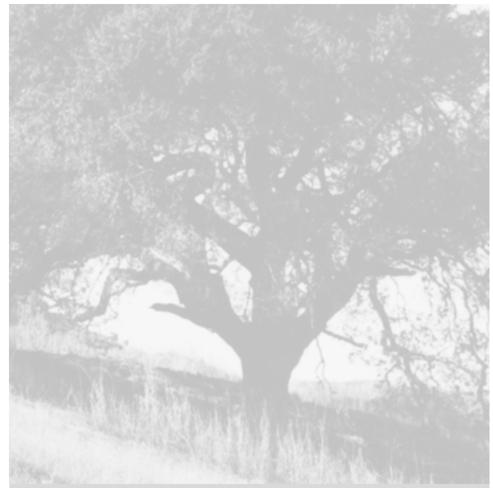
POSTERS



Overview—A Bird's-Eye View of the Poster Papers

John M. Bryant, Technical Chair

Thirty-one posters were displayed during the symposium. These covered a wide range of topics in highly creative and informative ways. Fifteen of these are presented here as extended summary papers. Topics are:

Poster Papers

Huntsinger—Changes in ownership, land use, and management in the oak woodlands from 1985 to 1992.

Shelly—A comprehensive profile of the hardwood industry in California.

Lubin—State and federal regulations, potential product contaminants, seasonal consideration, and sustainable harvesting issues related to production of special forest products.

Lawson, Zedler, and Seiger—A 5-year study of growth rates and mortality in two oak species.

Narog, Paysen, Corcoran, and Zavala—Explores stand vigor of canyon live oaks in relation to thinning and prescribed burning.

Fuchs, Krannitz, Harestad, and Bunnell—Considers the importance of Steller's jays in dispersal and regeneration of oaks.

Hubbell—A study of intercropping of valley oak and alfalfa during initial restoration efforts.

Scott and Pratini—Describes benefits of adding mineral soil from beneath mature Engelmann oaks to soil around seedlings planted in an irrigated field.

Weitkamp, Yoshida, and Tietje—A pilot study to guide planning for research on the effects of the Conservation Reserve Program on oak regeneration.

White—Statistical analyses of growth rings vs. stem diameters to estimate age of interior live oak in the San Bernardino Mountains.

Barry, Knight, and McCreary—Concludes that pruning of oak resprouts to enhance growth is not worth the effort.

McDougald and Frost—Evaluates the impact on vegetation of a 400-acre prescribed burn in Madera County in 1987.

Munton, Johnson, Steger, and Eberlein—Describes diets of California spotted owls at low elevations, in foothill riparian hardwood habitats.

Motz, R.W.—A nurseryman presents procedures and advice on establishment of native oaks without supplemental irrigation.

California's Oak Woodlands Revisited: Changes in Owners, Use, and Management, 1985 to 1992[1]

Lynn Huntsinger[2]

Introduction

A 1985 statewide survey of the goals, characteristics, and management practices of owners of California oak woodlands was instrumental in developing the research and extension components of the University of California's "Integrated Hardwood Range Management Program" (IHRMP) (Huntsinger and Fortmann 1990). The survey was based on a random selection of properties in the oak woodlands, instead of the more typical random selection from a list of names. In 1992, the owners of the same properties were resampled (Huntsinger and others 1997). Because this land-based sample was surveyed at two different times, it offers a unique opportunity to answer at least two kinds of questions central to the conservation of oak woodlands: What is the rate and nature of woodland land use change? Since Program implementation, have landowner practices and values changed? This brief summation compares some results of the second survey to those of the first, and addresses these questions for the years from 1985 to 1992.

The oak woodland can be thought of as an ecosystem at risk. Much of its value and character has to do with its being large and contiguous. Unsuited to crop or forest production, the foothill woodlands remain a vast, often interconnected acreage running through 38 of California's 52 counties—home to more wildlife than any other major habitat type in the state (Mayer and others 1986). Today there are two major forces that most threaten the extensive and overwhelmingly privately owned oak woodland. In the early decades of the century millions of hectares of oak woodland in valley bottoms were converted to cropland. Today, conversion for residential use is gobbling up woodland (Bolsinger 1988). Land values in many areas are far higher than those justifiable by range livestock production (Hargrave 1993, Johnson 1996). Incentive programs that reduce property taxes, like the California Land Conservation Act (CLCA or Williamson Act), require the support of firm land-use zoning designations that are often lacking (McClaran and others 1985).

The second major risk to oak woodlands is a perceived lack of regeneration of oak species in the woodlands (Muick and Bartolome 1987). Scientists and lay people alike have noted a lack of sapling-sized oak trees in many areas. Concerns that some parts of the woodland will eventually disappear because of attrition are exacerbated by the harvest of oaks for fuel and for increasing forage production. In 1985, when the Integrated Hardwood Range Management Program (IHRMP) was conceived, it was believed that this kind of oak removal was a serious problem in the woodlands.

[1] Presented as a poster at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996, San Luis Obispo, Calif.

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Comparing 1985 to 1992

Overall, oak woodland landowners still fall into the archetypes described as a result of the 1985 study (Huntsinger and Fortmann 1990) *(table 1)*. However, there have been changes in land status, owner characteristics, management, and attitudes about oaks.

Landownership Is Dynamic

During the period between surveys, an average of almost 4 percent of oak woodland properties were sold each year. According to database and assessor records, about 11 percent of ownerships in the original sample were subdivided during the 7 years between sampling periods. According to survey responses, over the past 5 years 9 percent of the ownerships and 7 percent of the woodland has been subdivided (Huntsinger and others 1997). Results of various field surveys conducted in the woodlands show an exponential rate of decline (Huntsinger and Hopkinson 1996). Holzman (1993) found that conversion rates over the past 60 years varied regionally, with more than a third of the woodlands developed in one region and an average conversion loss of 20 percent among the five regions studied. Ranchers interviewed in a Central Sierra study tended to believe that high land values and the estate and property taxes that go with them, coupled with irregular and low investment return from ranching, are major obstacles to the long-term future of ranching in areas where development pressures are high (Johnson 1996). Hargrave (1993) found that in El Dorado County, investment returns from land appreciation often exceeded those from livestock production. Landowners report that subdivisions are closer than ever to their own properties, and with subdivision, management conflicts between agricultural producers and urban refugees also become part of the scene (Huntsinger and Hopkinson 1996).

Landowner Goals Are Changing But Grazing Is Still the Major Land Use

There is a consistent trend away from using the land to produce products of any kind. But although the data show a general reduction in the use of oak woodlands for grazing and in the participation of landowners in livestock groups and economies, grazing is still, in fact, the major activity and the major underlying goal of oak woodland landowners *(table 2)*. This is especially true of larger parcels. This and other studies have indicated that about three-fourths of California's oak woodlands are grazed by livestock (Bolsinger 1988, Holzman 1993) and that, although fewer than half of ranches are solely supported by ranching (Richards and George 1996), ranching is the most important source of household identity for the majority of ranchers (Bartlett and others 1989, Richards and George 1996). Conservation of oak woodlands on any large scale will require the participation of the livestock industry. Trends among livestock grazers and other oak woodland landowners were the same: none of the results reported here were different when those who do not graze livestock were excluded from the analysis *(table 2)*.

Values and Practices Targeted by the IHRMP Were Affected

Although this type of survey cannot "prove" that the Program caused people to act differently, changes in values and behavior can be linked to program goals. Considerable IHRMP research was targeted to finding out how wildlife management could offer incentives to landowners to keep oaks through the marketing of hunting opportunities and habitat management, and in 1992, more landowners were aware of the value of oaks as wildlife browse *(table 2)* and were actively engaged in improving wildlife habitat.

IHRMP-sponsored research testing overstory-understory relationships in oak woodlands showed that, particularly in drier parts of the state, oaks at mid-canopy levels do not reduce forage production and, in some cases, extend the availability of green feed by increasing the species and phenological diversity of the grassland (Frost and McDougald 1989, McClaran and Bartolome 1989). This information was promoted through educational materials and workshops, and although removing oaks for increased forage production was the major reason large landowners gave for removing healthy oaks in 1985, today it is one of the least important reasons and is seldom done. Program efforts directed at owners of smaller properties have also apparently paid off. Owners of small properties tend not to cut oaks for economic reasons such as increasing forage production, but instead cut them for home use as firewood. Since 1985, the frequency of firewood cutting has decreased significantly, particularly for owners of small properties. Landowners are also much less likely to sell firewood than they were in 1985 *(table 2)*, perhaps reflecting program efforts to increase awareness that oak harvest may not always be sustainable. In fact, landowners in 1992 were far more likely to agree that "oaks are being lost in California" than they were in 1985. Landowners who valued oaks for browse, shade, wildlife habitat, soil conservation, and/or had contact with an advisory agency were significantly more likely to carry out oak-promoting activities such as planting oaks and protecting oak sprouts ($P < 0.1$, t-test).

Table 1—Two oak woodland archetypes identified as characterizing respondents in the 1985 and 1992 surveys.

Owner of small property	Owner of large property
Does not sell products from land	Sells products, most often livestock
More often absentee	Resident owner
More recent arrival	Long-term owner
Relatively amenable to oak use regulation	Anti-regulation
Less than half cut living oaks	Most cut living oaks
Growing in numbers	Relatively stable in numbers

Landowners Are Not Receptive to Regulation

As also indicated by this and other studies, ranchers and oak woodland landowners are not fond of regulatory options (Ellickson 1991, Huntsinger and Hopkinson 1996) *(table 2)*. However, they are apparently receptive to education and information programs, as well as to incentive programs like the Williamson Act that reduce the costs of high land values for producers, because about half of them have their land contracted under the Act. A dramatic increase in landowner awareness of the threat to California's oaks has occurred in the past seven years, and landowners have voluntarily responded with reduced cutting and increased protection of oaks *(table 2)*. Stewart (1991) indicates that ranchers are more willing to accept "carefully crafted oak related ordinances" than is apparent in the general response to regulation of oak use found in this study.

Conclusions

Several of the behaviors targeted by the IHRMP, including cutting of oaks for forage production enhancement and home firewood use, have shown dramatic reductions since the program began in 1985 *(table 2)*.

The owners of both large and small properties have demonstrated a receptiveness to the Program's education efforts. Ranching and livestock production, by maintaining large open space areas in private, productive ownerships, can play a critical role in conserving California's natural resources. If well managed, privately owned woodlands linking reserve areas and parks can magnify reserve effectiveness in protecting wildlife populations many times. Landowners, however, tend to be adamant about protecting their own rights to use their land as they see fit, including selling the land at a profit for real estate development (Huntsinger and Hopkinson 1996). Often the land represents the majority of a family's financial assets and landowners feel threatened by any public tendency to view the state's remaining open space as having an implicitly "public" character. Balancing the economic needs of the landowner and conservation goals will challenge Californians concerned about their landscape in decades to come.

Table 2—Change in landowner attitudes and management, 1985 to 1992

Percent of landowners who…	1985 (n=126)	1992 (n=115[1])	$P < (\chi^2)$
Cut living oaks[3]	70	50	0.04
Thin oaks	35	26	0.1
Cut oaks to increase forage	45	28	0.01
Poison oaks	7	2	0.05
Value oaks for natural beauty	82	88	ns
Value oaks as browse	51	67	0.02
Sell firewood	20	11	0.04
Believe oaks are being lost	59	79	0.004
Believe oak use should be regulated	32	39	ns
Graze livestock on land[4]	76	66	0.07

[1] About 30 percent of 1992 respondents participated in 1985 survey. There was no significant difference between their responses and those of new respondents. Response rates were 75 percent in 1985 and 1992.
[2] Chi-square analysis.
[3] Includes owners who cut only one oak.
[4] An estimated 71 percent of the woodland in 1992. Results reported in this table were no different when those who do not graze livestock were excluded from the analysis.

Although a program of research and extension can help reduce land use change by contributing to the economic well-being of ranchers through better or more diverse management, and to the enjoyment of oak woodlands by owners of small properties through enhanced wildlife and esthetic values, it cannot hope to prevent massive land use change as California's population expands into rural areas. Research and extension efforts must be complemented by some effort to influence the course of land use change in the oak woodlands we wish to conserve in California.

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Profile of the California Hardwood Industry[1, 2]

John R. Shelly[3]

Abstract: *The hardwood industry in California is not well documented and often is described as fragmented. An analysis of hardwood interests in the state reveals a wide gap between hardwood consumption and the supply of native hardwood lumber. A recent survey of individuals, companies, and agencies involved in hardwood utilization provides the data for profiling the hardwood industry. A questionnaire mailed to these contacts uncovered 22 hardwood mills in the state that produced an estimated 11 million board feet of hardwood lumber in 1995, and 38 suppliers that offer native hardwood lumber. A telephone survey of furniture manufacturers in California identified 860 companies that utilize hardwoods. The information obtained from this survey provides a comprehensive profile of the hardwood industry in California.*

The hardwood industry can be broken into three major segments: producers, suppliers, and secondary manufacturers. The producers, or primary manufacturers, are the sawmills that manufacture lumber. The suppliers are the wholesale/retail companies that supply lumber to the secondary manufacturers which make the finished goods. The major goods manufactured from hardwood lumber include: furniture, cabinets, and flooring. Previous studies by other researchers have identified a large secondary manufacturing industry in California; one recent survey reported 860 companies (Cohen and Goudie 1995). The project reported in this paper was undertaken to determine the size of the hardwood producer and supplier community and to identify the secondary manufacturers that use hardwoods. Information was gathered by a variety of methods including mailed questionnaires and telephone contacts which resulted in a directory of enterprises involved in the hardwood industry in California (Lubin and Shelly 1995).

Survey Methods

Companies and individuals were identified as potential constituents of the hardwood industry from a variety of sources. The starting point for the list was the hardwood mailing list of the University of California Forest Products Laboratory which was developed through personal contacts and attendance at workshops. Added to this mailing list were companies found in the following directories.

- 1995 Directory of the Wood Products Industry, Miller Freeman, Inc., San Francisco, CA.
- 1991 California Manufacturers Directory: Wood Products & Furniture, The California Hardwood Foundation, San Francisco, CA.
- 1994-95 California Furniture Manufacturers Association Membership Roster & Buying Guide, California Furniture Manufacturers Association, Los Angeles, CA.
- 1990 High Sierra Resource Conservation and Development Area: Hardwoods Directory Producers to Users, Sierra Economic Development District, Auburn, CA.
- 1992 California Forest Products Marketing Directory, California Department of Forestry and Fire Protection, Sacramento, CA.
- 1994 Markets Analysis and Marketing Strategy for CA Hardwoods, Supplement 1: Secondary Wood Products Manufacturers, U.S.

[1]Presented as a poster at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996, San Luis Obispo, Calif.

[2]Partial funding for this project was provided by contract with the California Department of Forestry and Fire Protection and an award from the U.S. Department of Commerce Economic Development Administration (EDA Project No. 07-19-04005).

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Department of Commerce Economic Development Administration, Sacramento, CA.

From the various sources, 265 potential lumber producers and/or suppliers and 1,022 potential secondary manufacturers using hardwoods were identified. The producers and suppliers were mailed a survey to confirm that they worked with hardwoods and to determine the characteristics of the enterprise. Those that did not reply to the mailed survey were contacted by phone. The secondary manufacturers were contacted by phone to confirm the information reported in the other directories.

Survey Results

Ninety-two of the 265 enterprises identified as potential producers and/or suppliers responded to the mailed survey; the remaining 173 were contacted by phone. Of the 32 percent of the contacts that were familiar with native California hardwood species, 22 of the enterprises were identified as lumber producers, 27 as suppliers, and the remaining 37 reported an interest in native hardwoods but no active involvement (Lubin and Shelly 1995).

Twenty-three percent of the secondary manufacturers were eliminated from the database because they exclusively used softwoods. Forty-five percent of the remaining 782 could not be reached with the addresses and phone numbers available, and no forwarding information could be obtained. It was verified that the remaining 429 companies used hardwoods. This information, along with the species used, is listed as an appendix in the *California Hardwoods and Nontimber Forest Products Directory of Producers and Suppliers* (Lubin and Shelly 1995). No further analysis was performed on the secondary manufacturers.

Lumber Producers

The native hardwood lumber producers were concentrated in northern California (*fig. 1*). Only one producer, of the 22 identified, was found south of the greater San Francisco Bay Area. The survey was likely biased towards northern California producers because they were the easiest to find. Undoubtedly there are small mills in other parts of the state processing urban and woodland species,

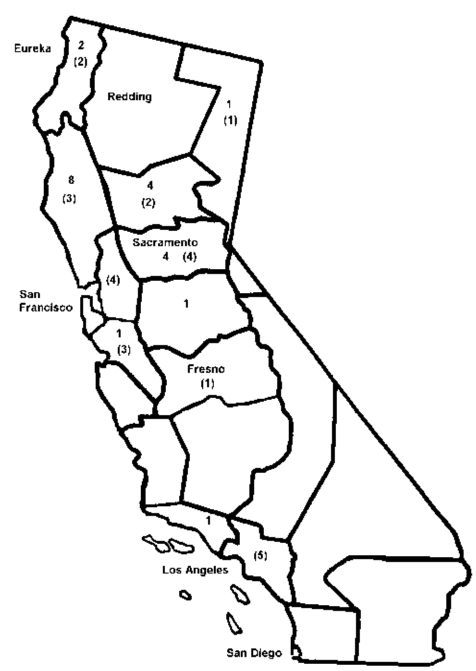

Figure 1—Location of native hardwood lumber producers and suppliers in California grouped by 3-digit postal ZIP code. The numbers represent the number of companies in a particular zone; suppliers are shown in parenthesis.

and an ongoing effort is focused on adding them to the survey database. It was known that a few medium-sized softwood mills in northern California have experimented with a limited hardwood production over the past few years, but they did not respond to the survey and were not included in this profile. However, it is worth noting that because of their size, these mills are capable of having a large impact on production figures.

A profile of the industry indicated mostly small companies working with a wide variety of species. *Figure 2* illustrates the range of species being used. Nearly all of the producers processed at least one of the main timberland species (California black oak, *Quercus kelloggi*, tanoak, *Lithocarpus densiflorus*, and madrone, *Arbutus menziesii*). Seven of them worked exclusively with timberland species, but the remainder also processed many woodland and urban species.

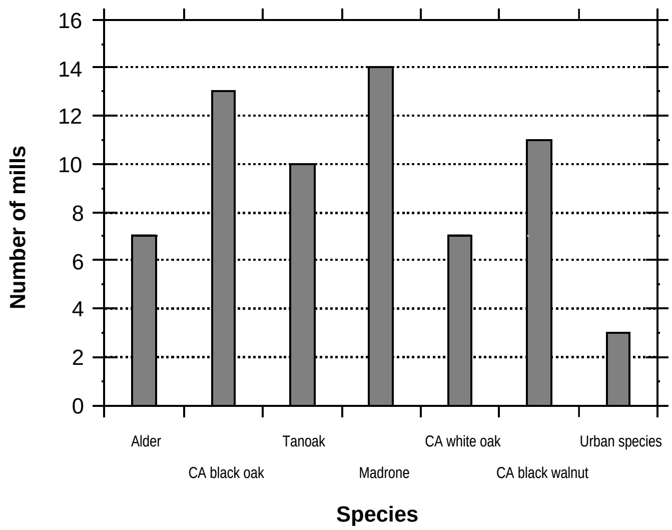

Figure 2—Summary of the number of mills that process various species of hardwood lumber. CA = California.

Most of the producers are small enterprises; only 5 of the 22 have an annual production greater than 50 thousand board feet and more than 5 employees (*fig. 3*). Although information on the type of milling equipment being used by each producer was not requested in the survey, it is believed from personal knowledge that almost all, except the two largest mills, use only portable sawmills.

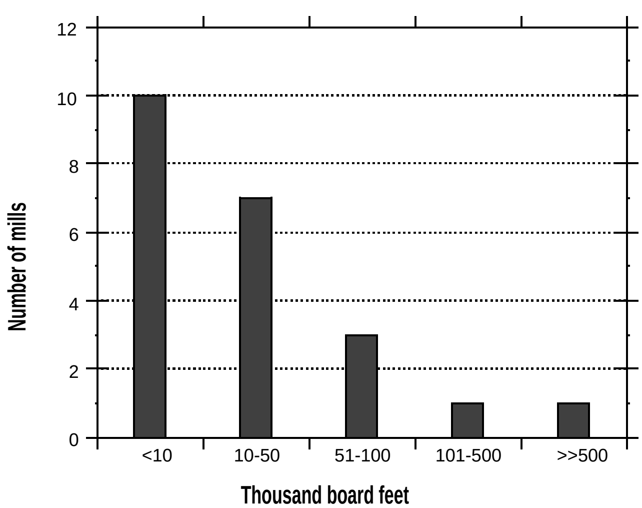

Figure 3—Summary of mill size based on the estimated annual production of hardwood lumber.

Lumber Suppliers

Twenty-seven suppliers were found throughout the state that confirmed they dealt with at least some of the native hardwood species. Although most of the lumber producers also supply lumber directly to manufacturers and individuals, they were not considered suppliers for the purposes of this survey. The suppliers identified in this survey tended to be concentrated near the major manufacturing centers of the State (*fig. 1*). Alder was the species most frequently supplied, but at least 12 suppliers indicated that they supplied the main timberland species of California black oak, tanoak, and madrone (*fig. 4*). California white oak and black walnut were also commonly carried (10 and 16 companies, respectively). Eight of the suppliers also indicated that they carried some native woodland species (listed as "other" in *fig. 4*). One supplier also carried lumber produced from a variety of urban species.

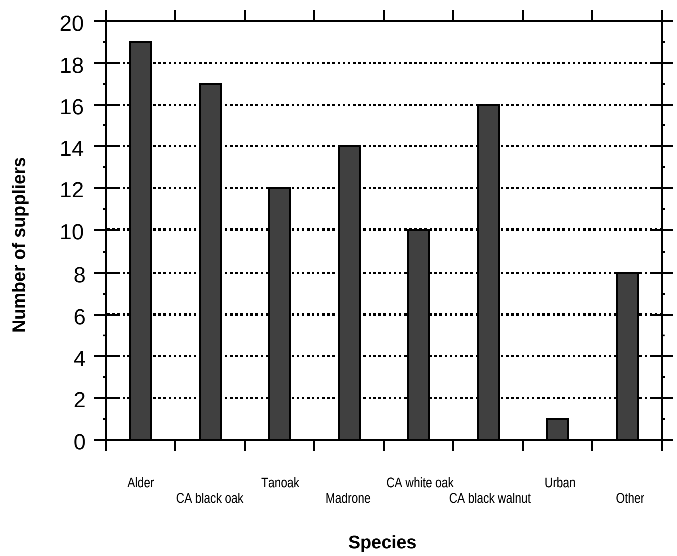

Figure 4—Summary of the number of suppliers that carry various species of California-grown hardwood lumber. CA = California.

Drying Capacity

Most of the lumber producers (64 percent) had only a passive lumber-drying capability (*table 1*) of either air drying or solar drying. Of the remaining eight producers, six had a dehumidification drying system, one had a conventional steam-heated kiln, and one had a vacuum drying system. The total producer-drying capacity was only 126 thousand board feet capable of a yearly production of about 1.3 million board feet, or only about 1 percent of the demand for west coast hardwood lumber. In addition to the kiln capacity of the hardwood lumber producers there is a sizable softwood-drying capacity in the state, and at least three suppliers have an additional 225 thousand board feet of dry kiln capacity. Some of this softwood capacity could conceivably be used to kiln dry partially air-dried hardwoods.

Table 1*—Hardwood drying capacity available from lumber producers and suppliers in California.*

Drying method	Number of mills	Total capacity in board feet
Passive		
Air	12	Unknown
Solar kiln	2	2,000
Active		
Dehumidification	6	69,000
Steam heat	1	50,000
Vacuum	1	5,000

Concluding Remarks

The survey identified 22 lumber producers and 25 suppliers that deal with native hardwood lumber and 429 secondary manufacturers that use hardwoods. The producers are mostly small enterprises using portable sawmills with only two having an annual production greater than 500 thousand board feet. These small producers tend to work with a wide variety of species, primarily including the timberland species of alder, California black oak, tanoak, and madrone, but also many woodland species such as valley oak (California white oak, *Quercus lobata*) and black walnut. Three enterprises indicated that they also use urban species such as elm and sycamore.

Lack of drying capacity is a serious shortcoming to developing a vital hardwood industry. The estimated 1.3 million board feet of annual hardwood lumber kiln capacity in California is only about 1 percent of the west coast hardwood lumber demand.

The hardwood industry is best described as fragmented. There is a mature, well-developed supplier and secondary manufacturing segment but the producer segment is in its infancy. As interest increases in finding higher-value uses than the present pulp chips, boiler fuel, and firewood for California's native hardwood resource, the producer segment is certain to grow. Some well-established softwood sawmills are experimenting with hardwood lumber production on a limited basis. Their input into the hardwood lumber supply would have a dramatic impact on the industry.

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The Utilization of Nontimber Forest Resources to Create Special Forest Products[1]

Dorothy Mockus Lubin[2]

Abstract: *Historically, our forest resources have been viewed primarily as a source of timber and wood products, such as lumber, plywood, and veneer. Compared to all that has been written about timber management and traditional timber products, discussion of the incredible variety of nontimber, or special, forest products has been almost nonexistent. This work provides a closer look at our forests and woodlands as complex systems capable of sustaining a wide diversity of special forest products. Most regions of the country possess the forest resources that represent opportunities for rural entrepreneurs to supplement their incomes. Many of the special forest products businesses have developed as cottage industries, utilizing an easily obtained or accessed resource to create a specialty product for a niche market. The category of special forest products includes such varied commodities as aromatics, berries and wild fruit, cones and seeds, forest botanicals, transplants and floral products, mushrooms, nuts, and weaving and dyeing materials. Though many of these special forest products originated as a specific cultural tradition, others are the result of a creative market analysis.*

State and federal regulations, potential product contaminants, seasonal considerations, and sustainable harvesting are some of the important issues related to the production of special forest products. Products can be categorized as those based on wood, such as aromatics, charcoal, animal bedding, and soil amendments, or as non-wood products, encompassing the product groups of edible fungi, forest botanicals, and floral products. The harvesting, marketing, and environmental considerations were explored for each of these major categories. It is important to note that these considerations can be unique to each product and continue to change as markets develop.

The range of products included in the special forest products label is too great to attempt to provide a comprehensive reference. The focus of this paper will be on those special forest products that are, or show potential to be, of the most economic significance for California's forests and woodlands.

Wood-Based Products

Charcoal

Charcoal is a form of highly porous, amorphous carbon, produced when wood or other carbonaceous substances are heated in the presence of little or no air, a process known as destructive distillation. The market for charcoal is mainly that of recreational activities and restaurant use. A small percentage of charcoal is utilized in certain metallurgical processes and as a filter to remove organic compounds, such as chlorine, gasoline, pesticides, and other toxic chemicals, from air and water. Many cities utilize high-quality filter charcoal to remove leachate from their landfills. Natural charcoal utilizes native hardwoods and fruitwoods, and the best product results from a raw material that is low in sulfur content. Hickory, mesquite, oak, and maple are all species used in charcoal production (Baker 1985).

[1]Presented as a poster at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996, San Luis Obispo, Calif.

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Natural charcoal, if marketed aggressively and creatively, can compete with large briquet producers in certain market areas. The advantages of the natural charcoal—an all natural, 100 percent hardwood product, no additives, no lighter fluid needed, reuse potential, more fuel efficiency than briquets—must be stressed to overcome the few disadvantages: irregularity of shape and size, tendency to flake and break, and cost (Baker 1985). It may prove strategic to link up with a grill company and focus on a regional market rather than attempt to break into a national market with a line of natural charcoal.

Flavor Enhancers

Many species of wood are used as flavor enhancers in grill cooking (*table 1*). Both restaurants and individuals take advantage of wood as a natural flavor enhancer. Wood in the form of chips and chunks is used by the residential consumer; roundwood is used by the restaurant trade; and sawdust is primarily used in the smoking and liquid smoke industries (Thomas and Schumann 1993).

Table 1—Woods used in grill cooking as natural flavor enhancers

Alder	Hickory	Sugar maple
Apple	Madrone	Tanoak
Bigleaf maple	Mesquite	Vine maple
Cherry	Oak	

Particle-Based Products

Chips, shavings, and bark are byproducts of a region's sawmills and wood processing plants. They may also be produced directly from biomass material. However the material is procured, it does provide an abundance of opportunities for supplemental income. This "residue" can be used as animal bedding and litter products, soil conditioners, amendments and mulches, landscaping and packing materials (Schumann 1979). It can also be used in a host of secondary wood products such as particleboard, fireplace logs, fuel pellets, and molded wood composite products (Hamilton and Levi 1987).

Non-Wood Products—Forest Botanicals, Forest Greenery, and Mushrooms

Forest Botanicals

Contained in the forests and woodlands are an abundance of plants that have market potential in culinary uses and medicinal and pharmaceutical purposes (Craker and Simon 1987; Miller 1988). The resulting products all require different processing and packaging procedures. Communication with a buyer is essential to ensure that the product is harvested, processed, and packed correctly.

Culinary Uses

Herbs and spices, edible greens, roots or tubers, and edible flowers are all categories of culinary forest botanicals. The herbs and spices are used as seasonings, to add aroma or color to foods and as ingredients in beverages such as herbal coffees, teas or soft drinks. The utilization of botanicals as natural food preservatives will no doubt increase over time, because the harvesting of edible greens, roots, tubers, and flowers has steadily risen over the past decade. Herbs require less water and fewer soil nutrients than more traditional farm crop; hence, small acreages of herb farms may become a familiar sight in the forests and woodland lots that are unsuitable for other cash crops.

Once dried properly, herbs can be marketed in several ways. Direct marketing methods include roadside stands, "U-pick" operations (in which the customers pick the herbs themselves), farmers' markets, gift baskets, and mail order. The market for fresh edible greens is a bit more limited. Fresh wild greens are delicate and must be handled carefully and delivered to the consumer in a timely fashion. A cooperative network marketing system may work best for the edible greens, particularly if the cooperative also offered other exotic edibles such as mushrooms, assorted berries, and edible flowers.

Plant identification is crucial for the edible botanicals. Misidentification of a plant could have potentially disastrous results for the edible greens business. A successful business plan for an edible greens business should include some sort of consumer education on the types of edible greens available, the identifying characteristics of the greens, and the potential uses.

Medicinal and Pharmaceutical Uses

A variety of medicinal and pharmaceutical compounds and nutritional supplements utilize forest botanicals in their manufacture. Though some of these products hold no real medicinal properties, they have established long-term markets and continue to represent an economic opportunity. Other forest botanicals do possess specific chemical properties that are of interest to pharmaceutical manufacturers and even though many of the compounds can be synthesized, new plant chemicals are continually being investigated. For example, taxol, from the Pacific yew, has recently proven to be an effective cancer-fighting drug for certain types of cancer and substantiates that there is still much to learn about the chemical compounds found in plants.

Marketing of medicinal plants for herbal and alternative health care is primarily achieved through small regional botanical or herb-buying houses that process and package the plant parts for final processors or retailers. Natural medicinal plant products are retailed largely through health food or natural food stores, although some drug and grocery stores stock a few medicinal plant products, such as herbal teas.

The issue of most importance in the forest botanicals business, especially in marketing medicinals, is to become fully familiar with federal and state regulations regarding health care products. If a product is marketed as a food substance or nutritional supplement, with no claims of medicinal value, the product will not have to undergo the extensive testing required to certify pharmaceutical drugs.

Forest Greenery

By far the most widely sold special forest product in the United States is evergreen boughs for the wreath-making industry. Hundreds of local people cut and collect boughs for sale to wreath companies. The wreath business is no longer limited to a holiday market, with the increasing popularity of manzanita and twig-type wreaths that are sold year-round. A successful greenery, transplant, and floral products business generally requires diversity of products and avoiding overdependence on seasonal products. A company may deal primarily in floral greens, but will use other products to fill in the gap, such as mushrooms or cones.

Weaving and Dyeing

A variety of materials grown in forests and woodlands can be used for weaving and dyeing (*table 2*). Though commercial utilization of these materials is not common, their utilization as part of a rural craft market does show potential (Adrosko 1971).

Harvesting

Table 2—Forest products used in weaving and dyeing

Alder	Hemlock	Manzanita	Ragweed
Alfalfa	Horsetail	Mistletoe	Sumac
Beargrass	Lichens	Oak	Tanoak
California laurel	Lupine	Oak galls	Yarrow
Douglas-fir	Madrone	Oxalis	

Forest botanicals should be harvested only from areas that have not been sprayed or otherwise contaminated. It is necessary to obtain permission from landowners before any harvesting. Collection of all forest products on a commercial scale from public lands requires permits. However, poaching is still a major concern. It has been estimated that the Forest Service is getting paid for only about one fourth of the material that is actually being harvested (Thomas and Schumann 1993). The most frequently poached items are beargrass, salal, and firewood.

A unique relationship can be developed between land managers and special forest products harvesters. When an area is scheduled for timber harvest, loggers can alert wildcrafters to new areas to harvest and the wildcrafters can help clean up a logged area by salvaging plants and plant parts, thus reducing the amount of slash, or “waste,” the logging crews must process.

Mushrooms

A variety of mushrooms are available for collection in the forests and woodlands. The major commercial use of the mushroom is for food, particularly in the exotic or specialty food markets. Mushroom use is expanding beyond the culinary arena; some fungi are being investigated for use in the biopulping process, as dyes for textiles, in medical research, and for use in reducing toxic materials in municipal dumps.

Forest Harvested Wild Mushrooms

A commercial market for wild edible mushrooms began developing in the early 1980’s, mostly in the Pacific Northwest, and has increased dramatically since then (Denison and Donaghue 1988). Of the many harvested, the most important wild mushroom species are the chanterelles (*Cantharellus cibarius*), morels (*Morchella conica* and *Morchella esculenta*), matsutake (*Armillaria ponderosa* or *Tricholoma matsutake*), boletus (*Boletus edulis*), and hedgehog (*Dentinum repandum*, or sweet tooth) (*table 3*).

Table 3—Forest-harvested and cultivated mushrooms

Cantharellus cibarius	Chanterelle
Lentinula edodes	Shiitake
Morchella conica	Black morel
Morchella esculenta	Yellow morel
Tricholoma matsutake	Matsutake
Amillaria ponderosa	Pine mushroom
Boletus edulus	Boletes
Dentinum repandum	Hedgehog or sweet tooth
Agaricus campestris	Meadow mushroom
Lyophyllum multiceps	Fried chicken mushroom
Caprinus commatus	Shaggy mane

The Forest Service has implemented a fee system for selling wild mushrooms to commercial harvesters. Personal use permits are needed for families or individuals collecting mushrooms in lesser quantities. Some timber companies allow mushroom harvesting on their land free of charge; others have some sort of fee schedule. Washington State adopted a Wild Mushroom Harvesting Act in 1988 that requires an annual license for buying or processing wild mushrooms (Thomas and Schumann 1993). California has no such requirement at this time, but as the industry continues to grow, licensing requirements and regulations are sure to evolve. Many mushroom harvesters have formed small, local networks to address issues, share information, and/or to cooperatively market their goods.

There have been no definitive studies on the effect that frequent harvesting has on the future production of mushrooms. The two factors that appear to have the greatest impact on the mushroom crop are the weather and timber clearcutting. A few years of drought or wild fluctuations in the temperature can inhibit the production of many species of mushrooms for several seasons. The practice of clearcutting timber can leave some areas devoid of mushrooms for up to 15 years (Thomas and Schumann 1993), and it has been proposed that a study be done to assess whether it might make more fiscal sense to devote some forest lands to the production of special forest products that have an annual yield, like mushrooms, rather than to a timber crop that can be harvested only once every 60 years. Licensing, leasing, and collection issues, though currently unresolved, are sure to be topics under increased discussion.

Cultivated Mushrooms

The most popular varieties of cultivated mushrooms are shiitake, chanterelle, oyster, and enoki. The methods of cultivation vary from species to species. The largest body of information is related to cultivation of the increasingly popular and versatile shiitake (*Lentinula elodes*), known for its high nutritional value and the ease with which it is cultivated. Mushroom cultivation is an excellent way to increase the revenue generated by forest lands with little disruption of the existing ecosystem. The wood generated from thinnings, that would otherwise be unmarketable, is perfect for mushroom cultivation. Wood that is used to cultivate shiitake may generate 10 times the revenue of the same wood sold for firewood. Other media such as corncobs and rice can be used to cultivate shiitake, but the best success has been achieved with oak logs (Stamets 1983).

Public Health Concerns

Mycologists throughout the United States have expressed concern over the possibility of a poisonous species of mushroom finding its way into the consumer market. At present, many states have no form of industry inspection or regulation, and pickers are not certified in any way. The ability to recognize a potentially poisonous mushroom is critical for individuals involved in this industry. Harvesters are encouraged to engage in continuing education regarding plant and mushroom identification.

Summary

The continued development of special forest products seems assured. The special forest products discussed above showcase the ingenuity and creativity people have employed to generate products from any available resource. Specialty products that incorporate more than one resource show some significant potential for commercial success. The Hoopa Valley Tribe in northern California has recently completed a feasibility study concerning the production of value-added special forest products, one of which is a gift box containing traditional items locally produced from native plants and resources, such as acorn soup, smoked salmon, and some medicinal herbal remedies. Production of an item such as this lends itself easily to a cooperative marketing strategy; gift and craft faires seem a natural market.

This industry shows no signs of declining and many signs of expanded development. Special forest products enterprises represent business opportunities to areas that are suffering the effects of a depressed timber industry. Many government agencies see the advantage in promoting and fostering these small industries. The route to sustainable economic development for many rural and fiscally disadvantaged communities will include innovative utilization and management of the available resources.

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Mortality and Growth Rates of Seedlings and Saplings of *Quercus agrifolia* and *Quercus engelmannii*: 1990-1995[1]

Dawn M. Lawson[2] **Paul H. Zedler**[3] **Leslie A. Seiger**[3]

Abstract: *This study followed the fate of oaks <10 cm in diameter at breast height (dbh) in nine experimental plots established in 1988 on Camp Pendleton, California. In that year, plots were burned in early season or late season, or left unburned as controls. Each tree was individually marked with a numbered steel tag, and its location along a transect was recorded. This paper reports the changes in this cohort from 1990 to 1995. The data show that there was significant mortality over that period, but that some individuals do "escape" and grow rapidly towards the canopy while many remain stunted. Engelmann oak (*Q. engelmannii*), though less successful in seedling establishment, had higher survival into the larger classes apparently because of a greater ability to survive in gaps. This pattern may explain how the two species coexist.*

This study focused on two oak species in coastal southern California: coast live oak (*Quercus agrifolia*) and Engelmann oak (*Q. engelmannii*), the dominant species in the Engelmann oak phase of southern oak woodland (Griffin 1990). Previous studies have hypothesized that *Q. agrifolia* may be increasing in dominance in Engelmann oak woodlands on Camp Pendleton (Lawson 1993). Understanding patterns of mortality and growth is necessary to manage the remaining woodlands to ensure that mixed stands will be preserved.

Methods

The study site is located on Marine Corps Base Camp Pendleton in San Diego County, California. The elevation is approximately 700 m with an average annual precipitation of 585 mm (Camp Pendleton weather records). The understory consists primarily of grassland with patches of poison oak (*Rhus diversiloba*) and scattered coastal sage scrub species.

The effect of fire on seedlings and saplings of the two species was evaluated using a randomized complete block design with three-fold replication. The treatments, applied in 1988, were early-season burn (July), late-season burn (October), and no burn (control). The blocks ranged from 5 to 10 ha and were divided into plots approximately equal in size. All saplings greater than 49.9 cm in height and less than 10 cm in diameter at breast height (dbh) were measured. Subsamples of seedlings (less than 50 cm in height) were sampled in belt transects. The location of each seedling with respect to tree canopies was recorded on a three-point scale by noting whether a seedling occurred beneath a tree canopy in (1) the outer half, (2) the inner half, or (3) in a gap between canopies. The plots were burned in 1988 and were resampled every 6 weeks the first year after the burn, every 8 weeks during the second year, and once in 1995. We are reporting on growth rates and survivorship, from 1990 to 1995, of the cohort sampled in the 1988 study.

[1] Presented as a poster at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996, San Luis Obispo, Calif.

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Analyses

The response variables analyzed were percent mortality and relative growth rate. Mortality was analyzed as a function of treatment, canopy location, block, and species using chi-square analysis. Logistic regression was used to determine the relationship between mortality and height. Data were categorized by height class, and the relative growth rate of each height class was determined as a function of treatment, canopy location, block, and species using an analysis of variance. Chi-square analysis was used to evaluate the location of recruitment with respect to canopies of mature trees.

Results

Growth

Relative growth rate did not differ significantly between species or among treatments. However, relative growth rate was strongly influenced by height class with the smallest individuals having the highest relative growth rates. Location relative to tree canopies was also an important factor influencing relative growth rate. The growth rates of "outer canopy" and "inner canopy" groups did not differ, but both were significantly lower than growth rates in the gaps ($P = 0.0051$).

Mortality

Of the 1214 individuals that were alive in the transects in 1990, 531 survived until 1995. Mortality was similar for both species, 56 percent for *Q. agrifolia* and 59 percent for *Q. engelmannii*. Survivorship between 1990 and 1995 was not significantly different with respect to prior burning treatment.

As expected, survival was highly size-dependent. Analysis by logistic regression predicted the probability of mortality in the 30-cm to 40-cm height class to be about 50 percent. After the plants reached 1 m in height, the predicted probability of mortality dropped to less than 30 percent and was less than 10 percent for individuals taller than 2 m.

Chi-square analysis showed that mortality varied significantly by canopy location ($P < 0.0001$). Gap mortality was 38 percent whereas mortality under oak canopies was 58 percent to 60 percent. This pattern held for each species, with mortality in the gaps slightly lower for *Q. engelmannii* (33 percent) than for *Q. agrifolia* (40 percent).

Recruitment

Between 1990 and 1995, 1118 new seedlings were established—1025 *Q. agrifolia* and 93 *Q. engelmannii*. This contrasted with the previous 2 years in which no seedlings were established in the transects (Lawson 1993). Seedling establishment was highest in the outer half of the canopy for both species, although this trend was stronger for *Q. agrifolia* than *Q. engelmannii*. *Q. engelmannii* was significantly more likely to establish in the gaps than *Q. agrifolia* ($P < 0.0001$).

Relative Stand Composition

The overall proportion of *Q. engelmannii* dropped from 20 percent in 1990 to 12 percent in 1995. When the data were evaluated by size class, however, a much different picture emerged. This can be shown by the change in the ratio of *Q. engelmannii* (Qe) to *Q. agrifolia* (Qa), which can be measured by drawing a ratio of this ratio for the years 1990 and 1995 and plotting this against size class. If there were no change in the relative proportions of the two species between the two sample years, this ratio of ratios would fall along the line Y = 1. Values below 1 indicate a shift toward *Q. agrifolia*, and values above 1 a shift to *Q. engelmanii* (*fig. 1*). A size trend in the data is clearly apparent (r_s = 0.88; P < 0.03). In the smaller size classes, the aggregate population shifted toward greater relative abundance of *Q. agrifolia*, but this tendency reversed with increasing size so that *Q. engelmannii* showed a relative increase in all the size classes above 30 cm (*fig. 1*).

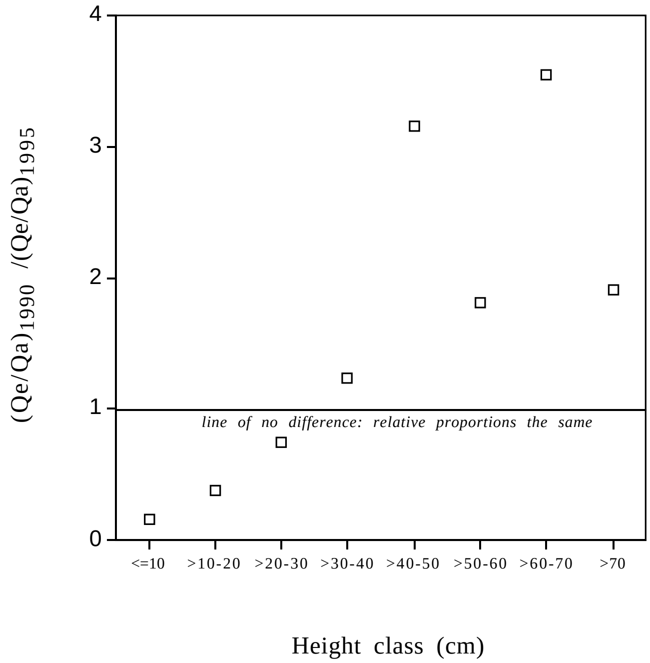

Figure 1—Plot of the ratio for 2 years, 1990 and 1995, of the ratio of *Q. engelmannii* (Qe) to *Q. agrifolia* (Qa) against size class. Points falling on the horizontal line Y = 1 show no change in the ratio of Qe to Qa from 1990 to 1995. Points above this line indicate increased relative abundance of *Q. engelmannii*, and below the line decreased relative abundance of *Q. engelmannii*. The trend in the points shows that the changes in relative abundance over the course of the study were size-dependent.

Discussion

Though the species did not differ with respect to growth rate and *Q. agrifolia* had greater seedling establishment, this did not necessarily give the advantage to *Q. agrifolia*. *Q. engelmannii* may compensate for poorer seedling establishment by greater survival in the gaps. *Q. engelmannii* was significantly more likely to establish in gaps than *Q. agrifolia*. Muick (1991) found that *Q. agrifolia* required shade for seedling survival. Snow (1972) noted that *Q. engelmannii* has the ability to delay shoot emergence in seedlings for a year. He hypothesized that this may allow this species to become established in open dry habitats more easily than *Q. agrifolia*, which his laboratory germination studies suggested may need more protected and moister habitats for initial establishment.

Conclusions

In Engelmann oak woodlands on Camp Pendleton, *Q. engelmannii* is much less abundant than *Q. agrifolia*, with roughly a little less than half the numbers per acre of *Q. agrifolia* (Lawson 1993). However, our data suggest that *Q. engelmannii* is not being displaced by *Q. agrifolia* and may actually be increasing, as evidenced by its increase in relative abundance in the larger size classes between 1990 and 1995. It appears that *Q. agrifolia* has an advantage in overall seedling establishment while *Q. engelmannii* is better able to establish in gaps where mortality is lower and growth rates higher. This pattern may explain how the two species coexist.

Acknowledgments

We thank Marine Corps Base Camp Pendleton for access to the study site. Many people assisted with the field work; we thank them and, in particular, Jane Tutton and Doreen Stadtlander. This work was funded by the Integrated Hardwood Range Management Program.

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Monitoring Fire Injury in Canyon Live Oak with Electrical Resistance[1]

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Miguel A. Zavala[3]

Fire-caused tree injury and mortality can generally be recognized by visible signs, but injury from heating can sometimes go undetected. Canyon live oak (*Quercus chrysolepis* Liebm.) mortality may be difficult to predict because tree death may not occur until 8 years after a fire. A shigometer, a specialized ohm meter, was developed to measure electrical resistance (ER) in live and dead wood. Measurement of ER has been used in other forest types, but never in canyon live oak. We present some results of early postfire monitoring of prescribed burning injury on canyon live oak with a shigometer.

An 8-hectare section of closed-canopy canyon live oak forest was divided into three blocks—each containing three different treatment plots: control, thin, and thin/burn. Trees were thinned to about 50 percent of basal area, and slash was left on site. A prescribed understory burn was completed in November 1985. In summer 1987, shigometer measurements were made on a subsample of 15 oaks from each of the nine plots. All trees were measured at four aspects (north, south, east, and west) of the bole and base for a total of eight readings per tree. ER values (in Kohms) were averaged for each treatment. We assumed that ER values greater than 50 Kohms indicated dead or dying tree tissue.

Of 135 oak trees measured, only those in the thin/burn treatment had ER values above 50 Kohms (*table 1*). The number of high ER readings per tree varied (*fig. 1*). Of the trees with values under 50 Kohms, mean ER readings for the control, thin, and thin/burn treatments were 21 Kohms, 15 Kohms, and 13 Kohms respectively.

Table 1—Electrical resistance (ER) arranged by treatment, value, and number of observations in a canyon live oak forest, San Bernardino National Forest, California.

Treatment	Number of trees[1]		Number of readings[2]
	ER < 50	ER > 50	ER > 50
	Kohms		
Control	45	0	0
Thin	45	0	0
Thin/burn	19	26	94

[1]45/treatment
[2]Sites/treatment (8/tree)

[1] Presented as a poster at the Symposium on Oak Woodlands: Ecology, Management and Urban Interface Issues, March 19-22, 1996, San Luis Obispo, Calif.

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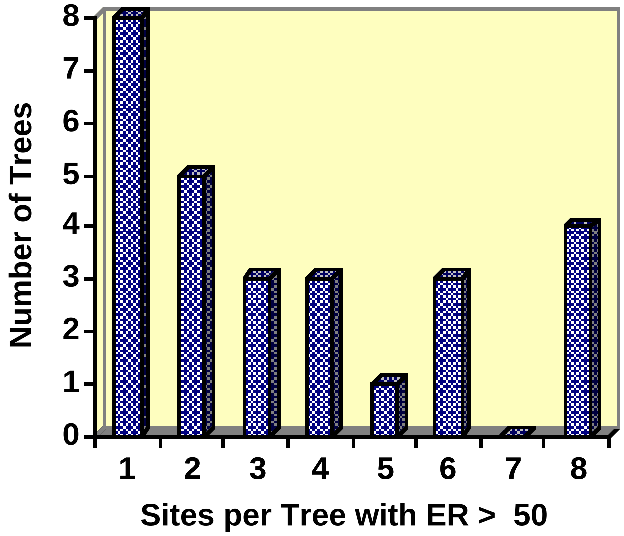

Figure 1—The number of trees which had high electrical resistance-ER (>50 Kohms) values for one to eight sites. Eight sites were measured (four base, four breast height) on each of the 27 canyon live oaks monitored on Skinner Ridge, San Bernardino National Forest, California.

No oaks in the thinned treatment had ER values greater than 50 Kohms. This suggests that thinning alone did not contribute to the high ER values observed on the thin/burn treatment trees. Initial fire injury (e.g., crown scorch or bole charring) was observed on all trees in the prescribed burn plots; yet, tree mortality was difficult to assess. Three years after the fire, evaluation of tree injury, based on visible fire damage, indicated that 69 percent of the trees in the thin/burn treatment had serious injury. Shigometer measurements made one year earlier showed that 58 percent of sample trees in the thin/burn treatment had detectable tissue damage with ER > 50 Kohms. This may or may not indicate that mechanically applied shigometry and visual evaluation techniques are interchangeable. However, the results from canyon live oaks with ER < 50 Kohms indicate that early detection of injury shortly after a burn treatment may be possible; this may not be the case using visual techniques. Measuring ER with a shigometer may improve early detection of injury and mortality in canyon live oak and influence the timing of management action.

Seeds That Fly on Feathered Wings: Acorn Dispersal by Steller's Jays[1]

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Fred L. Bunnell[2]

The Garry oak (*Quercus garryana*) is the only native oak in British Columbia. On southern Vancouver Island, Garry oak ecosystems have been severely reduced, fragmented, and degraded. Efforts are currently underway to protect and restore these ecosystems. In this study we investigated oak dispersal and regeneration, to supply information that will help guide conservation efforts.

Steller's jays (*Cyanocitta stelleri*) hoard Garry oak acorns to use as overwinter food. They transport acorns in their throats and bills and hide them singly in the ground at scattered locations. If the jays do not eat all of the hoarded acorns, seedlings may grow at the hoarding locations.

This study addresses the following questions: (1) How deep, and in what habitats, do jays hoard acorns? and (2) How do burial depth and hoarding habitat affect seedling emergence rates? Field work was conducted at two sites at Metchosin, the most southerly portion of Vancouver Island. Methods included: (1) observing hoarding, measuring burial depth of acorns, and assessing habitats used by jays; (2) measuring habitat along transects to estimate habitat availability; and (3) planting acorns at different depths and in different habitats and measuring seedling emergence during the first growing season.

How Deep Do Jays Hoard Acorns?

Virtually all acorns hoarded by jays were buried, but not usually in the soil (*fig. 1*).

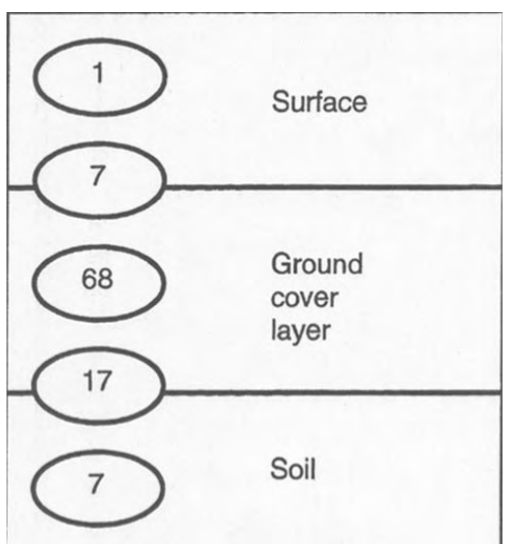

Figure 1—Percentages of hoarded acorns in relation to surface, ground cover layer, and soil (n = 151). Ground cover layer refers to leaf litter, moss, and matted grass roots.

[1] Presented as a poster at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996, San Luis Obispo, Calif.

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In What Habitats Do Jays Hoard Acorns?

Only a few habitat types were used by the jays in relatively high numbers and in much greater proportion than they were available (HC, CS, and RP). However, only about half of the hoards were placed in these three preferred habitats. The rest were distributed among a wide variety of habitat types (*fig. 2*).

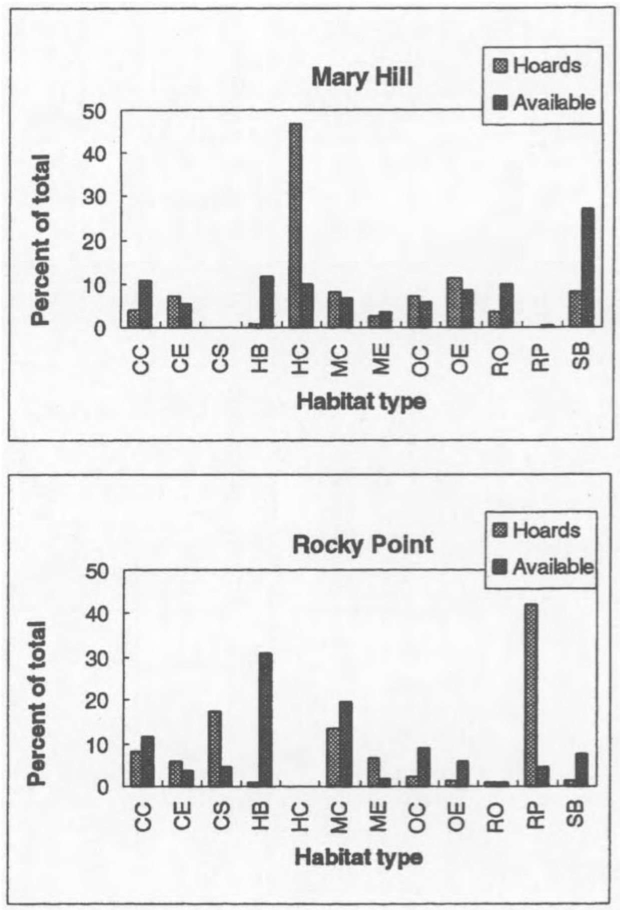

Figure 2—Comparison of use for hoarding and availability of habitat types in two study sites: Mary Hill (hoards n = 177; available n = 356) and Rocky Point (hoards n = 134; available n = 409). CC = conifer canopy; CE = conifer edge; CS = conifer sapling patch within the oak stand; HB = herb; HC = small clump of overlapping canopies of Garry oak, *Arbutus menziesii*, and *Pseudotsuga menziesii*; MC = mixed canopy; ME = mixed canopy edge; OC = oak canopy; OE = oak edge; RP = riparian; SB = shrub.

How Do Burial Depth and Habitat Affect Seedling Emergence Rates?

Effects of burial depth and habitat type were significant at both sites (ANOVA, $P < 0.05$). Acorns planted in the ground cover layer and in the soil fared significantly better than acorns planted on the surface. Acorns in the three habitats used most frequently by the jays had low emergence rates. Acorns in a number of habitats used less frequently by jays had high emergence rates (*fig 3*).

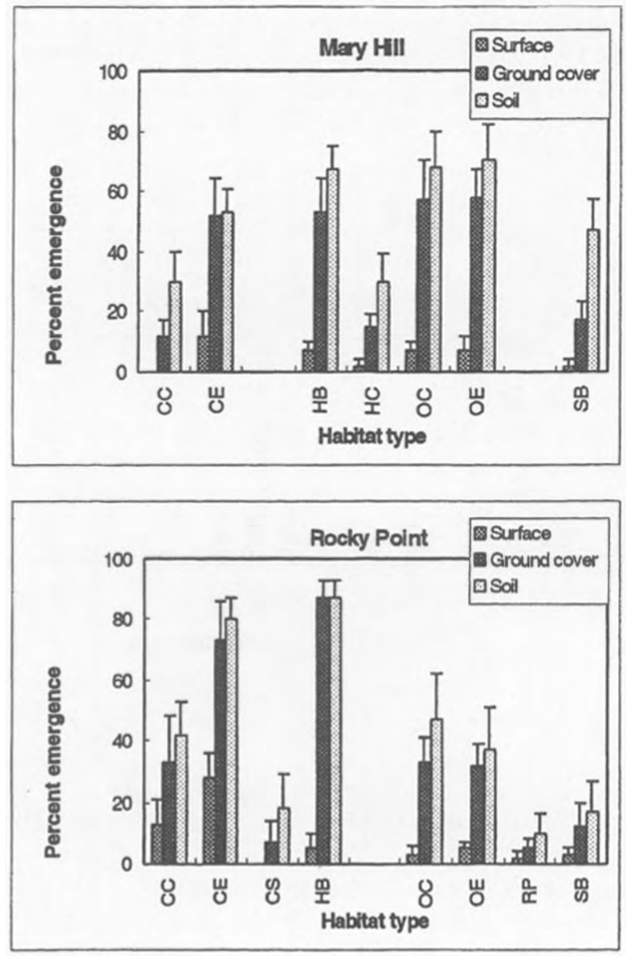

Figure 3—Results of acorn planting experiment at two sites (Rocky Point and Mary Hill). 2,700 acorns planted in a split-plot, completely randomized design; 6 replicates per treatment combination. Vertical bars represent standard errors. CC = conifer canopy; CE = conifer edge; CS = conifer sapling patch within the oak stand; HB = herb; HC = small clump of overlapping canopies of Garry oak, *Arbutus menziesii*, and *Pseudotsuga menziesii*; OC = oak canopy; OE = oak edge; RP = riparian; SB = shrub.

Conclusions

Burial of acorns by jays within the ground cover layer and soil may play a crucial role in Garry oak regeneration. On the other hand, jay habitat preferences may result in poor seedling emergence rates. Variability in use of habitats for hoarding may be essential for dispersal. Observations suggest that some of the variability noted in this study may be the result of spillover from preferred to adjacent habitat patches. Efforts to promote effective acorn dispersal might thus entail management for habitat patchiness, to juxtapose habitats preferred by the jays with habitats that foster oak regeneration.

Competitive Effects of Alfalfa on Survival, Growth, and Water Relations of *Quercus lobata* Seedlings[1]

Jean G. Hubbell[2]

Abstract: *Successful intercropping of native plants with farm crops without weed/crop control, requires knowledge of the native plants' competitive ability. To assess the competitive ability of* Quercus lobata *(valley oak), it was grown in second-year alfalfa fields. Alfalfa was either unmanaged (high competition) or reduced with glyphosate herbicide (low competition). A relatively small decrease (< 50 percent) in survival and growth in spite of a large decrease in light and water in the high competition treatment suggests a reasonable competitive ability of valley oak seedlings. Therefore, for valley oak restoration, competition reduction may be decreased or unnecessary. For this project granivory was the greatest obstacle to successful intercropping.*

Less than 4 percent of California's pre-European riparian forests remain, and remnants are generally small and fragmented (California State Lands Commission 1994, Cepello 1991, Roberts and others 1980, Smith 1980). This and the great ecological significance of riparian forests have generated an interest in riparian forest restoration.

The Sacramento River Project is designed to restore riparian forests, seasonal and permanent wetlands, and native grasslands along 161 km of the Sacramento River from Red Bluff south to Colusa. This project is a joint effort by The Nature Conservancy (TNC), the U.S. Fish and Wildlife Service, California Departments of Fish and Game and Water Resources, U.S. Army Corps of Engineers, and private landowners to create a corridor of lands adjacent to the river vía ownership, easements, and restoration.

Restoration of native plants is costly, due to the efforts required to maintain irrigation and weed control for several years until the plants are established. TNC defrays costs in a variety of ways, one of which is farming at the restoration site, which can reduce costs by approximately half (Griggs and Peterson 1997). Farming the site reduces costs by providing income for restoration and providing irrigation if restoration plants are intercropped with the farm crops. If intercropping can be done without weed / crop control around the native plants, then the restoration costs could be reduced even further. Successful intercropping without weed / crop control during initial restoration efforts requires knowledge of the competitive ability of the native plants. Thus TNC is interested in experimenting with intercropping of native riparian species with farm crops such as alfalfa (*Medicago sativa*) with and without weed / crop control.

A field experiment was designed to assess competitive effects of alfalfa on survival, growth, and water relations of valley oak (*Quercus lobata*) seedlings at Kopta Slough Preserve. The study addressed the general question, what is the competitive ability of valley oak when grown in alfalfa? The specific null hypothesis was: seedling emergence, survival, growth, and water relations are the same for valley oak when grown in alfalfa (high competition) as when grown in reduced alfalfa (low competition).

[1] Presented as a poster at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996; San Luis Obispo, Calif.

[2] Ecology graduate student, Department of Biological Sciences, California State University-Chico, Chico, CA 95929.

Methods

The 283-ha Kopta Slough Preserve, managed by TNC, is located on the west bank of the Sacramento River, 10 km east of Corning, in Tehama County, California, USA. The area has a Mediterranean climate, with an average annual precipitation of 54 cm. Soils are mapped as Columbia loam.

Acorns were harvested from the ground in October/November 1992 from three locations within 10 km of the site and stored in a cool place until planting.

Four locations in two second-year alfalfa fields were sown with valley oak acorns in December 1992. Three acorns were planted at each of the 432 planting spots in the two competition levels described below (864 total). Since acorn mass may affect emergence (Tecklin and McCreary 1991), mean acorn mass was estimated before planting, for each group of acorns to be planted in each set of treatment plots for each location.

Acorn predation and seedling mortality from animals, especially small mammals, are common problems for oak restoration/regeneration studies (Adams and others 1987, Adams and others 1991, Adams and Weitkamp 1992, Griffin 1980, McBride and others 1991, McCreary and Tecklin 1993, Plumb and Hannah 1991). Unfortunately, the project was too large to protect seeds at each of the 864 planting spots. However, a buffer zone (~183 m) was left between potentially high rodent populations and experimental locations. Acorns also were sown approximately 5 to 10 cm into the soil, as this can reduce acorn predation (Davis and others 1991, Tietje and others 1991). Although each seedling had a milk carton placed around it, milk cartons protected seedlings from herbicide applications more than herbivores.

Two levels of competition were established in March 1993: high (alfalfa) and low (reduced-alfalfa). In the high competition treatment, the alfalfa crop was not managed, such that it would grow over the valley oak seedlings. The low competition treatment entailed minimizing alfalfa and weeds by application of glyphosate herbicide in a meter-wide strip, three times during the growing season.

Measurements described below were taken during the 1993 growing season. Competitive ability of valley oak seedlings was assessed by percent emergence as of June, and by monthly survival and growth measurements made from April through September. Bimonthly midday photosynthetic photon flux density (PPFD) measurements, taken at valley oak seedling tops from July through September, described the light regime in each competition level. Bimonthly July-through-September stomatal resistance and soil moisture, as well as September stem predawn water potential, were used to study water relations. Emergence and survival data were analyzed using χ^2 tests. All other response variables were analyzed with least squares regression ANOVA.

Results

Valley oak seedling emergence did not differ significantly between alfalfa and reduced-alfalfa (4 percent versus 13 percent, respectively; $P = 0.823$). A negative relationship was found between percent emergence and acorn mass ($r^2 = 0.575$), with the heaviest acorns having the lowest emergence (0.3 percent) and the lightest acorns having the highest (11 percent) emergence.

June census of emerged seedlings was used as the baseline for percent survival. Seedlings grown in low competition had statistically greater survival (100 percent) than seedlings in high competition (58 percent) for July, August, and September ($P < 0.0001$). Patterns of growth, expressed as heights, also were significantly different between competition levels (*fig. 1*). Survival and growth were reduced 42 and 46 percent respectively, for seedlings grown in alfalfa.

Throughout the season, midday PPFD at seedling tops was decreased an average of 13-fold for alfalfa-grown seedlings (*fig. 2*). September predawn water potential was less negative in the low competition than in the high competition (-0.447 MPa vs. -0.875 MPa; $P < 0.0001$). Stomatal resistance and soil moisture also differed significantly (*figs. 3* and *4*). Thus, water availability was decreased as indicated by lowered percent soil moisture, increased stomatal resistance, and lowered predawn water potential for valley oak seedlings in alfalfa, despite irrigation.

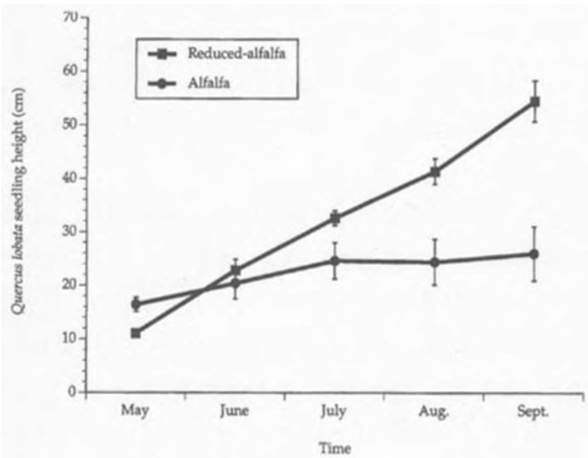

Figure 1—Mean heights of valley oak seedlings for high (alfalfa) and low (reduced-alfalfa) competition levels with standard error bars (n = 6, n = 10, respectively). Growth (as height) was significantly lower in alfalfa than in reduced-alfalfa (P=0.027).

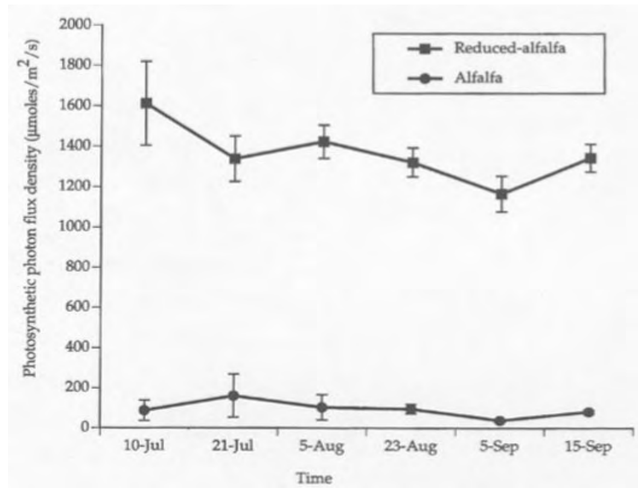

Figure 2—Mean midday photo-synthetic photon flux density (PPFD) (µmol/m^2/s) of valley oak seedlings in each competition level with standard error bars. PPFD was significantly lower in the alfalfa than in the reduced-alfalfa ($P < 0.0001$). Sample size differed between treatments and among months as follows: reduced-alfalfa n = 5 for 10-July and n = 10 for other times; and, in chronological order, alfalfa n = 3, 6, 6, 5, 6, 5.

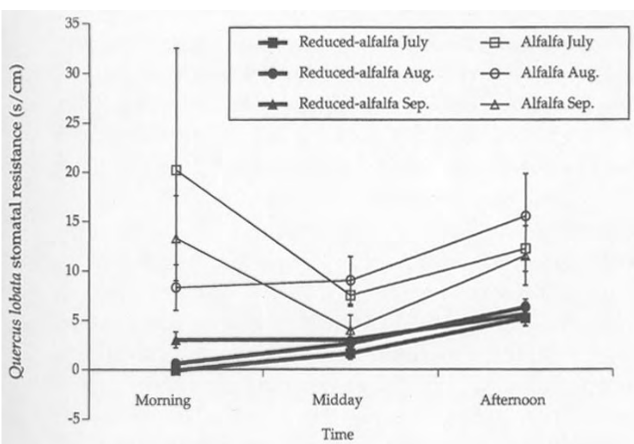

Figure 3—Mean stomatal resistance (s/cm) of valley oak seedlings in each competition level during the day with standard error bars. Stomatal resistance was significantly higher in the alfalfa than in the reduced-alfalfa ($P < 0.0001$). Sample size differed between treatments, among months and times of day as follows: in chronological order, reduced-alfalfa n = 5, 15, 15 for July, n = 15, 20, 20 for August, n = 20 all times for September; in chronological order, alfalfa n = 3, 9, 6 for July, n = 8, 10, 10 for August, n = 10, 8, 10 for September. Bimonthly measurements were averaged for each month.

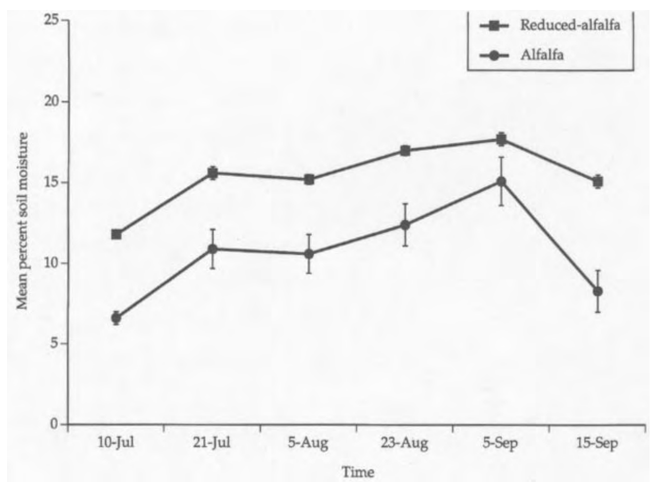

Figure 4—Mean percent soil moisture of valley oak seedlings in each competition level with standard error bars. Percent soil moisture was significantly lower in the alfalfa than in the reduced-alfalfa ($P < 0.0001$). Sample size differed between treatments and among months as follows: reduced-alfalfa n = 5 for 10-July and n = 10 other times, and alfalfa n = 3 for 10-July and n = 5 other times.

Implications for Valley Oak Restoration

Reduction of valley oak seedling survival and growth by less than 50 percent when grown with 13 times less light and reduced water availability in the alfalfa treatment reflects the ability of the valley oak seedlings to persist in suboptimal environments. This suggests a reasonable competitive ability for valley oaks in alfalfa. Griffin (1980) noted the persistence of valley oak seedlings in dense grass cover after three years in his Carmel Valley studies. Similar results also were found for valley oak plantings in grass cover after one and two years at Llano Seco Ranch south of Chico, California (J. G. Hubbell and F.T. Griggs, unpublished data[3]). Valley oak seedling tolerance for reduced water availability is in part due to deep tap roots initiated during fall acorn germination, as well as other morphological and physiological features typical of plants adapted to an arid climate.

[3]Unpublished data on file, The Nature Conservancy, Hamilton City, CA

Low overall percent emergence was probably due to granivores such as California ground squirrels (*Spermophilus beecheyi*), pocket gophers (*Thomomys bottae*), mule deer (*Odocoileus hemionus*), etc., since acorn shells were found at most planting spots in March 1993. However, no quantitative analysis was done. A negative relationship was found between acorn mass and percent emergence, with the lightest acorns having greater percent emergence than the heaviest. This relationship may further implicate granivory if animals preferentially selected large acorns, as might be suggested by optimal foraging theory. Despite efforts to reduce seed predation, so few seedlings emerged at the two locations closest to the buffer zone, that they were dropped from the study. Thus granivory confounded any assessment of competitive ability of valley oak in terms of emergence.

Seed predation in this study further supports the importance of considering granivores at restoration sites. Even if seedling transplants are utilized, they are subject to mortality from the same small mammals that are responsible for most seed predation (Adams and Weitkamp 1992, Tecklin and McCreary 1993). Thus an estimate of granivore/herbivore populations would be helpful. If granivore/herbivore populations are known to be high, then appropriate proven measures can be taken, such as above and below ground screening, tree shelters, etc., for small-scale projects. At present I am unaware of any large-scale measure that has been quantified, and is both economical and ecologically appropriate. Poisoning has long been used by farmers but is in disfavor for obvious ecological reasons. Flooding and raptor posts appear to be the most promising possibilities for lowland projects (Griggs and Peterson 1997). This is an area that needs further research.

The need to reduce light and water competition for valley oak seedlings depends on the goals of the restoration project. For projects requiring high survival, competition reduction (i.e., crop/weed control) or sowing more acorns than needed, will be necessary. For projects where lower survival and growth are acceptable, competition reduction could be minimized or eliminated (e.g., projects done by volunteers, where resources may be limited). However, as Adams and Weitkamp (1992) point out, competition may be irrelevant unless seed/seedling predators are controlled.

Acknowledgments

I gratefully acknowledge the invaluable field assistance of Rickelle Syrdahl, Shelly Kirn, Dave Wood, Rory Sheehan, Ben Scherb, Jenny Marr, and Doris and Larry Phillips. Thanks to Tom Griggs of TNC for help with planning, applying herbicide, and keeping the applied questions in mind. Comments by Dave

Wood, Bob McNairn, Jim Pushnik, and Larry Hanne of California State University-Chico and Daryl Peterson of TNC also were helpful in reviewing this poster and manuscript. This project was funded by The Nature Conservancy, San Francisco, California.

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The Effects of Native Soils on Engelmann Oak Seedling Growth[1]

Thomas A. Scott[2] Nanette L. Pratini[2]

Abstract: *We present 6 years of data from a study of restoration techniques for the Engelmann oak (*Quercus engelmannii*), a southern California endemic. Acorns and 1-year-old seedlings treated with native soil collected from a stand of native oaks were more vigorous than comparison trees in all measured variables: survival, tree height, trunk diameter, leaf volume, number of new leaves in spring, and number of trees producing acorns. These differences were apparent after the first year and have continued well into their sixth year. Results of root excavations in the second year were equivocal, with no significant differences in mycorrhizal infection rates or root length between treatments.*

The Engelmann oak (*Quercus engelmannii*) is endemic to Orange, Riverside, and San Diego Counties in southern California (Scott 1990). In 1988 we initiated a study of the effects of several commonly used restoration techniques on Engelmann oaks at South Coast Research and Extension Center (SCREC). The most successful of these was the addition, at the time of planting, of soil collected from under mature Engelmann oaks. These soils (hereafter referred to as native soils) may confer benefits owing to the presence of mycorrhizae, other beneficial soil microorganisms, or plant nutrients.

We have monitored growth and vigor of these trees from 1989 to present. The conditions at SCREC are not natural (we used weed control and irrigation); we wanted to test the potential growth rate enhancement that could be achieved if oaks were planted into a disturbed site and given a certain amount of post-planting care.

Methods

Study Site

SCREC is a University of California field station located in southern Orange County, at the approximate northern boundary of the species' natural range. Annual precipitation is slightly lower at SCREC than in most of the Engelmann oaks' range, but temperature and evapotranspiration rates are similar. The field was grown in barley from 1984 to 1988 in an effort to remove agricultural residues. The soil is classified as San Emigdio, a fine sandy loam. Soil depth is 60-120 inches, pH is moderately alkaline (7.8 - 8.4), and the soil is slightly calcareous. The field was sprayed with glyphosate approximately 4 weeks before seedling emergence in early 1989; subsequent weed control was through mechanical means (mulching, hand-trimming when necessary, and disking between rows). Seedling irrigation was based on CIMIS (California Irrigation Management Information System) estimates of weekly evapotranspiration rates (Scott 1991).

Seed Stock

All acorns were collected from a single Engelmann oak, located at Camp Pendleton Marine Base, San Diego County. It occurred in a relatively isolated stand with only four trees upwind as potential pollen sources. Acorns less than

[1] Presented as a poster at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996; San Luis Obispo, Calif.

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0.176 ounces and greater than 0.243 ounces were discarded; all others were germinated with peat and vermiculite until planting (approximately 2 weeks).

Acorns for the trees planted as seedlings were collected in the fall of 1987. They were planted into 4-in. by 12-in., 1-gal containers and grown in a greenhouse until November 1988.

Treatments

Native soil was collected from an Engelmann oak woodland at the Santa Rosa Plateau in western Riverside County. After removing leaf litter and debris, soil was taken to a depth of 7.8 inches, transported to SCREC (2 h) and used in planting.

In November 1988, acorns and seedlings were planted in four rows spaced 19.7 feet apart at SCREC. Acorn planting sites (n = 80) were placed 9.8 feet apart along the rows. Seedling planting sites (n = 40) were placed 19.7 feet apart along the same rows. Acorn treatment pairs consisted of quadruplets of equal radicle length, planted two per site. Fifty-six quadruplets were planted at 112 emitters along four irrigation lines. Seedling treatment pairs consisted of treated and nontreated seedlings matched by height.

Acorn treatment sites were excavated to a depth of 3.9 inches and backfilled with 1.1 pint of either field soil or native soil. Planting sites for the container trees were backfilled with either 1.1 lb of native soil amendment or field soil around the root and soil mass (approximately 7.7 lb). Twenty-eight seedling pairs were planted along the same four irrigation lines.

Measurements

Tree measurements were taken on a monthly basis for the first 4 years of the study and on an annual basis thereafter. Trunk diameters were measured at 3.2 inches above ground. As some trees had multiple main stems, total basal area of the combined stems was used for treatment comparisons. Leaf density in July 1994 was visually rated on a scale of 1-10, where 1 = sparse leaves and 10 = many leaves. The proportion of new leaves was visually estimated in March 1995 and assigned a score of 1 (no new leaves), 2 (new leaves on <30 percent of the branches), or 3 (new leaves present on 30 percent or more of the branches). The number of acorns produced on a tree (in October 1994) was ranked on a scale from 0 (no acorns) to 3 (most branches with several acorns each). All measurements and rankings were done by the second author. If more than one seedling emerged from an acorn planting site, both were left in place but only the largest (at 1 year of age) was monitored. Roots of the trees planted as seedlings were examined for the presence and extent of mycorrhizal fungi infection in July and August 1991 (2.5 years post-planting). Approximately 27 pints of soil were excavated from the north side of each tree at a distance of 3.9 inches from the trunk. Root material was sifted from the soil, refrigerated in water-filled vials, and examined within 1 day of collection. Total length of root fragments in the sample and the proportion of mycorrhizal-infected root tips were measured for each tree.

Results

Emergence rates of the acorns planted with and without native soil amendment were similar (85/112 and 80/112, respectively), but by January 1995, significantly more treated trees than untreated trees were still alive (*table 1*) (t-test, $P < 0.005$) (paired t-tests could not be performed because of the low number of pairs with both trees still alive in 1995). Survivorship was also significantly higher in the trees planted as seedlings with native soil than in the comparison trees (t-test, $P < 0.05$).

Table 1—Summary of differences between acorn and seedling trees planted with field soil and with native soil for the measured characteristics[1]

Soil treatment	Acorn trees			Seedling trees		
	Field soil (n = 19)	Native soil (n = 35)	Significance[2]	Field soil (n = 19)	Native soil (∑= 26)	Significance[2]
Emergence (*pct*)	71	76	n.s.			
Survival (*pct*)	46	88	***	63	90	*
Mean height (*feet*)	16.1	21.3	***	19.2	23.8	***
Mean basal area (*feet*^{2})	4.9	10.2	***	7.9	12.7	**
Mean leaf density rating (scale 1-10)	6.3	7.6	***	7.1	7.9	n.s.
Mean new leaf rating (scale 1-3)	2.5	2.9	**	2.9	2.9	n.s.
Trees producing acorns (*pct*)	32	57	n.s	58	65	n.s
Mean acorn crop rating (scale 0-3)	0.4	1.2	n.s.	1.1	1.4	n.s

[1]Measurments and significance tests are described in the text.
[2]*** = $P < 0.005$, ** = $P < 0.01$, * = $P < 0.05$, n.s. = $P \geq 0.05$

Mean tree height in January 1995 was significantly greater in the treated trees than in the comparison trees (t-test, $P < 0.005$). This was true for both the acorn-planted trees and the seedling-planted trees (hereafter referred to as acorn trees and seedling trees, respectively). Mean trunk basal area (in 1994) was also significantly greater in treated acorn trees (t-test, $P < 0.005$) and seedling trees ($P < 0.001$) than in comparison trees (*table 1*).

Treated acorn trees had higher mean scores for new leaf production (chi-square, df = 1, $P < 0.001$) and higher leaf density ratings (chi-square, df = 3, $P < 0.005$) than comparison trees. New leaf ratings and leaf density ratings for the seedling trees were slightly higher than in comparison trees, but not significantly so ($P > 0.05$).

Although a higher proportion of treated trees produced acorns in 1994 than comparison trees, the differences were not significant (chi-square, df = 1, $P > 0.05$). Acorn crop ratings were also nonsignificantly higher in soil-amended acorn and seedling trees than in nontreated trees (chi-square, df = 3, $P > 0.05$).

For the excavated root samples of treated (n = 27) and comparison (n = 23) seedling trees, neither mean total root length (378.5 and 363.7 feet, respectively) nor mycorrhizal infection rates (26 percent and 21 percent, respectively) could be differentiated between the treated and comparison trees planted as seedlings (paired t-test: df= 36, $P > 0.05$).

Discussion

Even after six growing seasons, the trees planted with native soil amendment were more vigorous than comparison trees in every variable measured. The treatment seemed to be most effective when used with acorns. Further research and analysis will, we hope, determine the most efficient techniques for long-term monitoring of tree vigor in this species.

Although we can define the benefit of using native soils to augment tree growth, we cannot precisely define the cause. Three possible explanations are:

(1) mycorrhizal infection rates were higher at treated sites the first year or two after planting but have decreased to background levels or spread to neighboring nontreated sites; (2) the benefit resulted from other biological factors in the native soils such as nitrogen-fixing bacteria, nematodes, or mites; or (3) the early benefits resulted from physical or chemical properties of the native soils, such as nutrients, pH, or soil structure. These are, of course, not mutually exclusive, and the result may have been a combination of factors. Planting sites were completely interspersed, and the trees with the highest growth rates were randomly distributed across the field; therefore it seems that field or systematic effects are unlikely. The lack of a sterilized comparison treatment does not allow us to rule out benefits resulting from physical or chemical differences between treatments. Additionally, we have observed significant, although less dramatic, differences in growth rates of Engelmann oaks grown in sterilized and unsterilized native soils collected from the same area (unpub. data[3]). The possible effects of other biological factors also cannot be ruled out, but would not be expected to cause by themselves the differences in growth that we observed. The first explanation is also difficult to rule out, that mycorrhizae from the native soil conferred a growth advantage during the first 2 years.

[3] Unpublished data on file, Dept. of Earth Sciences, University of Calif., Riverside.

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Conservation Reserve Program (CRP) Oak Regeneration Study[1]

William H. Weitkamp[2] Sally L. Yoshida[3] William D. Tietje[4]

The federal Conservation Reserve Program (CRP) was begun in 1985 to conserve and improve natural resources by taking highly erodible cropland out of grazing and crop production for at least 10 years. In California, San Luis Obispo County and southern Monterey County lead in CRP participation, with more than 100,000 acres of privately owned land entered in the program. Much of this land is blue oak (*Quercus douglasii*) or valley oak (*Q. lobata*) rangelands. During autumn 1995, we conducted a pilot study to acquire information for setting up a research project on the effects of the CRP on oak regeneration (*figs. 1* and *2*).

Study Objectives

Pilot Study

- Test study methods for site selection, field sampling, and data analysis.

Follow-up Study

- Assess oak regeneration on CRP versus non-CRP oak rangelands.
- Provide initial assessment of effect of CRP on the sustainability of oak rangelands.

Study Sites

CRP and non-CRP sites for the pilot study were established on ranches in northern San Luis Obispo and southern Monterey Counties (*fig. 3*). Criteria for selection were that the ranch was in the oak (*Quercus* spp.) woodland vegetation type and that it had been in the CRP for at least 5 years.

Methods

The Farm Service Agency (FSA), formerly the Agricultural Stabilization and Conservation Service (ASCS), administers the CRP. We identified eight ranches from aerial photos obtained at the FSA Office in San Luis Obispo County (*fig. 4*). On three of the ranches, a CRP site was compared with a nearby non-CRP site that was similar in tree cover and topography but was grazed by cattle.

At each ranch, we explored the use of two techniques to detect the level of oak regeneration: (1) Strip Transects, 25 m long and 6 m wide, established in the four cardinal directions at randomly selected mature oak trees within the CRP and non-CRP sites, and (2) Timed Searches of the CRP and non-CRP sites. Oak species and height were recorded for all seedling and sapling trees encountered along the transects or during the timed searches.

Results and Discussion

Pilot Study

The number of seedlings found per 120 minutes in the timed searches varied from 0 to 299 for three non-CRP fields and from 0 to 150 for nine CRP fields (*fig. 5*). The study areas in general had a low percentage of tree cover (see *fig. 4*), and the trees

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[1] Presented as a poster at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996, San Luis Obispo, Calif.

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Figure 1—Non-Conservation Reserve Program (non-CRP) land, which has been grazed by livestock, served as a control for the study.

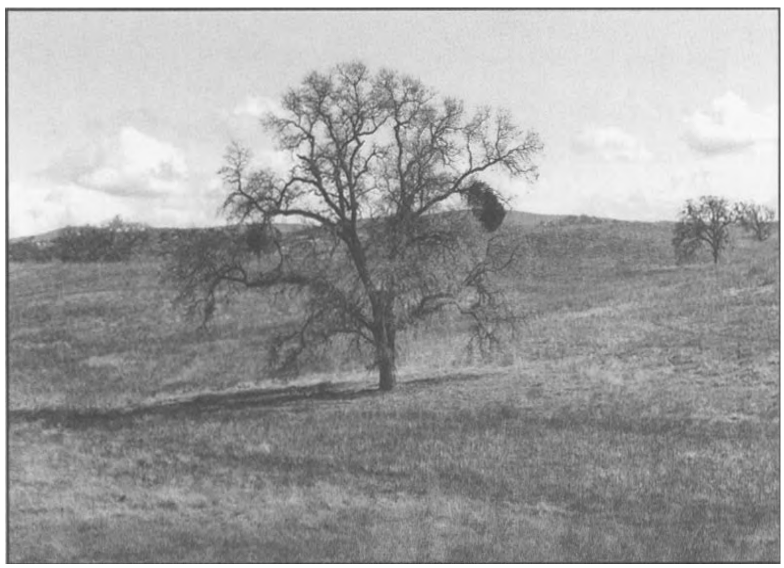

Figure 2—Conservation Reserve Program (CRP) land–no farming or livestock grazing has occurred on this land since being entered into the Program.

were located mainly in riparian areas, along fences, and on steep hillsides. Most seedlings were found within 15 meters of the drip lines of mature oak trees.

Because of the great variation in seedling counts and the small number of non-CRP fields, no statistically valid comparison of oak regeneration could be made between CRP and non-CRP fields. However, the number of seedlings found per unit of time (120 minutes) during the timed searches was positively and significantly ($P \leq 0.10$) correlated with the number of seedlings found per unit of area during the transect searches. Spearman's rank correlation coefficient between timed and transect searches was 0.6276 ($P = 0.0704$) as computed across management regimes on nine fields.

Follow-up Studies

Aerial photos will be used to select approximately 10 pairs of CRP and non-CRP fields. Because the pilot study indicated that timed searches were more efficient than area-constrained (transect) searches, timed searches will be used to count oak seedlings. The results will be used as baseline data to compare with future surveys and to assess the effects of eliminating farming and livestock grazing on oak regeneration.

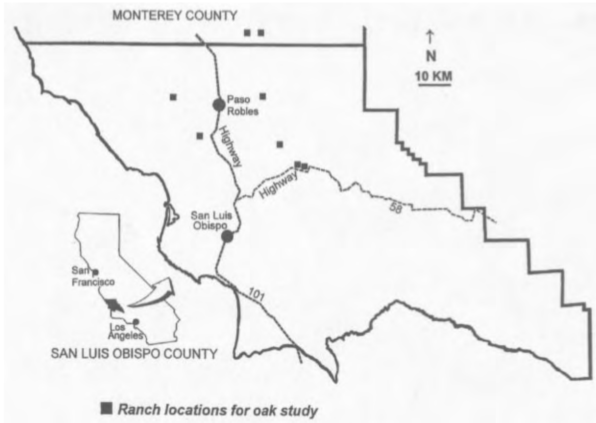

Figure 3—San Luis Obispo and southern Monterey Counties showing the locations of the eight ranches selected for study sites.

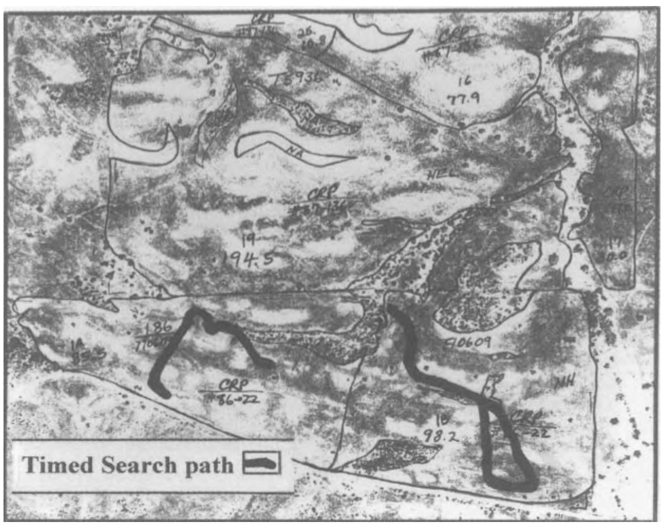

Figure 4—Aerial photos from the Farm Service Agency (FSA) in San Luis Obispo County were used to locate study sites and delineate Conservation Reserve Program (CRP) and non-CRP areas.

Figure 5—Non-Conservation Reserve Program blue oak woodland showing oak regeneration on area with planned grazing by cattle.

Acknowledgments

We thank the owners of the eight ranches, on which data were collected, for allowing access for study purposes. Justin K. Vreeland summarized the data. We appreciate the assistance given for the study by the Farm Service Agency Office, San Luis Obispo County. The study was funded by the University of California Cooperative Extension.

Quercus wislizenii Growth Rings[1]

Scott D. White[2]

Introduction

Growth rings are often used to determine ages of trees and shrubs, but interpretation necessitates (1) stem cores or cross-sections and (2) verification that rings are produced annually. Collecting cores from dense-wooded shrubs and hardwood trees is difficult and unreliable, because growth rings are rarely centered at the geometric centers of the stems. Cross-sections provide reliable data, but necessitate destructive sampling and may be inappropriate in many study areas. If reliable, stem diameter would provide a faster and less destructive technique to determine age, though it would not be as accurate as ring counts. This report describes *Quercus wislizenii* (interior live oak) growth rings in the San Bernardino Mountains (San Bernardino Co., California) and provides a linear regression of ring number vs. stem diameter as a means of estimating stem age. I anticipate that a clearer understanding of ring deposition will help generate a model of *Q. wislizenii* forest stand development and stem dynamics. Keeley (1992, 1993) has verified the annual nature of growth rings in several chaparral shrubs and used growth rings to analyze stem recruitment and shrub demography in long-unburned chaparral. He did not publish data for *Quercus wislizenii*, but his 1992 paper provided a regression equation to estimate stem ages from their diameters with constant values for 22 species, including *Q. wislizenii* at Mt. Tamalpais (Marin Co.). My results are compared with Keeley's regression line.

Methods

Four cross-sections were collected from living *Quercus wislizenii* stems and two adjacent *Prunus ilicifolia* stems. *P. ilicifolia* was selected for comparison because (1) it was growing within the same stand, (2) Keeley (1993) has established the annual nature of its growth rings, and (3) its rings were readily recognized and compared with rainfall data. Seventeen additional cross-sections were collected from dead *Q. wislizenii* stems on a fuelbreak site where much of the vegetation had been cleared and removed. Stem sections were prepared by sanding with 180-grit sandpaper on bench-mounted and/or hand-held disk sanders. Growth rings of the living *Q. wislizenii* and *P. ilicifolia* stem cross- sections were counted using a binocular dissecting microscope and correlated as closely as possible to annual rainfall data (San Bernardino County Flood Control District). After a correspondence between rainfall and ring width was established for recent decades, additional rings were counted without reference to rainfall data. Most *Q. wislizenii* stems are roughly elliptical in cross-section. Stem diameters were estimated by averaging the widest and narrowest distances across the cross-sections.

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Results and Discussion

Keeley (1993) concluded, "there is good evidence that for many shrubs growth rings give a close approximation of age," but cautioned against "assigning specific years to most rings." I find that *Quercus wislizenii* growth rings fit his synopsis closely.

Cross-sections taken from living *Prunus ilicifolia* stems clearly showed a series of closely spaced rings corresponding to the 1984-1990 drought years and a series of wide and narrow rings corresponding to high and low rainfall years in 1969-1972. *Quercus wislizenii* rings are much more uniform, but very narrow rings correspond well to years of exceedingly low rainfall in 1989 and 1972. Studying the appearance of rings dated to known rainfall years in cross-sections collected from living plants facilitated interpretation of cross-sections from dead plants in which the outermost ring could not be dated to a known year. Annual rings were generally distinguished from "waves" by the appearance of a few regularly spaced wide vessel elements in each one (see Keeley's [1993] description of *Q. dumosa* rings). Visible *Q. wislizenii* growth rings do not always correspond precisely to calendar years. Several of the cross-sections examined had discernible rings merging in a 'Y' pattern into either a single ring or a pair of rings so closely spaced that they could not be resolved under the microscope. The dead stems, particularly older ones, were often discolored and thus more difficult to interpret and a few closely spaced rings may have been overlooked. Even with these difficulties, rings reflecting rainfall patterns of the early 1970's correspond within a year or two to their count dates.

Linear regression of stem diameter against ring count is shown in *figure 1*. *Quercus wislizenii* stem diameters in the San Bernardino Mountains are larger than those at Mt. Tamalpais (Keeley 1992), perhaps because of lower latitude and a (presumably) longer growing season.

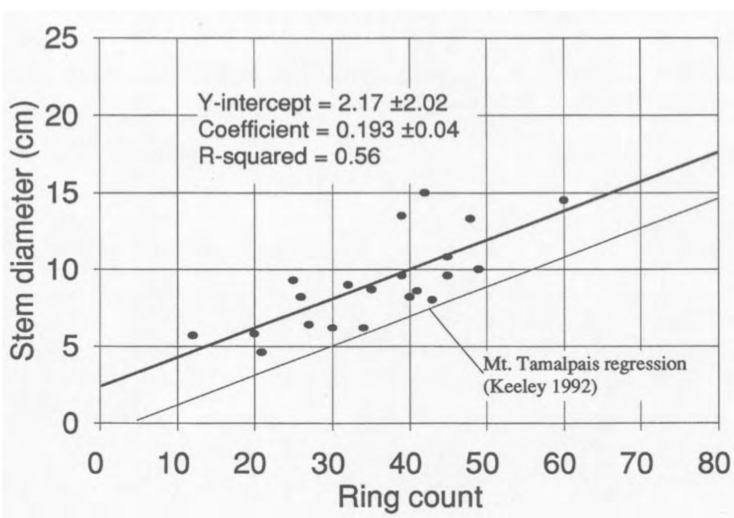

Figure 1—Regression of stem diameter vs. ring count for *Quercus wislizenii* in the San Bernardino Mts. (heavy line) and Mt. Tamalpais, California.

Ring widths were not measured or compared statistically, but ring width tended to be much more consistent from year to year within a single *Quercus wislizenii* stem than within a single *Prunus ilicifolia* stem or within single stems in Keeley's (1993) data. This may reflect deep rooting by *Q. wislizenii,* perhaps enabling constant growth rates even in years of relatively low rainfall. Wide variation in average ring width among stems was evident and is reflected by the regression line's wide standard errors (*fig. 1*). This pattern indicates that some stems grow much more vigorously than others, regardless of rainfall or other factors causing rapid or slow growth in any particular year. This variation may reflect differential light availability, insect attack, interaction with adjacent vegetation, or resource allocation to other products (e.g., acorns) among stems or among individual plants.

Quercus wislizenii forest stands in the San Bernardino Mountains have been defined on the basis of stem structure (White and Sawyer 1994). In each of these stands, at least 5 percent of the sampled stems were ≥15 cm in diameter, and in most of these stands, at least 5 percent of sampled stems were ≥20 cm in diameter. If these large stems follow the regression equation, then the oldest living stems in forest stands have expected ages of 75 to 100 years and minimum ages of 45 to 70 years. Since *Q. wislizenii* clones continually recruit new stems, stem ages cannot be taken to represent stand ages. If these forests replace dead canopy stems with new recruits, as seems likely, then the forests themselves may be much older.

I plan to refine the analysis presented here by increasing the sample size (particularly among larger stems), verifying the annual ring pattern against additional species with known annual growth rings, and comparing variation in ring widths among years, substrates, and geographic locations. I particularly hope that a larger sample size will reduce the regression line's standard errors and enable more precise determination of stem age based on diameter. A time-based model of stem recruitment and turnover in *Q. wislizenii* shrubland and forest canopies will be developed by applying the regression to existing stem diameter data.

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Pruning Oak Resprouts to Enhance Growth

Sheila J. Barry[1] Ronald S. Knight[2] Douglas D. McCreary[3]

Introduction

Firewood harvest on California's hardwood rangelands has increased since the mid-1970's with the expanding markets for firewood. There has been considerable concern about the amount of oak regeneration occurring in harvested areas and whether these stands can be sustained. However, one rancher in Tehama County (California) observed that oaks on his property sprout vigorously and grow rapidly after harvests. He has witnessed the same trees harvested twice during his lifetime and anticipates harvesting them again in the near future. Many other ranchers have also commented on significant regrowth of their oak woodlands after harvest. Their testimony was supported by a recent study measuring stump resprouting from oak trees harvested in Shasta and Tehama Counties. More than 54 percent of harvested trees on 20 different range sites resprouted (Standiford, 1996).

Unfortunately, oak resprouts initially seem to take on the form of a "bush." Numerous sprouts grow from a single stump. Over time, only two or three dominant sprouts seem to persist, and the regrowth takes on the form of a multi-stemmed tree.

In 1987, a study was initiated to investigate whether pruning 2 year-old oak stump regrowth to two dominant sprouts would enhance regrowth. It was thought that enhancing regrowth could result in a viable oak tree sooner and a shorter harvest interval.

Materials and Methods

A blue oak (*Quercus douglasii*) range site, west of Red Bluff, was selected for this study because of its history of successful stump sprouting and rapid growth of resprouts. Before the harvest in fall 1985, the site had 100 percent canopy cover with 300 trees/ha. Approximately 7 cords per ha were harvested.

Two years after the harvest, regrowth on 10 stumps was pruned. Two dominant sprouts were left unpruned on each stump. The 10 pruned stumps were paired with 10 nonpruned stumps with similar regrowth. Two dominant sprouts were identified from among the regrowth on each unpruned stump. Stumps were paired on the basis of location and similarity of size. Paired stumps were within 3 m of one another. From February 1987 to September 1990, the regrowth from the pruned stumps was controlled (pruned) so that only the two dominant sprouts persisted. After September 1990, further new sprouting ceased.

Basal diameter and height of the two dominant sprouts from both pruned and nonpruned stumps were measured immediately after the pruning in February 1987 and repeated in the early fall of 1987 to 1990, 1993, and 1995. Basal diameter of the stump was measured 10 cm above the ground line. In 1987-1990, dominant sprouts were straightened out to measure height. Height was measured as the distance from the ground to the tip. In 1993 and 1995, sprouts had grown too tall to straighten, and heights were measured to the top of the sprouts using a measuring stick.

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Means and standard deviations for basal diameter and height of sprouts from pruned versus unpruned stumps were calculated for each measurement date. Significant differences between means were determined using two-sample *t*-tests (Nintze 1995). Means from data with normal distribution were compared using the Equal-Variance Test. Means from data not normally distributed were compared using the Mann-Whitney *U* test. All means exhibited equal variance. Differences reported as significant were at the $P < 0.05$ level.

Results and Discussion

There were no significant differences between either the diameter or height of dominant oak sprouts on pruned versus unpruned stumps at time of pruning (*tables 1, 2*). However, after the first growing season, the dominant oak sprouts on pruned stumps had significantly larger diameters than those on unpruned stumps (2.88 cm versus 2.50 cm, respectively). Significant differences in height of dominant oak sprouts from pruned versus unpruned stumps were not achieved until after the second growing season (295.8 cm versus 271.5 cm, respectively). Although the relative difference in height and diameter of sprouts from pruned versus unpruned stumps has been maintained for the past 8 years, these differences in general have not increased very much. For example, in July 1995, dominant sprouts of pruned trees had a significantly larger basal diameter (9.8 cm vs 8.4 cm) and were significantly taller (465 cm vs. 440 cm) than sprouts of

Table 1*—Diameter of oak sprouts from pruned vs. unpruned (control) stumps*

Date	Mean		Standard deviation		*t*-Test	
	Control	**Prune**	**Control**	**Prune**	**Prob.**	**Test**
	cm		*cm*			
Feb-87	1.58	1.68	0.31	0.35	0.34	Equal-Variance *t*-test
Aug-87	2.50	2.88*	0.58	0.62	0.04	Mann-Whitney *U*
Aug-88	3.08	3.57*	0.61	0.77	0.03	Equal-Variance *t*-test
Aug-89	3.75	4.41*	0.83	0.87	0.01	Mann-Whitney *U*
Sep-90	4.32	5.10*	1.00	0.91	0.01	Equal-Variance *t*-test
Aug-93	6.42	7.41	1.78	1.42	0.10	Mann-Whitney *U*
Jul-95	8.40	9.75*	2.34	2.00	0.02	Mann-Whitney *U*

*Means are significantly different, $P \leq 0.05$

Table 2—*Height of oak sprouts from pruned vs. unpruned (control) stumps*

Date	Mean		Standard deviation		*t*-Test	
	Control	**Prune**	**Control**	**Prune**	**Prob.**	**Test**
	cm		*cm*			
Feb-87	199.9	206.6	35.5	33.9	0.55	Equal-Variance *t*-test
Aug-87	232.4	254.0	35.2	34.3	0.08	Mann-Whitney *U*
Aug-88	271.5	295.8*	41.8	46.5	0.05	Mann-Whitney *U*
Aug-89	287.1	322.8*	48.9	51.9	0.01	Mann-Whitney *U*
Sep-90	293.0	331.0*	59.1	54.4	0.01	Mann-Whitney *U*
Aug-93	372.2	403.2	59.9	70.0	0.14	Equal-Variance *t*-test
Jul-95	439.0	462.5	74.3	69.3	0.30	Mann-Whitney *U*

*Means are significantly different, $P \leq 0.05$

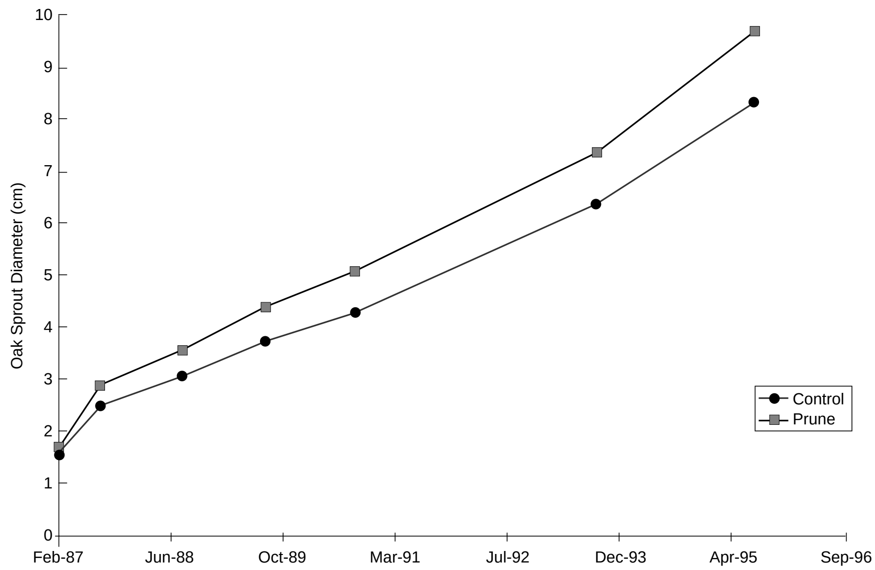

Figure 1—Diameter of oak sprouts from pruned vs. unpruned (control) stumps.

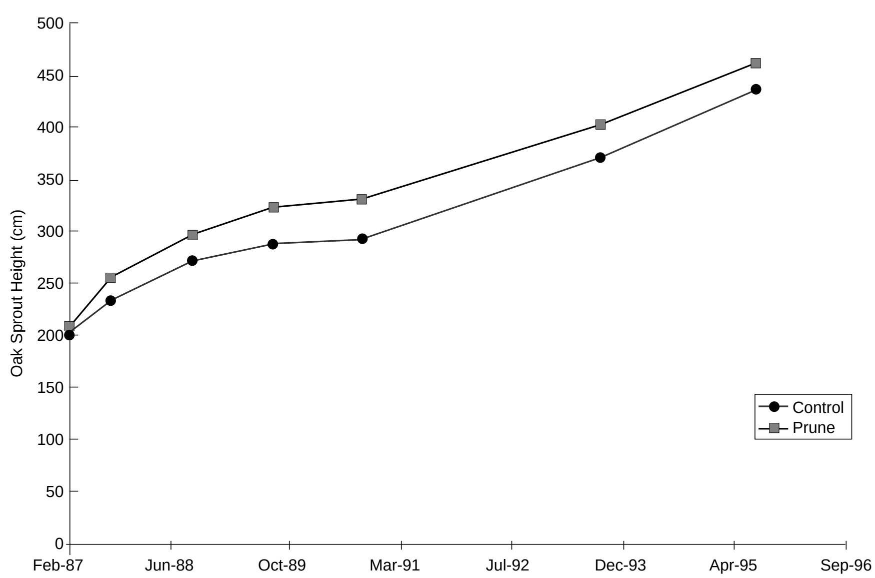

Figure 2—Height of oak sprouts from pruned vs. unpruned (control) stumps.

unpruned trees. *Figures 1* and *2* illustrate the diameter and height growth rate, respectively, of sprouts from pruned vs. unpruned stumps.

The initial hypothesis of this study was that pruning the regrowth of harvested oaks so that only two dominant sprouts persisted would improve the growth rate of the dominant sprouts and develop into a viable oak tree more quickly. After the first season of growth following the pruning, we observed that the sprouts from pruned stumps had larger diameters than those from unpruned stumps. After two growing seasons, similar observations were made in regard to height. Since these initial increases, however, the growth between the pruned and unpruned groups has been very similar. When considering differences in growth rates of sprouts from pruned versus unpruned stumps over an 8-year period, it seems that the additional growth achieved by pruning is relatively small and not worth the effort expended.

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Assessment of a Prescribed Burning Project: 1987–1995[1]

Neil K. McDougald[2] **William E. Frost**[3]

Abstract: *A multiple objective vegetation management program was initiated in 1986 to improve livestock management and provide an anchor for a community fuelbreak system. Burn preparation activities and the prescribed burn greatly reduced woody vegetation canopy cover in areas where the initial canopy cover was dense. Primary reductions were from removal of the shrub component and interior live oak (*Quercus wislizenii*). Blue oak (*Quercus douglasii*) and valley oak (*Quercus lobata*) were largely unaffected, partially because of their occurrence in areas of less dense vegetation and lower canopy cover than those where interior live oak was found.*

A multiple objective vegetation management program was initiated in 1986 to improve livestock management and provide an anchor for a community fuelbreak system through manipulation of woody vegetation on the Ellis Ranch near North Fork, California. A 600-acre burn was conducted in 1987 through the California Department of Forestry's Vegetation Management Program with the goal of reducing the canopy cover of woody plants and the fuel volume. Accomplishment of these goals would increase accessibility to the land for the livestock producer, resulting in increased efficiency and effectiveness in livestock management, and provide an area for fire suppression activities to be successful in stopping a wildfire before it reached the community.

Study Area

The Ellis Ranch is located two miles southwest of North Fork on Road 200, Madera County, California. The ranch ranges from 2,500 to 3,250 feet in elevation and receives an average of 32 inches of precipitation annually. Three soil series are present on the ranch: Ahwahnee (*Mollic Haploxeralf*); Auberry (*Ultic Haploxeralf*); and Holland (*Ultic Haploxeralf*). The vegetation is mixed chaparral and oak with an understory of annual herbaceous plants. Dominant woody species include blue oak (*Quercus douglasii*), interior live oak (*Quercus wislizenii*), valley oak (*Quercus lobata*), foothill pine (*Pinus sabiniana*), wedgeleaf ceanothus (*Ceanothus cuneatus*), mariposa manzanita (*Arctostaphylos mariposa*), western mountain mahogany (*Cercocarpus betuloides*), western redbud (*Cercis occidentalis*), and California coffeeberry (*Rhamnus californica*).

Methods

In 1986 a Vegetation Management Program project was entered into by Walter Ellis and the California Department of Forestry. In summer 1987 approximately 600 acres of the Ellis Ranch, and neighboring ranches, were burned. Pre-burn preparation was conducted, consisting of crushing brush and interior live oak using a D-4 bulldozer, felling of selected foothill pine, and selective cutting of interior live oak for firewood.

Six 0.20-acre plots were established in 1986. These reflect each of the different canopy cover–slope class designations present in the project area, as described by Passof and others (1985). The classes present during the period of this study were:

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Class designation	*Slope*	*Canopy cover*	*Predominant tree species*
	pct	*pct*	
C	<30	26 - 40	Blue oak, valley oak
E	<30	41 - 60	Blue oak, valley oak
GG	<30	>60	Interior live oak
HH	>30	>60	Interior live oak

Each plot was sampled in 1986 before the burn preparation work had begun, in July 1987 after completion of burn preparation, in October 1987 following the August burn, in November 1988 and 1989, and again in November 1995. Each tree more than 4 inches d.b.h. was measured and heights estimated with a clinometer. Hardwood tree volume was determined using equations developed by Pillsbury and Kirkley (1984). Canopy cover was measured through the use of the line intercept method (Canfield 1941) on ten 92.5-foot transects randomly located in each plot beginning along the northeast boundary of the plot. Analysis of variance was conducted for the canopy cover measurements to determine whether a significant change had occurred among the sampling dates (Little and Hills 1978). All seedlings within each plot were counted.

Results and Discussion

Plot 1

At the beginning of the project, the site description for this plot was "HH", i.e., the area had greater than 30 percent slope and more than 60 percent canopy cover of predominately interior live oak. At the final sampling date the site was still classified as "HH" although much of the canopy cover was composed of yerba santa (*Eriodictyon californicum*), rather than predominately interior live oak.

The total canopy in 1986 was dominated by interior live oak with a fairly large blue oak component. Small amounts of other species were present, including foothill pine, mariposa manzanita, western mountain mahogany, California coffeeberry, and wedgeleaf ceanothus (*table 1*). Total canopy cover and interior live oak canopy cover were significantly reduced by pre-burn preparation. The selective crushing of interior live oak was also evident from the resulting piles which occupied 39 percent of the area upon completion of the preparation work.

Table 1—Canopy cover of woody vegetation in Plot 1.

Species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	1988	1989	1995
	pct					
Interior live oak	69a[1]	31b	6c	10c	13c	34b
Blue oak	15a	15a	3b	1b	10a	2b
Mariposa manzanita	3	1	0	0	0	0
Western mountain mahogany	3	2	0	0	0	0
Foothill pine	2	1	0	1	0	0
California coffeeberry	2	0	0	0	0	0
Wedgeleaf ceanothus	0	1	0	1	0	5
Yerba santa	0	0	0	3	7	26
Total canopy cover	94a	51b	10d	14cd	30c	66b

[1]Values in a row followed by a different letter were significantly different, $P > .05$

Burning also significantly reduced the total canopy cover. Both blue oak and interior live oak were significantly reduced as trees were killed, but left standing. In addition, the small shrub component was eliminated. Blue oak canopy in 1989 had returned to a level similar to that at the beginning of the study because of stump sprouting from the trees removed. By 1995 the blue oak canopy was significantly reduced because of mortality of the sprouts. Interior live oak canopy has increased to 34 percent from a low of 6 percent (*table 1*). These sprouts are increasing in size and are anticipated to recover to previous canopy cover levels.

Before preparation activities there were 40 interior live oak stems in the plot containing 1.21 cords of wood. Only seven were left following the burn preparation work, reducing the volume (*table 2*). All seven of these stems survived the burn but were subsequently removed by wood cutters in 1989. In contrast, all five blue oak trees in the plot were left untreated during the preparation work and remained standing following the burn. Blue oak wood volume was 2.57 cords at all sampling dates through 1988 (*table 2*). All blue oaks were removed by wood cutters during fall 1989.

Table 2—Volume of wood in Plot 1.

Tree species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	Post-burn 1988	Post-burn 1989	Post-burn 1995
	cords					
Interior live oak	1.21	0.72	0.72	0.72	0.00	0.00
Blue oak	2.57	2.57	2.57	2.57	0.00	0.00

Plot 2

The site designation for Plot 2 was “C” at both the beginning and end of the project, i.e., slope under 30 percent and canopy of 26 to 40 percent, predominately blue oak. Total canopy cover in 1986 was 33 percent (*table 3*) , composed largely of blue oak and interior live oak. No preparation work was conducted in Plot 2 and thus the canopy cover was similar in the second sampling. After the burn, the canopy cover was virtually identical to the cover in the initial sampling, with the exception of the removal of poison oak. No significant changes in canopy cover occurred in this plot during the period of the study.

Table 3—Canopy cover of woody vegetation in Plot 2.

Species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	Post-burn 1988	Post-burn 1989	Post-burn 1995
	pct					
Interior live oak	10	5	6	1	2	3
Blue oak	23	23	24	29	22	23
Wedgeleaf ceanothus	0	2	1	3	2	0
Poison oak	0	2	0	0	0	0
Mountain mahogany	0	0	0	0	1	0
Total canopy cover	33	32	31	32	28	26

All trees present in 1986 were unchanged following the burn. The tree stand consisted of four interior live oaks and five blue oaks. Total wood volume has not significantly changed over the 9 years (*table 4*).

Table 4—Volume of wood in Plot 2.

Species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	1988	1989	1995
	cords					
Interior live oak	0.15	0.15	0.15	0.15	0.15	0.15
Blue oak	2.56	2.56	2.56	2.56	2.56	1.83

Plot 3

Plot 3 was classified as an "E" site at the beginning of the study, with less than 30 percent slope and between 41 and 60 percent canopy cover, predominately blue oak. Blue oak composed the vast majority of the canopy cover in 1986, with small amounts of interior live oak, mariposa manzanita, wedgeleaf ceanothus, and foothill pine (*table 5*). Burn preparation work left the blue oak and removed most of the other four species. Burning significantly reduced the total canopy cover to 35 percent with all shrub species being removed. By the end of the project the site was classified as "C" as the total canopy cover had been reduced to 29 percent.

Table 5—*Canopy cover of woody vegetation in Plot 3.*

Species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	1988	1989	1995
	pct					
Interior live oak	5	0	0	0	0	0
Blue oak	37	40	35	35	28	35
Mariposa manzanita	4	0	0	0	0	1
Wedgeleaf ceanothus	1	0	0	0	0	0
Foothill pine	0	0	0	0	0	1
Total canopy cover	47a[1]	40ab	35b	35b	29b	37b

[1]Values in a row followed by a different letter were significantly different, $P > 0.05$

All trees within the plot were left standing, a volume of 0.80 cords of blue oak (*table 6*). The interior live oak reflected in the canopy cover were trees rooted outside the plot whose canopy partially covered the plot area. These were not included in the wood volume determination. In addition, the lone digger pine was left standing.

Table 6—Volume of wood in Plot 3.

Species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	1988	1989	1995
	cords					
Blue oak	0.80	0.80	0.80	0.80	0.80	0.82

Plot 4

Plot 4 typifies the situation where the slope was gentle (<30 percent) and canopy cover was dense (>60 percent), classified as "GG." At the beginning of the project, the canopy cover was 100 percent, primarily interior live oak (80 percent), with foothill pine, California bay (*Umbellularia californicum*), western redbud, and California coffeeberry comprising the remainder (*table 7*). The majority of shrubs were mature plants, in mostly unavailable form. Burn preparation work reduced the canopy cover to 86 percent, with the reduction largely due to removal of interior live oak. The western redbud canopy increased significantly because of a unique situation in which the plants were shifted off vertical to an approximate 45-degree angle by the bulldozer, yet remained rooted and growing. The prescribed burn eliminated both the interior live oak and all of the shrub component, with only the foothill pine remaining to make up all of the 11 percent canopy cover.

Table 7—Canopy cover of woody vegetation in Plot 4.

Species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	Post-burn 1988	Post-burn 1989	Post-burn 1995
	----- *pct* -----					
Interior live oak	80a[1]	39b	0d	30b	15c	26b
Western redbud	2c	18a	0c	6bc	14ab	15a
California coffeeberry	1	0	0	0	0	0
Foothill pine	15a	18a	11a	9a	0b	0b
California bay	7ab	11a	0c	2bc	0c	9a
Wedgeleaf ceanothus	0c	0c	0c	0c	6b	43a
Yerba santa	0	0	0	1	2	0
Total canopy cover	100a	86b	11d	48c	39c	93a

[1]Values in a row followed by a different letter are significantly different, $P > 0.05$

In 1989, 2 years following the burn, the canopy cover had increased to 39 percent, a mixture of interior live oak (15 percent), western redbud (14 percent), wedgeleaf ceanothus (6 percent), and yerba santa (2 percent). The age class of the community had changed dramatically from the beginning of the project, with interior live oak present only as sprouts, and the shrubs as all young plants and all available to browsing animals. Almost all shrubs exhibited little evidence of browsing. An exceptionally large number of seedlings were present for yerba santa (187) where no plants had been detected before this sampling.

In 1995, 8 years after the burn, total canopy cover was similar to the pre-project situation (93 percent). The makeup of the canopy was changed, with interior live oak comprising 26 percent, wedgeleaf ceanothus 43 percent, western redbud 15 percent and California bay 9 percent. This area has shifted from a tree-dominated canopy to a largely shrub-dominated canopy. The plants present are primarily mature plants with the exception of western redbud, which has an even mix of young and mature plants. The large number of seedlings of yerba santa present in 1989 did not persist to the 1995 sampling.

There have been no interior live oak trees recruited into the stand from seedlings, although 88 seedlings were present in the pre-project sampling, 22 in the post-preparation sampling, and two in 1989. The volume of wood in Plot 4 (determined for trees more than 4 inches d.b.h.) was reduced significantly, from 2.14 cords in the pre-project sampling, to 1.3 cords following preparation work, and 0 cords following the burn which removed all interior live oaks greater than 4 inches d.b.h. (*table 8*).

The site was still classified as "GG" at the end of the study, as the total canopy cover was returned to 93 percent from a low of 11 percent after the 1987 burn.

Table 8—Volume of wood (in cords) in Plot 4.

Species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	Post-burn 1988	Post-burn 1989	Post-burn 1995
	cords					
Interior live oak	2.14	1.30	0.00	0.00	0.00	0.00

Plot 5

Plot 5 is an example of an area with less than 30 percent slope and canopy cover dominated by large trees (valley oak), classified as "E" at both the beginning and end of the study. Total canopy cover at the beginning of the project was 58 percent, primarily valley oak (45 percent) and interior live oak (11 percent), with a small shrub component of California wild rose (*Rosa californica*) (2 percent) (*table 9*). The canopy cover has changed little over all phases of the project and through the 8 years after the burn. The valley oak, interior live oak, and wild rose components have not changed. A small increase in total canopy cover has occurred because of the establishment of blue oak and western redbud, both contributing 1 percent canopy cover in 1995. Despite the presence of valley oak and interior live oak seedlings on three sampling dates, none was successful in establishing.

Table 9—Canopy cover of woody vegetation in Plot 5.

Species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	Post-burn 1988	Post-burn 1989	Post-burn 1995
	pct					
Interior live oak	11	10	10	9	11	10
Blue oak	0	1	1	1	1	2
Valley oak	45	46	44	43	47	45
Western redbud	0	2	0	1	1	2
California wild rose	2	3	0	4	3	5
Total canopy cover	58	62	55	58	63	64

The plant community in Plot 5 has been largely unchanged and is typical of areas in which the canopy was either sparse or dominated by a few large, well-spaced oaks. The only fluctuation was elimination of seedlings (63 wild rose, 3 poison oak) by the burn. Seedlings of shrub species were not found at any sampling dates after the burn. The volume of wood present in Plot 5 did not change over the 8-year period, but was a steady 2.3 cords throughout (*table 10*).

Table 10—Volume of wood in Plot 5.

Species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	1988	1989	1995
	cords					
Valley oak	2.30	2.30	2.30	2.30	2.30	2.30

Plot 6

Plot 6 was designated as a "C" site at all sampling dates. It had a slope less than 30 percent and canopy cover of 26-40 percent dominated by valley oak. No preparation work was conducted in Plot 6, and canopy cover remained constant over the entire project period (*table 11*). No trees were removed, and the volume for the large (30+ inch d.b.h., 75 feet tall) valley oak was 5.14 cords at all sampling dates (*table 12*). No shrubs were present at any time.

Table 11—Canopy cover of woody vegetation in Plot 6.

Species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	1988	1989	1995
	pct					
Blue oak	0	1	1	0	2	2
Valley oak	32	30	31	31	29	33
Foothill pine	1	2	2	3	5	4
Total canopy cover	33	33	34	34	36	39

Table 12—Volume of wood in Plot 6.

Species	Pre-project 1986	Post-preparation 1987	Post-burn 1987	1988	1989	1995
	cords					
Valley oak	5.14	5.14	5.14	5.14	5.14	5.14

Summary

Areas dominated by interior live oak were those most affected by the project. On sites where deciduous oaks (blue or valley oak) were dominant, there was a lesser effect, primarily because of the larger spacing between trees. Pre-burn preparation work, where conducted, greatly impacted the vegetation. In general, total overstory canopy cover was reduced by the preparation activities where initial canopy cover was >60 percent, largely due to removal of interior live oak and selected shrubs by crushing and firewood cutting. Total wood volume was reduced by these same means. These activities also changed the species composition as interior live oaks were felled and crushed while blue oaks and valley oaks were avoided. The age and form class of the shrub component was shifted from predominately mature or decadent and largely unavailable before the project, to seedling or young plants and mostly available following the preparation work. Shrub numbers and canopy cover were decreased. The disturbance of the preparation activities stimulated tree seedling establishment.

The burn had little effect on total canopy cover overall, consuming piles created during the preparation work and opening up the area. Burning did not greatly affect species composition, though some shrubs were eliminated and all seedlings were destroyed. Fuelwood volume was not affected. Seedling numbers were greatly affected by the project. In general, blue oak, interior live oak, and valley oak seedling numbers decreased. The most dramatic changes were increases in yerba santa and wedgeleaf ceanothus. In one half of the plots these species were non-existent in the initial inventory, whereas 2 years after the burn, large numbers of seedlings were present and some had already grown to be classified as young plants. In these areas these species now make up about one half of the total canopy cover.

Eight years following the burn the total canopy of the burn area is similar to the pre-project inventory in many areas. Those which had an initially large canopy cover (>60 percent) had a significant reduction after the burn (with the exception of the valley oak dominated area), but the canopy cover has increased to near pre-project levels. The composition of the community has changed, with the shrub component replacing a large amount of the canopy formerly occupied by trees. In the areas which had an initial canopy cover of about 40 percent or less, there has been little change in total canopy or the makeup of the canopy over the 8-year period.

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Acorn Collection, Storage, Sorting, and Planting for the Establishment of Native Oaks Without Supplemental Irrigation[1]

Ronald W. Motz[2]

Advantages of Direct Seeding and Importance of the Taproot

Although the most common method of planting oaks is from containerized seedlings, direct seeding of acorns into the landscape produces clearly superior trees. The root system develops naturally without the twisting, girdling, or spiraling that often occurs in traditional containerized seedlings. Most important, the taproot grows at its natural rate without any premature termination or damage. The taproot is able to penetrate deeply to the water source while also providing a firm anchor to the seedling and food storage to help ensure survival. The taproot grows from the end (apical meristem), and once it is exposed to air or damaged, as is inevitable in traditional containers, it *never regenerates* (although multiple replacement roots usually form at the point of injury.) A seedling without a taproot will have less chance of survival without supplemental irrigation since it will never develop the root system nature intends for it to successfully adapt to the planting site.

Direct seeding of acorns is often discouraged because growers expect poor germination rates and a high loss of planted acorns to rodents. These problems are eliminated with careful selection and storage of acorns and the use of newly available low-cost tree shelters to protect the seed and growing seedling in the ground. The seed-handling method described below has been shown in numerous settings to produce germination rates >95 percent. When used with the appropriate tree shelters, a high rate of healthy vigorous saplings with strong natural root systems will result. While other planting strategies may be effective in some circumstances, results will be less predictable, and more follow-up and maintenance may be required.

Collection of Acorns

Yearly weather patterns and geography affect when acorns are ripe for harvest. Acorns are ready when the caps are removed easily without damage to the acorns. Usually when acorns start dropping to the ground, most of the acorns remaining on the tree are ripe. Acorns may be picked directly from the tree when they are ripe. The freshest seeds are collected this way. Seeds may also be gathered from the ground. Choose the acorns that are green or dark brown. Light brown color usually indicates that the acorns have been on the ground longer and are more likely to have become dehydrated. Select the largest acorns, and avoid those with obvious cracks, holes, or damage from rodents or worms, and those that feel unusually light or hollow.

[1] Presented as a poster at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996, in San Luis Obispo, Califor.

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Collect acorns as close to the proposed planting site as possible, preferably within 25 miles, and within 500 feet of the planting site's elevation. Maintain a broad genetic base by choosing individual trees sufficiently separated to avoid collection from closely related individuals (Lippitt 1991). Keep a record of the specific trees or groves from which the acorns were collected. Note the date and exact location and species of the trees. These notes, perhaps supplemented with photos made in the field, can help locate the trees in future years. Avoid purchasing seeds when the specific collection site is not known.

The harvest time can vary, plus or minus 1 to 4 weeks, from year to year, based on yearly weather changes. Oak trees in the wild can have unpredictable reproduction patterns, with some trees producing an acorn crop only once every 3 to 5 years and others producing only a handful of acorns. However, trees in parks or trees that have received supplemental watering can produce a crop each year. These trees often produce the largest acorns, with the most predictable crop.

Controlled studies have shown that larger acorns produce bigger seedlings faster (Tecklin and McCreary 1991). A larger seed has more cotyledon to feed the radicle and rapidly growing root system. The seed is still supporting root growth long after the root has started to branch. Plants increase on the basis of their present size because of the geometric rate of cell division, and therefore a larger seed produces more cells faster. Larger acorns produce better seedlings both in the nursery setting and with direct seeding into the landscape, but using the largest available acorns is especially crucial in wildland planting where growing conditions will be less controlled. The early advantage of more stored food for the emerging seedling may be critical to early seedling survival.

Storage of Acorns

Direct seeding from the tree into the landscape is the best planting method. But where this is not practical, because the planting site is remote from the source of acorns, or there is insufficient ground moisture to ensure successful germination at the time of harvesting, storage of the acorns is necessary. The primary goal of storage is to reduce the metabolic activity (i.e., keep the seed dormant) and maintain the health and vigor of the acorn until planting time. Proper storage technique is essential to *maintain metabolic inactivity*. It is preferable to keep the radicle from emerging, even inside the shell, until the acorn is planted in the soil. If the radicle emerges during storage, the roots will continue to twist as the acorn is repositioned in storage and in planting. The acorn is perishable, and the other goals of storage are to prevent the acorns from drying out, becoming moldy, or freezing. Some oak species require a cold wet storage period (stratifying) to simulate winter conditions and allow germination.

Do not wash or soak acorns before storage, as the water and room temperature will start the germination process. Freshly harvested acorns should be stored at 33-41 °F as soon as possible. A home refrigerator is adequate; however, the temperature will vary greatly within each appliance. Use a thermometer to check for the coldest spot. *The temperature should not reach freezing*. For larger quantities, commercial cold storage facilities are preferred, since the temperature will be maintained continuously within 1-2 degrees of the ideal. Longer storage of 3 to 4 months can be successfully achieved this way, but temperature closer to 33 °F is important for long-term storage.

The easiest way to store acorns is in 1-gallon zip-lock-type plastic bags. Fill them only *half full* with acorns. Add a handful of dry peat moss. Peat moss is slightly acidic, which inhibits bacterial growth, and it absorbs excess moisture given off by the acorns, which helps prevent mold growth. *Do not seal the bags*.

Leave them completely open, and lay them on their sides to allow air circulation so the acorns do not become moldy.

Planting of the acorns should be scheduled once the ground has been saturated with substantial rain. Acorns will thus be stored for 1 to 2 months at most.

Once the radicle has emerged, the acorn is already past the optimum opportunity for successful planting, since the tap root, which grows from the end (apical meristem), may be damaged when exposed to air. If the acorn is to be planted at this point, the radicle must be kept moist and the acorn planted as soon as possible. However, if the tip of the radicle is discolored or damaged, the acorn should be discarded.

Sorting

Seeds should be sorted after an initial storage period and immediately before planting. Seeds can be sorted for size by eye or mechanically, by weight or by screen.

No more than a few days before scheduled planting, remove the desired quantity from cold storage and place them in a plastic bucket filled with cold water. Soak the acorns for a few hours. The unhealthy seeds will float, and the solid seeds will sink to the bottom. Discard the "floaters." Drain the remaining healthy acorns, and dry them on newspaper about 1 hour at room temperature before replacing them in the bags. Place a handful of new peat moss in the bag with them, and store as described above, but this time for no more than a few days.

If the available crop of healthy acorns is inadequate, an alternative soaking method may rehydrate some "floaters," that would otherwise be considered inferior. After the soaking and separation described above, re-soak the "floaters", changing the water every 12 hours. Retrieve the acorns that sink, and continue soaking the remaining "floaters" until no more acorns sink. Drain and store any salvaged acorns as described above. Sometimes even seeds with obvious damage from insects or rodents can be salvaged, but it is important that the apex of the acorn (i.e., the end opposite from the cap) not be damaged.

Preparation for Planting

Remove from storage only enough acorns for a day's planting. Maintain the acorns at a cold temperature at all possible times. Keep the acorns cool while transporting them to the planting site, for example, by using an ice chest. *Never leave the acorns unrefrigerated for more than a few hours*. Any acorns that are not planted that day should be refrigerated again until the next planting time.

Planting: Direct Seeding into the Landscape

Once autumn rain has fallen and the ground moisture is sufficient, *time is of the essence*. Sowing the acorns as early as possible is *extremely* important (McCreary 1990). The taproot must penetrate to levels where moisture will be present the following summer. Plant only 1 acorn per hole, no more than 1 inch deep with 1 inch of soil covering the seed above ground level. Planting acorns too deep in soil with poor drainage may result in the newly emerged radicle being flooded or deprived of oxygen and may make it difficult for the shoot to grow through the soil. The use of a low-cost tree shelter is recommended, for protection and enhanced growth.

If the first winter's rainfall totals have been below normal, partial top-pruning of the seedlings may be beneficial (McCreary and Tecklin 1993). This should be done before summer approaches to decrease transpiration of moisture through the leaves and conserve the limited available ground moisture. Where feasible because the extent of the planting is limited and the site is accessible, supplemental watering will accelerate growth. However, if acorns are stored properly and the above procedures are followed, establishment of trees from acorns is extremely successful even without supplemental watering.

Acknowledgments

A special thanks goes to Janet Bozzo for her technical help and to Jennifer Seiffert for her help in editing the manuscript.

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The Diet of California Spotted Owls in Riparian Deciduous and Oak Habitats of the Southern Sierra Nevada[1]

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***Abstract**: From 1988 through 1992 we studied diets of California spotted owls (*Strix occidentalis occidentalis*) in low-elevation riparian deciduous and oak habitats in the southern Sierra Nevada. Spotted owl pellets were collected at roost sites between 300 and 685 m elevation in the Sierra and Sequoia National Forests and were examined for remnant bones, feathers, and insect exoskeletons. Remains of 664 individual prey were found. Mammals comprised 70.0 percent of prey frequency and 96.5 percent of prey biomass. The remainder consisted of birds (4.8 percent of prey frequency and 3.4 percent of prey biomass) and insects (25.2 percent of prey frequency and 0.1 percent of the prey biomass). Woodrats (*Neotoma *spp.) were the primary prey, accounting for 79.5 percent of the biomass. Pocket gophers (*Thomomys *spp.), the only other prey representing more than 5 percent of the biomass, comprised 11.0 percent of the biomass. A larger proportion of pocket gophers, voles, and insects and a smaller proportion of woodrats, mice, and birds were taken in the breeding period than in the nonbreeding period.*

Diet studies of the California spotted owl in the Sierra Nevada of California have focused on mixed-conifer habitats (Laymon 1988, Marshall 1942, Thrailkill and Bias 1989, Verner and others 1992). Preliminary results from our study were the first reported diets from all seasons for California spotted owls in riparian deciduous and oak habitats of the Sierra Nevada (Verner and others 1992). This paper describes diets of California spotted owls in low-elevation riparian deciduous and oak habitats of the southern Sierra Nevada and summarizes diets in breeding and nonbreeding periods.

Study Area

The study area of approximately 90 km^2 was located on the Sierra and Sequoia National Forests in Fresno County, California, 34 km east of Fresno. The dominant vegetative types were digger pine-oak, blue oak savannah, and low-elevation riparian deciduous habitats (Verner and Boss 1980). Spotted owls were usually located in riparian deciduous or oak habitats between 300 and 685 m elevation.

Methods

Pellets were collected at spotted owl nest and roost locations from February 1988 through October 1992. Pellets were grouped by period of deposition: breeding period included pellets egested from March 1 through August 31, and nonbreeding period included pellets egested during the remainder of the year. Pellets collected at the same site on the same day or within several days were combined into one sample (Forsman and others 1984). Pellets were dissected and components identified using a magnifying lamp and a dissecting microscope. Skeletal remains, feathers, and pieces of exoskeletons were used to identify prey items. A Carnegie Museum of Natural History specimen collection and other

[1] Presented as a poster at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996, in San Luis Obispo, Calif.

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references and keys (Borror and DeLong 1964, Burt and Grossenheider 1976, Dunning 1984, Forsman and others 1984, Ingles 1990, Jameson and Peeters 1988, Robbins and others 1983, Swan and Papp 1972) were used to identify prey and estimate mean weights. The number of individual mammals and birds per sample was obtained from the largest number of skulls or identical bone structures for each prey taxon. The number of insects was obtained from either the largest number of paired mandibles or the largest number of legs divided by six. Biomass was calculated by multiplying observed frequency of each taxon by its estimated mean weight. Prey frequency and biomass were summarized for breeding and nonbreeding periods.

Results

We collected and analyzed 520 pellets. Sampling intensity varied between sites, seasons, and years. At each of four sites, 76-184 pellets were collected. The remaining seven sites accounted for 31 or fewer pellets each. At five sites sampling was limited to either the breeding or the nonbreeding period. Almost half (239) of the pellets were collected in the breeding period of 1989 and the nonbreeding period of late 1989 and early 1990.

We identified 664 prey items. Identification to species of all prey items was not possible because remains were incomplete. At least 20 species (nine mammals, six birds, and five insects) were present (*table 1*). Mammals comprised 70.0 percent of all prey and 96.5 percent of the biomass. Large prey (greater than 100 g) represented 48.5 percent of the prey and 91.8 percent of the biomass. Woodrats contributed the most biomass to owl diets, followed by pocket gophers (*table 2*). Mice (mostly *Peromyscus* spp.), birds, voles (*Microtus* spp.), moles (*Scapanus latimanus*), insects, and shrews (*Sorex* spp.) accounted for the remainder of the biomass. Other owl species (western screech owl, *Otus kennicotti*; northern saw-whet owl, *Aegolius acadicus*; and unidentified owls) and western scrub-jays (*Aphelocoma californica*) were the most numerous birds identified (*table 1*). Insects comprised 25.2 percent of the prey but accounted for only 0.1 percent of the biomass (*table 2*).

The percent frequency and percent biomass of woodrats, mice, and birds decreased and those of pocket gophers and voles increased in spotted owl diets from the nonbreeding period to the breeding period (*table 3*). The difference in percent biomass between periods was greatest for pocket gophers, followed by woodrats. Insects exhibited the largest percent frequency change between periods, increasing in the breeding period, but percent biomass remained less than 0.2 percent for each period.

Discussion

Large prey dominated the diet of California spotted owls in this study. Combining pellets for analysis, as done here, provides a conservative estimate of the proportion of large prey (Marti 1987); thus, large prey numbers may have been underestimated. Although a variety of prey were taken, woodrats (79.5 percent of the biomass) and pocket gophers (11.0 percent of the biomass) were the primary prey. These values agreed with the observations of Verner and others (1992) that California spotted owls generally rely on one to four prey species groups for at least 85 percent of the diet biomass, and in the Sierra Nevadan foothills and throughout southern California the diets are composed of 79 to 97 percent woodrats by biomass. Maximizing the desired prey species for spotted owls in the oak woodlands may require different management techniques than used in the mixed-conifer forests. In conifer habitats, the primary prey

Table 1—Number, percent, mean weight, and cumulative percent biomass of 664 prey items identified in 520 California spotted owl pellets.

Categories / Common name	Taxon	Number	Percent of total (664)	Mean weight	Cumulative percent biomass
				g	
Woodrats					
Bushy-tailed woodrat	*Neotoma cinerea*	1	0.2	327.5	0.4
Dusky-footed woodrat	*Neotoma fuscipes*	221	33.3	271.0	69.4
Woodrat	*Neotoma* spp.	31	4.7	271.0	9.7
Gophers					
Botta's pocket gopher	*Thomomys bottae*	22	3.3	155.5	4.0
Pocket gopher	*Thomomys* spp.	39	5.9	155.5	7.0
Mice					
Mouse	*Peromyscus* spp.	110	16.6	29.5	3.8
Calif. pocket mouse	*Perognathus californicus*	2	0.3	18.5	< 0.1
Pocket mouse	*Perognathus* spp.	1	0.2	18.5	< 0.1
Jumping mouse	*Zapus* spp.	1	0.2	22.5	< 0.1
Voles					
California vole	*Microtus californicus*	2	0.3	53.5	0.1
Vole spp.	*Microtus* spp.	22	3.3	53.5	1.4
Moles					
Broad-footed mole	*Scapanus latimanus*	2	0.3	56.0	0.1
Shrews					
Shrew spp.	*Sorex* spp.	2	0.3	7.5	< 0.1
Other Mammals					
Unknown mammal	Class Mammalia	2	0.3	157.4	0.4
Unknown small mammal	Class Mammalia	7	1.1	20.0	0.2
Birds					
Spotted towhee	*Pipilo maculatus*	1	0.2	40.5	0.1
Warbler	Family Emberizidae	1	0.2	9.2	< 0.1
Western scrub-jay	*Aphelocoma californica*	9	1.4	86.4	0.9
Woodpecker	Family Picidae	1	0.2	66.2	0.1
Northern saw-whet owl	*Aegolius acadicus*	1	0.2	82.8	0.1
Western screech owl	*Otus kennicotti*	3	0.5	150.0	0.5
Unknown owl	Family Strigidae	3	0.5	127.6	0.4
Unknown avian	Class Aves	13	2.0	86.1	1.2
Insects					
Grasshoppers	Order Orthoptera	2	0.3	1.0	< 0.1
Crickets	Family Gryllacrididae	1	0.2	1.0	< 0.1
Jerusalem cricket	*Steropelmatus* spp.	28	4.2	1.0	< 0.1
Beetles	Order Coleoptera	2	0.3	2.0	< 0.1
Scarab beetles	Family Scarabaeidae				
	Plecoma tularencus	11	1.7	1.0	< 0.1
Long-horned beetle	Family Cerambycidae	1	0.2	2.0	< 0.1
Long-horned beetle	*Ergates* spp.	3	0.5	2.0	< 0.1
Long-horned beetle	*Prionus* spp.	11	1.7	2.0	< 0.1
	Order Hymenoptera				
Ants	Family Formicidae	100	15.1	0.05	< 0.1
Unknown insect	Class Insecta	8	1.2	1.0	< 0.1

Table 2—Summary of spotted owl diets by prey categories for all seasons.

	Individual prey items		Biomass	
	Number	Percent	Total	Percent
			g	
Woodrats	253	38.1	68,619.5	79.5
Gophers	61	9.2	9,485.5	11.0
Mice	114	17.2	3,323	3.9
Voles	24	3.6	1,284	1.5
Moles	2	0.3	112	0.1
Shrews	2	0.3	15	< 0.1
Other	9	1.4	454.8	0.5
Birds	32	4.8	2,928.4	3.4
Insects	167	25.2	89	0.1
Total	664	100.1	86,311.2	100.0

Table 3—Percent frequency and percent biomass of prey in California spotted owl pellets.

	Nonbreeding period[1]		Breeding period[2]	
	Percent of individuals	Percent biomass	Percent of individuals	Percent biomass
Woodrats	45.9	81.9	27.3	74.3
Gophers	7.3	7.3	11.9	18.5
Mice	24.1	4.7	7.6	2.2
Voles	2.6	0.9	5.0	2.7
Moles	0.5	0.2	0.0	0.0
Shrews	0.3	< 0.1	0.4	< 0.1
Other	1.6	0.7	1.1	0.2
Birds	6.7	4.2	2.2	1.8
Insects	11.1	0.1	44.6	0.1

[1] $n = 386$
[2] $n = 278$

species is the northern flying squirrel (*Glaucomys sabrinus*) (Verner and others 1992) or a combination of woodrats and northern flying squirrels (Laymon 1988, Thrailkill and Bias 1989) in the central Sierra Nevada. In low-elevation riparian deciduous and oak habitats of the Sierra Nevada, management for spotted owls should include managing for woodrat populations (Verner and others 1992).

Diets of spotted owls vary by season. Forsman and others (1984) reported an increase in the proportion of pocket gophers, western red-backed voles (*Clethrionomys occidentalis*), and insects in the breeding period diet of the northern spotted owl (*S. o. caurina*). Ganey (1992) generally found an increase in insects in the breeding period diets of the Mexican spotted owl (*S. o. lucida*). We also found an increase in the proportion of gophers, voles, and insects during the breeding period. However, Forsman and others (1984) found an increase in the proportion of small birds and shrews during the breeding period, whereas we found a decrease in birds during this period and only one shrew present in the pellets of each period. Our results indicating an increase in the proportion of insects in pellets collected in the breeding period may be misleading. One pellet contained approximately 100 small ants (Formicidae), the only ants found in this study. More than 90 percent of the change in percent frequency of insects between periods was due to the ants from this pellet. Although Forsman and others (1984) also reported ants in spotted owl pellets, it is possible that the ants found in this study were on a cached prey item when it was consumed, and thus may not represent prey items but rather an incidental part of the diet.

It is unknown whether the differences in percentages of prey groups found in the spotted owl diet reflect selection of certain species or merely differences in prey abundance or availability. Several factors may have affected the estimation of the breeding and nonbreeding period diets. Laymon (1988) found that significant pair-to-pair differences in diets were not exceptional in spotted owls in the central Sierra Nevada in similar habitat and concluded that pooling is rarely justified. Differences in diets of breeding and nonbreeding spotted owl pairs have been documented (Barrows 1987, Thrailkill and Bias 1989). Annual differences in the diet of spotted owl pairs have been observed (Forsman and others 1984, Laymon 1988). We pooled data from all sites and years to estimate prey numbers for each period. Thus the comparison of the diets between periods should be viewed with caution. Further studies are required to examine the interplay of site, period, and annual variation in the low-elevation riparian deciduous and oak habitats of the Sierra Nevada.

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