both. And although only indirectly involving the forest, it often includes the growing and harvesting of special forest products such as nuts, berries, medicinal plants, pollen, mushrooms, and greenery. It also includes such services as renting out bees, being wildland and hunting guides, or leasing land for fish and game preserves (Thomas and Schumann 1993). With fully 80 percent of California's hardwood types in private ownership and much

of that in small nonindustrial holdings (Bolsinger 1988), plainly any comprehensive hardwood management plan must include “the little guy.”

Recent emphasis on agroforestry worldwide (Garrett 1991) has shown some different ways of regarding this special kind of forestry. Thomas (1992) notes that a broad-based approach must be employed to allow increased productivity (and wealth) to flow to small entrepreneurs in the countryside and in the small towns. Resource renewability, through a sustainable-use strategy, is the key to successful long-term agroforestry. Furthermore, landowners need to organize into cooperatives and associations and have a broader outlook for securing capital, new skills, and the marketing of their services and products. Martin and Prather (1991) agree that sustainable resource and community development go hand in hand, but that betterment of the people needs to be emphasized. Further, greater human utility, greater efficiency of resource use, and a balance with the environment that is favorable to both humans and most other species should be the goal.

The many environments provided by California’s forest-zone hardwoods range from the cool, damp rainforests near the Pacific Coast to the warm and winter-wet forests of the westside Sierra Nevada, to the forests of canyon live oak and California black oak at higher elevations. As a result, a plethora of microsites for growing forest and understory crops are available. Many of these can be enhanced by stand and understory manipulation. The large amount of amorphous organic matter and nutrients beneath hardwoods also is conducive to the growing of special forest products. In general, the nutrient pool beneath hardwoods is larger than that below softwoods, recycles faster, and contains more calcium. Many medicinal crops grow well beneath the hardwood canopy, and some of them provide a surprisingly high yield. Ginseng (*Panax quinquefolium*) in Kentucky, for example, is a \$5 million annual crop. Roots from planted crops sell for \$100 per pound; a well-tended crop will generate about 2,000 pounds per acre (Hill 1991).

A world of opportunity awaits the entrepreneur in the field of manipulating the hardwood environment for growing medicinal crops and other special forest products. In agroforestry, the most important factor in the management perspective is the social aspect. By fostering several yields, the landowner’s opportunity to make a living from the land is increased. Scheduling the yield, especially if coordinated with other growers, will produce many worthwhile benefits, just as it did for primary products from the forest.

The Urban Interface

Large and seemingly never-ending increases in California’s human population have caused many people to move to higher elevations “to get away from it all.” As a result, much development has occurred in the form of single homes and mountain subdivisions where California black oak grows and, to a lesser extent, at higher elevations where other hardwood species are found. The urban interface also encompasses those areas where cities and towns have

expanded into native hardwood forests. At the urban interface, the hardwood forest takes on a special character because the forest “becomes as much about people as it does about trees” (Herr 1992). The interface forest is lived in and deeply cared about by people who are active in promoting its welfare (Johnson 1987). No discussion on managing hardwoods in the forest zone would be complete without mentioning this special kind of “forest.”

Other than having more people in closer contact with the forest environment, the four major yields from the land remain the same as for hardwoods in the general forest zone. If anything, all are intensified, including the occasional cutting of trees to better observe wildlife and fall colors or to lower fuel loadings to lessen the likelihood of fire damage. Fire incidence, however, probably will increase—more people usually mean more fires. The lowering of tree density could cause less water loss by transpiration and result in additional streamflow. Of course, for shy, deep-forest species of wildlife, the fragmented habitat would be anathema, but for those species that adjust well to a moderately disturbed environment, this type of forest would be beneficial. The end use of products from trees cut in the urbanized forest might differ because more trees would be cut and used for fuelwood. The largest and best trees, however, could end up being sawn for fine furniture in a local cottage or cooperative industry (McDonald and Huber 1994).

Combined Yields

Of all the attributes of hardwood ecosystems, the one that stands out is the high value of the acorns and berries to many bird and other animal species. Conifer and shrub habitats can provide cover, shelter, and reproduction areas, but they cannot provide the sustenance derived from acorns and berries. Consequently, the hardwood manager should concentrate on taking all necessary steps to foster crown expansion, rapid growth, and ultimately large crops of fruits and berries. And in ring-porous hardwoods, like California black oak, the faster the tree grows, the higher the density and worth of the wood. The wood of diffuse-porous hardwoods like Pacific madrone and tanoak also increases in value as the growth rate increases.

The silviculturist can facilitate multiple yields by continuously manipulating the density and structure of stands. One manipulation is a series of thinnings. After each thinning, however, the typically narrow-crowned trees do not have sufficient crown area to handle the influx of nutrients and water sent upward by the roots. This imbalance often results in the formation of hundreds of short-lived epicormic branches on tree boles, particularly on deciduous oak species like California black oak. These form a sort of temporary crown. Epicormic branches slow development of the true tree crown, produce no acorns, devalue the quality of the tree bole for lumber and wood products, use water, and are visually unappealing. Therefore, a delicate balance between the tree and its environment must be maintained to promote rapid

growth with a minimum number of epicormic branches. Several light thinnings that give tree crowns room to expand are recommended (McDonald and Ritchie 1994). Eventually, the number of trees that remain will be in balance with the potential of the site. The majority will be straight and tall, large, and full-crowned with very few epicormic branches.

An example of balancing the conifer timber harvest and the food requirements of deer in a winter range took place on the Stanislaus National Forest in central California (Potter and Johnston 1980). Deer numbers and acorn consumption, and acorn production by tree size, density, and distribution were examined and estimated. The overall guideline specified that 30-40 percent of the area be occupied by California black oak trees in aggregations of 0.1 to 1.0 acres. In some instances, conifers will be removed and, in others, black oaks will be manipulated, both as single trees and as aggregations, to achieve and sustain the desired level of acorn production.

It cannot be emphasized enough that the total worth of carefully grown forest hardwoods, particularly if deciduous, is maximized with large trees (*fig. 10*). Such trees have high wildlife value because of high acorn production, high esthetic value because of a pleasing shape and form, high timber value because of high-quality boles, and high water-producing value because of increased storage through throughfall and decreased use because of relatively low numbers per acre.

Opportunities abound for integrating esthetics and wildlife within a wide range of habitats. As an example, Henderson (1988) identified eight living plant components and eight abodes within the hardwood forest on small pieces of privately owned ground in the north-central United States. Presumably, a manager could match specific species of wildlife to specific abodes, which alone and together had a given esthetic value within the landscape.



Figure 10—Many acorns, a pleasant sight, and some quality wood are manifest in large trees.

Hardwoods, especially California black oak and Pacific madrone, are well suited to areas of special application. Certainly the matching of esthetics and wildlife fits well into urbanized forestry. And in agroforestry, with what is called “an alley-cropping system” (rows of conifers outside of rows of hardwoods), the environment produced should provide a high growth rate, minimize epicormic branching, create an understory ideal for growing special crops, and constitute a food-lined, wildlife travel zone ideal for quail, turkeys, pheasants, skunks, raccoons, deer, and many birds.

In summer-dry California, water is a critical necessity for wildlife. Streams, ponds, swamps, marshes, lakes, beaver ponds, springs, gravel pits, and their associated riparian zones constitute both natural and man-made habitat. In addition to the benefit to wildlife, water is pleasing to the human eye and has enhanced esthetic value. Unfortunately, vegetation management practices are unlikely to be extensively implemented until institutional changes are made to reflect the true economic worth of water. At present, there is little incentive for land managers to emphasize water until the worth of the water is recognized and they are paid accordingly (California Department of Forestry and Fire Protection 1988). This could change, however, if the concept of total yield was applied to hardwood forest land.

Guidelines and Recommendations

Because the job is formidable and the uncertainties are many, arriving at guidelines and recommendations for managing California’s forest-zone hardwood ecosystems are best denoted by Pogo: “We are faced with insurmountable opportunities.”

A key to directing the course of future hardwood management in California’s forest zone is recognition that the hardwood species are numerous, their ecosystems are many, and the plant communities of which they are a part are both complex and diverse. In addition, their distribution is widespread, their inventory is large, their physical environment is variable, and their adaptations and evolutionary strategies are complex.

Unlike the current softwood inventory, hardwoods are plentiful in all sizes, ages, structures, and densities. The manager is not restricted by gaps in the resource base when making management plans.

Four major uses of the hardwood resource, each of which ultimately becomes a “yield,” in the near future and largely on public land, have differential potential value. These yields are wildlife, water, esthetics, and wood products.

All four yields are best managed if given an expanded base in space and time. Past management emphasis has mostly been on only a few species, in small areas, and only

for a few-score years. This no longer is suitable. The silviculturist must be free to manipulate ecosystem components at the stand level, at the landscape level, and at all levels in-between.

The fundamental unit for managing hardwoods in the 21st century will be the ecological type, or in the case of wildlife—the habitat. These are what will be strived for. Both can be large or small, joined or disjunct, long and narrow, or short and wide. They are dynamic in space and time but can be manipulated to modify both attributes. If they are reasonably devoid of excessive fuels and fuel ladders, so much the better.

Silviculture will be the mechanism for accomplishing the desired goal of creating, maintaining, and prolonging ecological types and habitats. The complex team, of which ecologists will be a part, will develop the objectives, but on both public and private land it will be the silviculturists who accomplish them.

The practice of silviculture will be called on as never before. It will be the silviculturist who creates habitats when and where needed, sustains them, and even prolongs them when necessary. To be effective, silviculturists must be free to use all their traditional tools like broadcast burning, clearcutting, herbicides, and a host of other vegetation manipulation techniques. There is a time and place for the careful application of each. Silviculturists must employ relatively new techniques like geographic information systems (GIS), invent new ones, and broaden old ones to meet the challenges of manipulating hardwoods on larger areas and in longer timeframes. They also will need to become more familiar with the ecology of heretofore uneconomic species, understand the dynamics of plant and animal communities, and, above all, concentrate on the ecological processes that govern life as we know it.

Special attributes of the hardwood resource allow yields to be manifest both alone and together. The propensity of hardwoods to produce large amounts of acorns and berries at critical times of the year, for example, is an outstanding attribute for wildlife. Each of the other yields has a special time, place, and purpose when it too has outstanding value as an individual yield and as part of a combined yield.

Management of forest-zone hardwoods can be enhanced by recognizing and emphasizing four factors that make up this new management perspective. These are teamwork, scheduling, social considerations, and total yield.

As never before, teams of stakeholders, scientists, and managers are going to be needed to solve complex biological and economical problems that are beyond the scope of individuals. Finding ways of paying for managing ecosystems and of recognizing and reporting accomplishments constitutes a major challenge.

Scheduling promotes the partnership between the providers of raw material and the manufacturers of products. It provides a predictable flow of raw material to the manufacturer in an orderly manner. In turn, the manufacturer pays for this material and helps defray the stand-tending and harvesting costs. The

predictable supply of raw material leads to the development of commerce with stable jobs, a stable payroll, and stable economies for people and communities.

The importance of social considerations—people and a way of life—in managing components of ecosystems cannot be overemphasized. Ecosystems and human livelihoods both need to be sustained. Forest-zone hardwoods, by virtue of their high diversity of habitats and structures, provide a wide range of opportunities for cottage industries and the development of special products from the forest. Through cooperatives and marketing associations, a big opportunity exists for small products from little-known species on relatively small areas to have large values and big benefits to rural Americans and to extend to the special management situations of agroforestry and the urbanized forest as well.

The concept of total yield means placing a dollar value on amenities as well as on commodities. Pleasing scenery, additional acre-feet of water, the stabilizing of an endangered species, quality wood for fine furniture—all have value that needs to be accounted for. When this is done, real worth can be evaluated in a more realistic way. Below-cost timber sales, for example, might not be below cost anymore when the gains from wildlife, water, and pleasing scenery are added to the return from the wood.

Integrating the concepts of scheduling, total yield, sustainability, considering people to be key components of ecosystems, and employing all of them in a landscape context can lessen the traditional boom and bust of the forest products industry and of resource management in general.

A final recommendation is to recognize that *large* hardwood trees provide the highest total yield. Wildlife, esthetic, timber, and water values are greatest when trees are large. Although a balance among all sizes and age classes is necessary, silviculturists may want to emphasize this size class, attain it as fast as possible, and sustain it for as long as possible.

References

- Atzet, Thomas; Martin, Robert E. 1992. **Natural disturbance regimes in the Klamath Province**. In: Kerner, Hannah M., ed. Proceedings of the symposium on biodiversity of Northwestern California; 1991 October 28-30; Santa Rosa, CA. Rep. 29. Berkeley, CA: Wildland Resources Center, University of California; 40-48.
- Baumhoff, Martin A. 1963. **Ecological determinants of aboriginal California populations**. In: Publications in American Archeology and Ethnology. Volume XLIX. Berkeley, CA: University of California Press; 155-235.
- Bolsinger, Charles L. 1988. **The hardwoods of California's timberlands, woodlands, and savannas**. Resour. Bull. PNW-RB-148. Portland OR: Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 148 p.
- Burns, Russell M.; Honkala, Barbara H., technical coordinators. 1990. **Silvics of North America, Volume 2. Hardwoods**. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture; 877 p.
- Burton, Bruce, Owner, Willits Lumber Co. [Personal communication with Dean W. Huber]. June 1993.

- California Department of Forestry and Fire Protection. 1988. **California's forests and rangelands: growing conflict over changing uses**. Sacramento: California Department of Forestry and Fire Protection; 67-71.
- Chaney, Ralph. W. 1925. **Studies on the fossil flora and fauna of the western United States. II. The mascal flora--its distribution and climatic relation**. Publication 349. Washington, DC: Carnegie Institution; 25-48.
- Cheatham, Norden H.; Haller, J. Robert. 1975. **University of California natural land and water system: an annotated list of California habitat types**. Berkeley: University of California. (no pagination)
- Clark, Jeanne. ed. 1992. **Managing California's wildlife and timber**. Published cooperatively by many public and private organizations and companies; 22 p.
- Conner, Richard N. 1988. **Wildlife populations: minimally viable or ecologically functional?** Wildlife Society Bulletin 16(1): 80-84.
- Cooper, William S. 1922. **The broad sclerophyll vegetation of California. An ecological study of the chaparral and its related communities**. Publication 319. Washington, DC: Carnegie Institution; 119 p.
- De Becker, Sally; Sweet, Ann. 1988. **Crosswalk between WHR and California vegetation classifications**. In: Mayer, Kenneth E.; Laudenslayer, William F., eds. A guide to wildlife habitats of California. Sacramento, CA: California Department of Forestry and Fire Protection; 21-39.
- Diaz, David, Regional Ecologist, Pacific Southwest Region, San Francisco, California. [Personal conversation with Philip M. McDonald]. 1992.
- Dixon, J.S. 1934. **A study of the life history and food habits of mule deer in California. Part II. Food habits**. California Fish and Game 20(4): 315-354.
- Economic Development Administration. 1968. **The Hoopa Valley Reservation hardwood study report**. Washington, DC: U.S. Department of Commerce; 162 p.
- Economic Development Administration. 1994. **Markets analysis and marketing survey for California hardwoods**. Washington, DC: U.S. Department of Commerce; 114 p.
- Edwards, Milton B. 1957. **California black oak--its management and economic possibilities**. Journal of Forestry 55: 506-510.
- Eyre, F.H. 1980. **Forest cover types of the United States and Canada**. Washington, DC: Society of American Foresters; 148 p.
- Franklin, Theodore. President, Pacific Rim Forest Industries, Inc. [Personal communication with Dean W. Huber]. April 1993.
- Garrett, H.E., ed. 1991. **The 2nd conference on agroforestry in North America**; 1991 August 18-21; Springfield, MO. 403 p.
- Griffin, James R.; Critchfield, William B. 1972. **The distribution of forest trees in California**. Res. Paper PSW-82. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 118 p.
- Grinnell, Joseph. 1936. **Up-hill planters**. The Condor 38: 80-82. (March)
- Hall, Guy H., President, Cal Oak Lumber Co. [Personal communication with Dean W. Huber]. November 1993.
- Heady, Harold F.; Zinke, Paul J. 1978. **Vegetational changes in Yosemite Valley**. Occas. Paper 5. Washington, DC: National Park Service, U.S. Department of Interior; 25 p.
- Henderson, Carrol L. 1988. **Woodland landscaping for wildlife**. In: Hoekstra, Thomas W.; Capp, Jack, compilers. Integrating forest management for wildlife and fish; 1987 October 18-21; Minneapolis, MN. Gen. Tech. Rep. NC-122. St. Paul, MN: North Central Forest Experiment Station, Forest Service, U.S. Department of Agriculture; 13-17.
- Herr, Serena. 1992. **New medicine for urban ills**. California ReLeaf Remarks 4(3): 1,4,5.
- Hewlett, John D.; Hibbert, Alden R. 1961. **Increases in water yield after several types of forest cutting**. Reprinted from Quarterly Bulletin International Association Scientific Hydrology. Louvain, Belgium. Sept.; 5-17.
- Hill, Deborah B. 1991. **Agroforestry specialty crops**. In: Garrett, H.E., ed. The 2nd conference on agroforestry in North America; 1991 August 18-21; Springfield, MO. 210-220.

- Huber, Dean W.; McDonald, Philip M. 1992. **California's hardwood resource: history and reasons for lack of a sustained hardwood industry.** Gen. Tech. Rep. PSW-GTR-135. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 14 p.
- Johnson, Paul S. 1993. **Perspectives on the ecology and silviculture of oak-dominated forests in the central and eastern states.** Gen. Tech. Rep. NC-153. St. Paul, MN: North Central Forest Experiment Station, Forest Service, U.S. Department of Agriculture; 28 p.
- Johnson, Sharon G. 1987. **Hardwood resource management and enhancement: the local picture and future prospects.** In: Plumb, Timothy R.; Pillsbury, Norman H., technical coordinators. Proceedings of the symposium on multiple-use management of California's hardwood resources; 1986 November 12-14; San Luis Obispo, CA. Gen. Tech. Rep. PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 411-415.
- Jungwirth, James, Consultant. [Personal communication with Philip M. McDonald]. August 1994.
- Keeley, Jon E. 1977. **Seed production, seed populations in soil, and seedling production after fire for two congeneric pairs of sprouting and nonsprouting chaparral shrubs.** Ecology 58: 820-829.
- Klein, Steven. 1991. **Development of micro-thin veneers using rotary peel technologies.** Abstract of a talk given at the Smart Wood Products Conference, 1991 April 16-17; Eugene, OR.
- Kummerow, Jochen. 1973. **Comparative anatomy of sclerophylls of Mediterranean climatic areas.** In: di Castri, Francesco; Mooney, Harold A., eds. Mediterranean type ecosystems, origin and structure. New York: Springer-Verlag; 157-167.
- Langner, Linda L. 1991. **Use of wilderness values in Forest Service policy and planning.** In: Proceedings of the conference on the economic value of wilderness; 1991 May 8-11; Jackson, WY. Gen. Tech. Rep. SE-78. Asheville, NC: Southeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture; 239-243.
- Laudenslayer, William F., Jr.; Grenfell, William E., Jr. 1983. **A list of amphibians, reptiles, birds, and mammals of California.** Outdoor California 44(1): 5-14.
- Leopold, A. Starker; Riney, T.; McCain, R.; Tevis, Lloyd, Jr. 1951. **The Jawbone deer herd.** Bull. 4. Sacramento: Calif. Div. Fish and Game; 139 p.
- Litton, R. Burton, Jr. 1968. **Forest landscape description and inventories—a basis for land planning and design.** Res. Paper PSW-49. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 64 p.
- Litton, R. Burton, Jr.; McDonald, Philip M. 1980. **Silviculture and visual resources.** In: Proceedings of the 1979 convention, Society of American Foresters; 1979 October 14-17; Boston, MA. 97-102.
- Litton, R. Burton, Jr.; Tetlow, Robert J. 1978. **A landscape inventory framework: scenic analyses of the Northern Great Plains.** Res. Paper PSW-135. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 83 p.
- Magill, Arthur W.; Schwarz, Charles F. 1989. **Searching for the value of a view.** Res. Paper PSW-193. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 9 p.
- Martin, Paul B.; Prather, Peggy. 1991. **Towards a sustainable agriculture and protection of the natural resource base.** In: Garrett, H.E., ed. The 2nd conference on agroforestry in North America; 1991 August 18-21; Springfield, MO. 351-363.
- Mayer, Kenneth E.; Laudenslayer, William F., Jr. 1988. **A guide to wildlife habitats of California.** Sacramento, CA: California Department of Forestry and Fire Protection; 166 p.
- McCollum, Daniel W. 1991. **How much is wildlife watching worth?** Alaska's Wildlife 23(2): 4, 40.
- McDonald, Philip M. 1969. **Silvical characteristics of California black oak (*Quercus kelloggii* Newb.).** Res. Paper PSW-53. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 20 p.
- McDonald, Philip M. 1978. **Silviculture-ecology of three native California hardwoods on high sites in north-central California.** Corvallis, OR: Oregon State University; 309 p. Dissertation.
- McDonald, Philip M. 1980. **Growth of thinned and unthinned hardwood stands in the northern Sierra Nevada . . . preliminary findings.** In: Plumb, Timothy R., technical coordinator. Proceedings of the symposium on the ecology, management, and utilization of California oaks; 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 119-127.
- McDonald, Philip M. 1982. **Adaptations of woody shrubs.** In: Hobbs, S.D.; Helgersson, O.T., eds. Proceedings of a workshop on reforestation of skeletal soils; 1981 November 17-19; Medford, OR. Corvallis, OR: Forest Research Laboratory, Oregon State University; 21-29.
- McDonald, Philip M.; Huber, Dean W. 1994. **California's hardwood resource: status of the industry and an ecosystem management perspective.** Gen. Tech. Rep. PSW-GTR-153. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 24 p.
- McDonald, Philip M.; Litton, R. Burton, Jr. 1987. **Enhancing the roadside view—creating pleasing views can be expensive.** Journal of Forestry 85(11): 19-23.
- McDonald, Philip M.; Minore, Don; Atzet, Tom. 1983. **Southwestern Oregon-Northern California hardwoods.** In: Burns, Russell M., technical compiler. Silvicultural systems for the major forest types of the United States. Agric. Handb. 445. Washington, DC: Forest Service, U.S. Department of Agriculture; 29-32.
- McDonald, Philip M.; Ritchie, Martin W. 1994. **Epicormic branching of California black oak: effect of stand and tree characteristics.** Northwest Science 68(1): 6-10.
- McDonald, Philip M.; Tappeiner, John C., II. 1987. **Silviculture, ecology, and management of tanoak in northern California.** In: Plumb, Timothy R.; Pillsbury, Norman H., technical coordinators. Proceedings of the symposium on multiple-use management of California's hardwood resources; 1986 November 12-14; San Luis Obispo, CA. Gen. Tech. Rep. PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 64-70.
- McDonald, Philip M.; Whiteley, Raymond V. 1972. **Logging a roadside stand to protect scenic values.** Journal of Forestry 70(2): 80-83.
- Minckler, Leon S. 1989. **Coming revolutions in forestry.** Journal of Forestry 87(4): 63-64.
- Mooney, Harold A.; Dunn, E. Lloyd. 1970. **Convergent evolution of Mediterranean-climate evergreen sclerophyll shrubs.** Evolution 24: 292-303.
- O'Hara, Kevin L.; Seymour, Robert S.; Tesch, Steven D.; Guldin, James M. 1994. **Silviculture and our changing profession. Leadership for shifting paradigms.** Journal of Forestry 92(1): 8-13.
- Ohmann, Janet L.; Mayer, Kenneth E. 1987. **Wildlife habitats of California's hardwood forests—linking extensive inventory data with habitat models.** In: Plumb, Timothy R.; Pillsbury, Norman H., technical coordinators. Proceedings of the symposium on multiple-use management of California's hardwood resources; 1986 November 12-14; San Luis Obispo, CA. Gen. Tech. Rep. PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 174-182.
- Parker, Ike; Matyas, Wendy J. 1980. **CALVEG: A classification of Californian vegetation.** San Francisco, CA: Pacific Southwest Region, Forest Service, U.S. Department of Agriculture; 168 p.
- Plumb, Timothy R.; McDonald, Philip M. 1981. **Oak management in California.** Gen. Tech. Rep. PSW-54. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 11 p.
- Potter, Donald; Johnston, Barbara. 1980. **An approach to managing California black oak and hardwoods on a deer winter range in**

- central California.** In: Plumb, Timothy R.; technical coordinator. Proceedings of the symposium on the ecology, management, and utilization of California oaks: 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 112-116.
- Robinson, C.S. 1931. **Feeding habits and forage requirements of Rocky Mountain mule deer in the Sierra Nevada Mountains.** Journal of Forestry 29(4): 557-564.
- Roy, Douglass F. 1962. **California hardwoods: management practices and problems.** Journal of Forestry 60: 184-186.
- Singer, Michael J.; Xiaohong, Huang; Epifanio, Charlette. 1990. **Selective oak removal does not harm water quality.** California Agriculture 44(2): 17-19.
- Stein, William I. 1990. *Umbellularia californica* (Hook. & Arn.) Nutt. In: Burns, Russell M.; Honkala, Barbara H., technical coordinators. Silvics of North America. Volume 2. Hardwoods. Agric. Handb. 654. Washington, DC: Forest Service, U.S. Department of Agriculture; 826-834.
- Swank, W.T.; Miner N.H. 1968. **Conversion of hardwood-covered watersheds to white pine reduces water yield.** Water Resources Research 4(5): 947-954.
- Swank, Wayne T.; Douglass, James E. 1974. **Streamflow greatly reduced by converting deciduous hardwood stands to pine.** Science 185: 857-859.
- Tappeiner, John C., II; McDonald, Philip M. 1980. **Preliminary recommendations for managing California black oak in the Sierra Nevada.** In: Plumb, Timothy R.; technical coordinator. Proceedings of the symposium on the ecology, management, and utilization of California oaks; 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 107-111.
- Thomas, Margaret G. 1992. **Forest resource strategies for rural development.** Washington, DC: Cooperative Forestry, Forest Service, U.S. Department of Agriculture; 7 p.
- Thomas, Margaret G; Schumann, David R. 1993. **Income opportunities in special forest products. Self-help suggestions for rural entrepreneurs.** Agric. Info. Bull. 666. Washington, DC: Forest Service, U.S. Department of Agriculture; 206 p.
- Urie, Dean H. 1977. **Ground water differences on pine and hardwood forests of the Udell Experimental Forest in Michigan.** Res. Paper. NC-145. St. Paul, MN: North Central Experiment Station, Forest Service, U.S. Department of Agriculture; 12 p.
- U.S. Department of Agriculture, 1991. **Strategic plan for the Forest Products Laboratory.** Madison, WI; 11 p.
- U.S. Department of Agriculture, Forest Service, 1993. **National hierarchical framework of ecological units.** Washington, DC; 30 p.
- Verner, Jared. 1987. **The importance of hardwood habitats for wildlife in California.** In: Plumb, Timothy R.; Pillsbury, Norman H., technical coordinators. Proceedings of the symposium on multiple-use management of California's hardwood resources; 1986 November 12-14; San Luis Obispo, CA. Gen. Tech. Rep. PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 162.
- Verner, Jared; Boss, Allan S. 1980. **Using the publication.** In: Verner, Jared; Boss, Allan S., technical coordinators. California wildlife and their habitats: western Sierra Nevada. Gen. Tech. Rep. PSW-37. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 9-10.
- Wolf, C.B. 1945. **California wild tree crops.** Claremont, CA: Rancho Santa Ana Botanical Garden; 68 p.



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