Sustaining Oak Woodlands in California's Urbanizing Environment

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California's oak woodlands, also known as hardwood rangelands, cover 10 million acres, or ten percent of the state (Bolsinger 1988; Greenwood et al. 1993; Pacific Meridian Resources 1994). These areas have an overstory tree canopy, predominantly in the oak genus (*Quercus spp.*), and an understory of exotic annual grasses and forbs, and occasional native perennial grasses (Griffin 1973; Bartolome 1987; Holmes 1990; and Allen et al. 1991).

Since European settlement of California, oak woodlands have been managed primarily for livestock production. These areas have taken on a new importance because of the recognition that they have the richest species abundance of any habitat in the state, with over 300 vertebrate species, 5000 invertebrate species, and 2000 plant species found on oak woodlands (Verner 1980; Barrett 1980; Garrison 1996). Oak woodlands also provide water quantity and quality, outdoor recreation, and aesthetics. Over 80 percent is in private ownership (Greenwood et al. 1993).

The five major oak species occurring on oak woodlands include three deciduous white oak species – blue oak (*Quercus douglasii*), valley oak (*Quercus lobata*), and Engelmann oak (*Quercus engelmannii*); and two evergreen oaks – coast live oak (*Quercus agrifolia*) and interior live oak (*Quercus wislizeni*).

California has one of the most rapidly growing human populations in the world. The state's population has grown from less than 100,000 people in 1850, to over 31 million people today (an average annual rate of growth of 3.4 percent) to a projected 63 million people in the next 50 years (Medvitz and Sokolow 1995). This population growth is having an impact on oak

woodlands. A survey of oak woodland owners showed that the majority of all owners now live less than 5 miles from a subdivision (Huntsinger and Fortmann 1990; Huntsinger 1992). These surveys also showed that approximately one-third of the properties changed owners between 1985 and 1992, and 5 percent were subdivided for residential development. The urban interface with oak woodlands, once confined to the major population centers of the San Francisco Bay, Sacramento, and the Los Angeles basin, now extends throughout the entire state.

Oak woodland conservation strategies must recognize the widespread extent of this broad habitat type, its role in the state's economic livelihood, and its important ecological values. This paper assesses how urbanization affects oak woodland sustainability, which includes maintaining:

- ecosystem processes at multiple scales;
- the existing diversity of biological organisms;
- economic viability over the long-term.

Each of these items will be discussed in some detail below, as well as some of the conservation policies being implemented in the state.

Spatial and Temporal Aspects of Sustainability

Landscape-Level Sustainability

Landscape factors affecting oak woodland distribution include long-term climatic factors, and more recently, human-caused events. Pollen analysis shows shifts in distribution of oak stands along altitudinal gradients (Byrne et al. 1991). Over the past 40 years, California's oak woodlands have decreased by over one million acres on a statewide scale (Bolsinger 1988) due to human-induced factors. Major losses from 1945 through 1973 were from rangeland clearing for enhancement of forage production. Major losses since 1973 were from conversions to residential and industrial developments. Regionally, some oak woodlands have decreased due to urban expansion (Doak 1989), firewood harvesting (Standiford et al. 1996), range improvement (Bolsinger 1988), and conversion to intensive agriculture (Mayer et al. 1985). Habitat fragmentation, increased conflicts between people with different value systems, predator problems, and soil and water erosion have resulted.

Stand Level Sustainability Considerations

From 1932 to 1992, blue oak woodland canopy density and basal area increased under typical livestock grazing, and fire exclusion policies (Holzman 1993). This indicates that many oak stands are stable to increasing over a moderately long period, despite perceived natural regeneration problems (Muick and Bartolome 1986; Bolsinger 1988; Swiecki and Bernhardt 1993). However, more than 20% of the study sites were converted to other land uses, primarily residential subdivisions, during this period (Holzman 1993). A similar study of changes in tree and total woody cover of foothill oak woodlands from 1940 to 1988 found these areas were relatively stable (Davis 1995).

Pollen analysis studies document the dynamics of hardwood rangeland composition over a very long-term period and highlight the changing influence of human populations (Byrne et al. 1991). Oak woodlands were relatively stable during the long period of use by Native Americans. Following European settlement, livestock introduction, and clearing for intensive agriculture approximately 150 years ago, oak densities declined. Exotic annuals first show up in the pollen record at this same time. Since this initial exploitation of the oak resource in this early settlement period, oak cover has increased dramatically. Current oak densities derived from the pollen record are at their highest level, due to fire exclusion policies of the last 50 years,

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and low intensity, extensive management practices associated with ranching uses.

Maintaining Ecosystem Processes

Beginning with the introduction of domestic livestock and exotic annuals by European settlers, oak woodland ecosystems have changed dramatically. Herbaceous composition has changed from perennials to annuals (Holmes 1990). Fire intervals and intensity have increased (McClaren and Bartolome 1989). Overstory cover, if not converted to another land use, has generally increased (Holzman and Allen-Diaz 1991). Soil moisture late in the growing season has decreased, and soil bulk density has increased due to compaction from higher herbivore densities (Gordon et al. 1989). Riparian zones are now less dense and diverse (Tietje et al. 1991). A general summary of the changes in ecosystem inputs from pre-settlement conditions to the current time is shown below (Table 1). These ecosystem process changes are discussed below.

Herbaceous Composition

The pre-European herbaceous community in oak woodland understory included native perennial bunchgrasses and forbs (Holmes 1990). Native species were displaced by alien annuals from Europe, Asia, Africa and South America with arrival of European settlers (Burcham 1970). Urbanization is accelerating exotic invasion, although mitigation projects often require restoration with native grasses.

Soil Processes and Nutrient Cycling

Soils under oak canopies have higher organic matter, greater cation exchange capacity, lower bulk density and greater concentrations of some nutrients than open grasslands due to organic matter input from oak leaf litter and nutrient leaching from rainwater drip (Jackson et al. 1990; Frost and Edinger 1991; Firestone 1995). This nutrient effect from oak cover gradually dissipates after tree removal (Kay 1987). Woodlands with native perennial grasses have higher soil moisture later in the growing season than those with exotic annual grasses (Gordon et al. 1989). Exotic invasions and the resulting decrease in available water later in summer months may explain some of the observed lack of sapling recruitment in oak woodlands. Removal of oaks in the development process depletes the reservoir of soil organic matter and disrupts nutrient cycling. Adjacent interface areas retaining oak cover help to maintain nutrient cycling processes.

Grazing Processes and Forage Production

Livestock grazing has had a major impact on California's oak woodlands. By 1880, Spanish coastal missions had four million sheep and one million cattle (Holmes 1990) fostering a large demand for forage and oak browse. Currently, two-thirds of all woodlands are grazed (Huntsinger 1992). In addition to domestic livestock grazing, feral hogs consume acorns while rodents such as ground squirrels and pocket gophers utilize large quantities of acorns and seedlings.

Grazing has both positive and negative effects on oak woodland sustainability. Positive grazing effects include: reduced moisture competition between oaks and herbaceous material (Hall et al. 1992); reduced leaf area in seedlings, which may help conserve moisture late in the growing season (Welker and Menke 1990); habitat for rodents who consume acorns and young seedlings may be reduced; and fuel ladders are eliminated, reducing the probability of crown fires in grazed woodlands. Some of the negative effects of livestock grazing include: livestock and other grazing animals consume oak seedlings and acorns (Swiecki and Bernhardt 1993; Adams et al. 1992 ; Hall et al. 1992); grazing may increase soil compaction, making root growth for developing oak seedlings more difficult (Gordon et al. 1989); and soil organic matter may be reduced.

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*Oak woodland clothes the hillside above large valley oaks (*Quercus lobata *Nee) on the valley floor at 1,000 m elevation at Fort Tehon State Park, California, as seen during the Ventura County field trip of the Second International Oak Conference.*

The effect of oak canopy on forage quantity and quality vary depending on precipitation, oak species, and amount of cover (George 1987; . Kay 1987; Jansen 1987; Holland and Morton 1980; Frost and McDougald 1989; Ratliff et al. 1991; Holland 1980). Oaks compete with the forage understory for both sunlight and moisture, and alter the nutrient status of the site because of the deep rooting of oaks and nutrient cycling from litter fall.

Urbanization has decreased livestock grazing in interface areas due to high land prices, conflicts with urban neighbors, and reduced market access. This results in higher fuel accumulation and increased fire risk to both habitats and residential structures. Grazing pressure on oak regeneration and riparian habitats may be reduced, however.

Oak Regeneration and Recruitment Processes

There is concern whether adequate oak regeneration exists to sustain current stand structure. Oak regeneration surveys (Bolsinger 1988; Muick and Bartolome 1987; Standiford et al. 1991; Swiecki and Bernhardt 1993) have shown a shortage of sapling trees for certain species (especially blue oak, Engelmann oak, and valley oak) in certain regions of the state (low elevation, south- and west-facing slopes, shallow soils, high natural or domesticated herbivore populations). This shortage of small trees may result in loss of oak stands as natural mortality factors or tree removal eliminate large, dominant trees in the stand.

Blue oak recruitment may arise from a gap mechanism where an understory seedling bank persists until a moderate stand disturbance (such as clearing, fire or natural tree mortality) occurs, after which sapling recruitment proceeds (Swiecki and Bernhardt 1993). Valley oak has experienced inadequate regeneration since the last century (Griffin 1973; Bernhardt and Swiecki 1991; and Danielsen and Halverson 1991). Alien annual grasses, which make less water available to oaks than native perennial grasses, may be one cause of this effect.

Stump sprouting has been widely observed in most oak woodland species. Studies have shown a high probability of achieving stump sprouting for blue and live oak species. This observa-

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tion reduces the concern that a lack of sapling trees once suggested (McCreary et al. 1991; Standiford et al. 1996).

In urbanizing areas, the trend of increasing tree density will continue to lead to conditions where poor sapling recruitment will occur. This is only a problem if mortality of overstory trees exceeds recruitment of seedlings into larger tree sizes.

Oak Restoration and Planting

Planting acorns or seedlings is necessary where recruitment is inadequate to maintain desired oak cover. However, the same factors limiting natural oak regeneration makes it difficult to artificially regenerate native oaks. Substantial care must be taken to plant, protect and maintain young oaks in the field. Techniques for establishing oaks have been well-described and success of over 90 percent is not uncommon (McCreary 1996). Currently, over one million oak seedlings are planted annually in California (IHRMP 1994). A very large proportion of these seedlings are planted as part of restoration projects required as mitigation for various urban development projects. Costs per surviving seedling are quite high (Standiford and Appleton 1993). However, the urbanization process and its associated environmental regulations has created the capital, and the economic justification, to accomplish restoration of large areas of oak woodlands, partially reversing the negative impacts of the development process.

Riparian Management Processes

Although a small percentage of the state's water supply originates on hardwood rangelands, virtually all of it flows through oak woodland riparian zones (CDF 1988). Also, most of the state's major reservoirs are located on oak woodlands. Riparian zones provide important habitat for wildlife and aquatic organisms. Management activities influence water quality, and wildlife and fisheries habitat. Yet, removal of up to one-third of the oak canopy had little effect on water quality and yield in one regional study (Epifanio et al. 1991). New efforts have been started to develop rangeland management practices to minimize erosion as part of the state's water quality management plan (Humiston 1995). In urban interface areas, riparian zones are often subject to very high levels of human use for recreational purposes. Scott and Pratini (1996) documented how urban development increases human use of riparian areas, lowering the habitat value for various wildlife species and decreasing overall biological diversity.

Fire Ecology Processes

Fire is a natural part of California's oak woodland ecosystem and has been an important management tool since Native Americans inhabited these areas. Fire influences oak woodland stand structure, regeneration, wildlife habitat, nutrient cycling, and economic uses. Fire also creates significant health and safety risks to people living in oak woodlands and the interface area.

The ecological effects of fire depend on their frequency, intensity, and size of patches that occur from fire-induced tree mortality. Recent increases in the acreage of stand destroying

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Table 1. Comparison of oak woodland conditions before European settlement, during extensive ranching period, and in urban interface areas.

Pre-European Settlement Conditions	Extensive Ranching Period	Current Urban Influence
Perennial herbaceous layer	Exotic annual invasion	Increasing annual invasion, especially noxious weed
Regular fire interval	Continuation of regular fire interval	Fire suppression policies and long fire interval and increased intensity
More open overstory layer	Range clearing and tree thinning	Increased overstory layer of unconverted stands
Soil moisture higher, later into growing season	Soil moisture late in growing season decreased due to exotic annuals	Decreased soil moisture late in growing season due to exotic annuals
Lower soil bulk density	Increased soil bulk density	Increased soil bulk density
Snags, large woody debris	Snags, woody debris cleaned up in typical management activities	Less attention to clean-up; increased snags and woody debris
Dense, diverse riparian zone	Riparian zones less dense and diverse	Higher human use of riparian zones, and increased storm runoff from urban areas
Lower herbivore densities	Higher herbivore density, primarily domestic livestock	Decrease in domestic livestock

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fires has resulted from decades of attempting to exclude fire from woodlands.

McClaren and Bartolome (1989) have shown fire frequencies in oak woodlands of 7 to 25 years during occupation by Native Americans and early ranchers. Fire was a common management tool until the 1950's, when fire suppression became the dominant practice. These past higher fire frequencies may have created conditions more conducive for oak regeneration. McClaren and Bartolome (1989) showed that oak recruitment was associated with fire events, and has been rare since fire suppression. The importance of fire on oak regeneration may be due to: enhanced postfire oak sprout growth; improved seedbed for acorns; reduced moisture competition from herbaceous species; and reduced habitat for wildlife species that feed on acorns and seedlings. Fire also kills diseases and insects, such as the filbert weevil (*Cucurlio occidentalis*) and the filbert worm (*Melissopus latiferreanus*), which can infest the acorn crop (Lewis 1991). High frequencies of low intensity fires also reduce fuel ladders under oak canopies preventing high intensity crown fires.

Maintaining Biological Diversity

A second way that urbanization influences the sustainability of oak woodlands is through its effects on biodiversity. Oak woodlands provide habitat for over 300 vertebrate wildlife species, 2000 plant species and 5000 insect species. Favorable woodland habitats supply food, water, and cover to sustain wildlife species. Each habitat element provides unique niches, favoring particular wildlife species. Conversely, the absence of a particular element in a habitat may limit species diversity. Examples of oak woodland habitat elements that are important to consider include riparian zones, vernal pools, wetlands, dead and downed logs and other woody debris, brush piles, snags, rock outcroppings, and cliffs.

Riparian habitat elements are used by almost 90 percent of all hardwood rangeland wildlife species, illustrating the importance of conserving this habitat element where present. Over one-third of all oak woodland bird species use snags, suggesting that strategies to maintain snags will result in greater wildlife species diversity. Downed woody debris from fallen limbs or dead trees, provide an extremely valuable habitat for most reptiles and amphibians, as well as for many bird species. Oak woodland management for wildlife must include these trees as well as trees in various stages of vigor in order to maintain critical wildlife habitat (Block and Morrison 1990). Mid-elevation hardwood rangeland habitats, with several oak species, vertical diversity in vegetation structure, and diverse riparian zones, have the richest diversity of wildlife (Motroni et al. 1991).

The threats of urbanization to biodiversity on oak woodlands include: 1) fragmentation of large blocks of extensively managed hardwood rangelands; 2) reduction in important habitat elements such as snags, woody debris, and diverse riparian zones; and 3) increasing interface with urban areas, bringing household pets, humans, and fire suppression policies into contact with hardwood rangeland habitats. These threats to biodiversity can be reduced by encouraging cluster development and conservation of connecting corridors between large hardwood rangeland habitat blocks in developing areas (Giusti and Tinnin 1993).

Maintaining Economic Viability and Utilization of Oak Woodlands

Oak woodlands have been important to humans living in California for centuries. Management practices utilized by Native Americans and the ranching community maintained large blocks of habitat that supported ecosystem processes at a variety of scales. However, as people have left the major urban areas of the state to seek the aesthetic and amenity values of oak woodlands, these areas are being converted to residential and industrial uses. Some of the economic and utilization issues from these land use changes are discussed below.

The original human inhabitants of oak woodlands were Native Americans. Acorns were the dietary staple for three-fourths of all Native Americans in California, and sustained their cultures (Pavlik et al. 1991; McCarthy 1993). Many cultural traditions and celebrations focused on oaks. Oaks and acorns were also used as medicines and dyes. Burning was the most prevalent and effective management tool used by Native Californians to manage the oaks and the acorn crop (McCarthy 1993) and to keep prized oaks from being dominated by conifer species.

Since the 1800s, oak woodlands have been used mainly for domestic livestock products. Dramatic annual fluctuations in livestock markets, coupled with risk from forage shortages due to high variability in annual rainfall, has made many livestock operations marginal. There is also a high opportunity cost to extensively managed livestock operations from high value land uses such as suburban developments or intensive agricultural products such as wine grapes. One study shows land value for grazing represents only 20 percent of the current total land value for residential development in the central Sierra Nevada (Johnson 1996). Uncertainty about federal grazing policies, inheritance taxes, the pyramid of heirs, low profitability, high risk, and high opportunity cost have accelerated conversion of extensively managed private ranches to suburban developments.

Historical efforts to increase ranch profitability focused on enhancing forage production through removal of the oaks. This simplification of the ranch ecosystems paid short-term dividends in improved forage yields, but risk from fluctuating product markets and weather variability continued to make ranching a low profitability enterprise.

New markets developed in the last 20 years for the oaks on hardwood rangelands for firewood and as habitat for commercial hunting enterprises. This diversified economic portfolio has helped to enhance the economic sustainability of these areas by spreading risk out over several enterprises, increasing overall returns per acre, and providing an economic incentive to conserve more diverse woodlands (Standiford and Howitt 1990; Standiford and Howitt 1993). Diversified markets have reduced tree harvesting and intensity of livestock use.

Historically, the market value of oak woodlands for subdivision near urban areas has exceeded their value for amenities and ecological functions. Recent human population increase in these areas, however, has raised the potential values of woodland amenities to a point where they may be a financially viable alternative to land development (Scott 1996). Woodlands provide a large component of the quality-of-life sought by many relocating industries, and the relatively low cost of industrial sites in these woodlands is equally appealing. Woodland owners along the wildland urban interface often find that their management options track public demand for specific values. If woodland conversions trigger a public demand for amenity protection, the solutions typically must be found on private lands. Open space easements, and other deed restrictions provide financial, tax, or development incen-

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tives for the voluntary maintenance of public amenity values on private lands (Duwe undated). Mitigation banking provides another economic value for hardwood rangeland in urban interface areas (Reyes-French and Cohen 1991).

Conservation Policies and Strategies

A series of policy instruments to conserve oak woodlands have evolved in California against the backdrop of the ecological and economic factors described above. Various interest groups have expressed concerns about oak woodlands to the California State Board of Forestry (BOF), the state regulatory and policy-making body responsible for forest and rangelands. In response to these concerns, the BOF asked the University of California (UC), the California Department of Forestry and Fire Protection (CDF), and the California Department of Fish and Game (CDF&G) to develop a program of research, education, and monitoring to conserve hardwood rangelands (Passof and Bartolome 1985). This program is known as the Integrated Hardwood Range Management Program (IHRMP). With the development of the IHRMP, the BOF decided that an intensive educational program, problem-focused research, and frequent monitoring of the resource was the most effective way to work with landowners and local governments to resolve hardwood issues.

The IHRMP has funded 66 research studies over ten years, which in turn has stimulated additional research on various aspects of hardwood rangelands. These research studies, resulting in over 250 new scientific articles, contribute to the base of understanding of the ecological and managerial processes extent on hardwood rangelands (IHRMP 1992). Research results have been disseminated in IHRMP-sponsored symposia and workshops and incorporated directly into educational documents and newsletters.

Surveys were implemented to evaluate the effectiveness of education as a conservation policy (Stewart 1991; Huntsinger and Fortmann 1990; Huntsinger 1992). These showed that individuals who participated in IHRMP educational programs were more likely to carry out oak enhancing management activities practices (protect sprouts, maintain fixed oak canopy levels, thin softwoods to promote oak growth, planting oaks) than non-participants. After a seven year period of intensive educational outreach, oaks were more valued by landowners for wildlife habitat, soil protection, enhancement of property values, and for browse and mast production. The number of large owners selling firewood or cutting trees for forage enhancement decreased. During this same time period, the number of owners who conducted wildlife habitat improvements increased.

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A preserved natural woodland of Engelmann oak (Quercus engelmannii *Greene) at Arcadia, near Los Angeles, California.*

Local Policy Initiatives

In May, 1993, the BOF held hearings to evaluate the effectiveness of seven years of research and education as an approach to oak woodland conservation. These hearings showed strong support for the continuation of research, outreach, and monitoring, and revealed a large number of threats facing hardwood rangelands. Firewood harvesting was recognized to be a concern only in the northern Sacramento Valley, while conversion to subdivisions was important in the central Sierra Nevada, San Francisco Bay Area, Central Coast, and Southern California (IHRMP 1994). These findings confirmed that statewide regulations would not be able to effectively address the wide diversity of conservation issues. The BOF decided to intensify its outreach to local governments, and encourage their participation in local policy development with the assistance of the IHRMP. The IHRMP has worked closely with local governments to encourage the development of local policies to conserve hardwood rangelands. Currently, 37 counties have adopted or started the process of adopting local conservation strategies. These strategies fall into three categories, namely: county voluntary guidelines; land use planning; and tree harvesting ordinances. Each of these are discussed below.

County Voluntary Guidelines

At the 1993 BOF Hardwood Hearings, political and agricultural leaders from a northern Sacramento Valley county volunteered to initiate a county-based effort to address concerns about widespread oak firewood harvest. A county oak committee composed of various resource agencies, environmental groups, and agricultural groups was appointed. They developed a set of voluntary oak retention guidelines to maintain economic viability of grazing and ecological values of hardwood rangelands, which was passed by the county Board of Supervisors, and mailed to all landowners in the county (Gaertner 1995). With this successful pilot project, several other counties began to develop voluntary guidelines. Currently, 12 counties are in various stages of developing voluntary guidelines. Each effort addresses important local issues, and includes education and monitoring. For example, several of the voluntary guidelines in the northern Sacramento Valley address impacts from firewood harvest, while biomass harvest, fire protection, and soil erosion were important issues addressed in southern Sierra guidelines. Most of the guidelines also have general recommendations on urban development patterns to help guide local land use policies.

General Planning Process

The county General Plan sets policies governing land use. Sample language on the importance of oak woodlands have been developed by the California Oak Foundation for possible inclusion in individual county general plans, and mailed to all county planning departments. Pilot educational activities have started in several Central Coast counties to utilize overlays of hardwood habitat maps and parcel maps in a geographic information system (GIS) to implement landscape-based oak conservation strat-

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egies in the county planning process (Tietje and Berlund 1995). In southern California, the IHRMP has worked closely with three county planning offices and Boards of Supervisors in the design of a corridor system to minimize the effects of habitat fragmentation. General regional and county-wide habitat conservation plans (HCP) have been coordinated with the goals of the IHRMP in Southern California.

Ordinances

Some areas have utilized ordinances to protect oaks. Ordinances create a regulatory environment at the county or city level, and usually involve a permitting process for the removal of any tree over a certain size class, and mitigation standards where tree removal is allowed. Most tree ordinances have focused on the single tree rather than at a broad habitat scale. CDF has developed an educational book on ordinances which describes the importance of setting objectives for an area prior to writing an ordinance, and monitoring whether the objectives have been accomplished (Bernhardt and Swiecki 1991). This book has been distributed to all counties in the state. At this time, there are 11 counties which have ordinances designed to protect oak trees.

Conclusion

Oak woodlands are an important ecological component in California. Sustainability of ecological values is of concern due to rapid population growth, and the resulting conversion and fragmentation of hardwood rangeland habitats. Important information has been developed on the ecology and sustainable management of hardwood rangelands through activities of the IHRMP. Sociological and biological monitoring shows that diverse audiences have accepted and acted on educational information. A large number of counties have started the process of adopting local conservation strategies to conserve hardwood rangelands. Education and research have played a major role in conservation. Major accomplishments have been made in rural areas of the state, where livestock and natural resource management are the predominant land use. Where individual landowners have the ability to implement management activities that affect large acreages, education and research has contributed to decisions that favor conservation of oak woodlands.

However, for much of California, conversion of oak woodland habitats to urban or suburban land use is having the largest impact on sustainability of resource values. Educational materials developed on hardwood rangeland conservation in land use planning have been widely accepted by professionals working in the land use arena. However, incorporating these educational materials into successful land use plans adopted by the county government is only beginning. Since conversion to residential and industrial uses is ultimately a land use decision, it is a political process involving action by elected officials with input from different constituencies. The political and economic forces vary greatly in different parts of the state. Since "success" in this area involves multiple individuals agreeing on a political course of action, this issue will present the largest challenge for a research and education strategy. It needs to be evaluated very carefully over the next several years to determine if education and research alone are sufficient to sustain the ecological values of hardwood rangelands.

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