FIRE MANAGEMENT ALONG THE WILDLAND–URBAN INTERFACE IN SOUTHERN CALIFORNIA: A SEARCH FOR SOLUTIONS AT THE SANTA MARGARITA ECOLOGICAL RESERVE

Claudia Luke
Field Station Programs, 5500 Campanile Drive, San Diego State University, San Diego, CA 92182

Paul H. Zedler
Arboretum and Nelson Institute for Environmental Studies, University of Wisconsin-Madison, Madison, WI 53706

Sedra Shapiro
Field Station Programs, 5500 Campanile Drive, San Diego State University, San Diego, CA 92182

ABSTRACT

Fire management planning incorporates biological, economic, social, and political objectives. In southern California, urbanization and agricultural development bring humans into close contact with wildland areas and increase fire threats to life and property. At the same time, these developments isolate fragments of habitat that must be the remaining supporters of a highly endemic flora and fauna. Social pressure to conduct prescribed burns for the purposes of safety at the wildland–urban interface further constrains prescribed burn plans, potentially detracting from biological management objectives. Land managers who do not adopt the most aggressive fire prevention measures, such as wholesale clearing, risk lawsuits. To reverse this alarming trend, fire management planning must 1) use adaptive management to increase information on the biological effects of burns in altered, fragmented habitats; 2) collaboratively develop fire management plans to share information and decision-making with known stake holders; 3) work to modify local and state policies so that homeowners receive information on risks and responsibilities at the wildland–urban interface; and 4) develop ongoing informative education programs.

keywords: biological objectives, California, safety, South Coast Ecoregion, threatened and endangered species, wildland–urban interface.

Citation: Luke, C., P.H. Zedler, and S. Shapiro. 2004. Fire management along the wildland–urban interface in southern California: a search for solutions at the Santa Margarita Ecological Reserve. Pages 284–293 *in* R.T. Engstrom, K.E.M. Galley, and W.J. de Groot (eds.). Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

Fire management is a complex issue involving biological, economic, social, political, and legal factors, and nowhere is this more apparent than in southern California. The steady increase in the state's human population during the last 50 years is causing ever greater impact as suburban-style tract homes extend into former ranch and wildlands. Results of this expansion include fragmentation and isolation of habitat, loss of biodiversity, and invasion of exotic species. Southern California, recognized internationally as a biodiversity hotspot (Myers et al. 2000), now has the dubious distinction of supporting the greatest number of threatened and endangered species in the United States (Dobson et al. 1997).

There is disagreement as to how human influence has changed fire frequency and intensity in shrub-dominated landscapes (e.g., Minnich 1995, Keeley et al. 1999, Zedler and Seiger 2000) but universal agreement that shrublands have always burned in intense fires, and that complete fire exclusion by any means short of total removal of the vegetation is neither possible nor desirable. The present challenge is therefore how to develop ways that land development can coexist with the inevitable fact of wildland fire. The memory of tragic losses of human life and property during recent decades underscores the importance of developing workable solutions.

Designated natural areas, traditionally refuges, have a critically important role to provide primary habitat for rarer and more habitat-specialized plants and animals. If sufficiently funded, refuges are managed by experts who monitor the environment and take scientifically justified actions when necessary to maintain natural conditions. To provide a refuge for native plants and animals, these areas must be managed according to the best biological information and protected as much as possible from incompatible adjacent land uses or local regulations. In southern California, all of these considerations apply with particular force because of the unique challenges involving fire—prevention, suppression, biological response to wildfire, and the need for using fire as a management tool.

Our concern is with a particular type of natural area—the university teaching and research field station. Like other field stations, the Santa Margarita Ecological Reserve (SMER) was created to provide a natural outdoor laboratory for researchers and students. Because ecosystems are infinitely complex, environmental study requires long-term observations with precision instruments and controlled experiments that isolate causative factors. The need to provide such conceptually substantial experiences imposes additional requirements on an already challenging fire management situation. Specifically, fire disturbance and its effects on species interactions are valuable processes to be studied by researchers and classes.

STUDY AREA

The Santa Margarita Ecological Reserve is a 1,740-ha field station consisting mainly of mature chaparral communities on steep slopes. Narrow bands of riparian and oak woodlands line the banks of the Santa Margarita River where it cuts through the reserve in Temecula Gorge, an 8-km rocky canyon. Facilities on the north and south sides of the reserve provide living and laboratory facilities for visiting classes and researchers who come to the site to study a wide variety of environmental processes.

The reserve is managed by San Diego State University Field Station Programs (SDSU FSP). An on-site Reserve Director (C. Luke) is responsible for working with regional managers, partners, and community members to coordinate regional conservation programs and reserve research. Working with various agencies, conservation organizations, on-site researchers, and community groups, the Reserve Director proposes management actions for the reserve and works through the on-campus Executive Director (S. Shapiro) to gain input and recommendations from advisory and ad hoc committees composed of SDSU faculty and staff (Figure 1) with multidisciplinary interests. The fire management planning effort at SMER began in 1998 as a collaborative effort with an adjacent land owner (Fallbrook Public Utility District) and outreach partner (Mission Resource Conservation District). The plan is scheduled for completion in June 2003 and is being guided by three reserve management goals: maintain native species richness and natural environmental processes, provide research opportunities, and ensure the safety of reserve visitors. These goals are not mutually exclusive but they are often in conflict.

FIRE MANAGEMENT OBJECTIVES AND CHALLENGES

Although fire is a natural process, simply returning fire to the site at the historically documented frequency (which, in any case, is not well documented) may not achieve desired management goals. In this section, we discuss the diversity of goals that managers should consider when designing fire management plans.

Natural Environmental Processes and Species Richness

Managers should recognize the increasing importance that natural areas play in species preservation. Reserve lands are quickly becoming one of the few areas in the South Coast Ecoregion where a full complement of native species can be studied. Loss of once-common habitats, such as coastal sage scrub, over the last 50 years has caused serious declines in many species. Even many low-elevation habitat types that are still common regionally (e.g., chaparral, grassland, Engelmann oak [*Quercus engelmannii*] woodland, riparian woodland) are poorly represented on lands that protect these habitats into the future (Davis 1995). The problem promises to increase in the future, and island-like reserves, such as SMER, are gaining increased responsibility for maintaining these species in perpetuity.

Managers also need to understand the role that their natural area plays in preserving biodiversity on a regional scale. For example, the Santa Margarita Ecological Reserve lies in a 30-km low-elevation saddle that links the Santa Ana Mountains in the west to an inland archipelago of mountainous public lands (San Diego Ranges and northward through the San Jacinto, San Bernardino, San Gabriel, Castaic, and Padres ranges to the Sierra Nevada). The inland ranges consist of vast tracts of foothill and mountain habitats (Stephenson and Calcarone 1999) and support a wide diversity of species, including wide-ranging predators such as cougar (*Puma concolor*). Encroachment of urban and agricultural development has reduced native vegetation in the linkage to an irregular and blotchy strip between the Santa Ana and San Diego ranges. If appropriate dense vegetative cover is not maintained

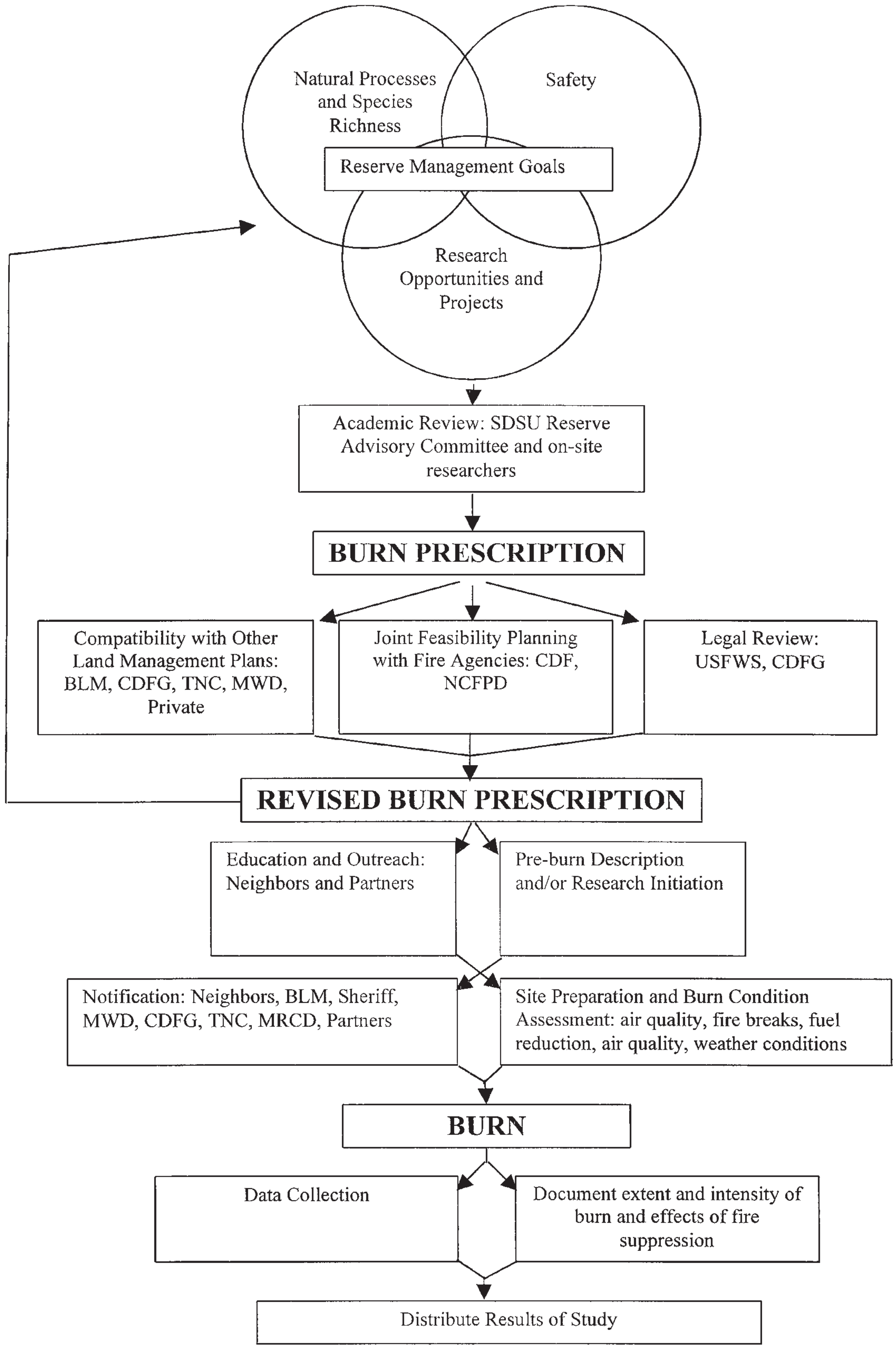

Figure 1. Process needed to develop a prescribed burn plan at the Santa Margarita Ecological Reserve, Riverside County, California. Abbreviations: BLM = Bureau of Land Management, CDF = California Department of Forestry and Fire Protection, CDFG = California Department of Fish and Game, MRCD = Mission Resource Conservation District, MWD = Metropolitan Water District, NCFPD = North County Fire Protection District, SDSU = San Diego State University, TNC = The Nature Conservancy, USFWS = U.S. Fish and Wildlife Service.

Table 1. Focal species sensitive to habitat fragmentation chosen for study at the Santa Ana–Palomar Mountains Habitat Connectivity Workshop at the Santa Margarita Ecological Reserve, Riverside County, California, March 2001.

Species	Fire risks and management concerns identified by workgroups
Cuyumaca meadowfoam (*Limnanthes gracilis*)	Fire may have little impact due to low fuel loads in vernal pools
Our Lord's candle (*Yucca whipplei*)	Most adults are killed by fire and recolonization is from seeds that survive fire. Because dispersal is likely limited, this species could be exterminated from habitat fragments with very hot fires
Engelmann oak (*Quercus engelmannii*)	This species is sensitive to fire and could disappear from burned habitat fragments
Rainbow manzanita (*Arctostaphylos rainbowensis*)	Fire increases germination and this species may require fire to maintain vigorous populations
Timema walkingstick (*Timema podura*)	Because they are unable to fly and do not burrow, this species may be especially vulnerable to fires
California sister (*Adelpha bredowii*)	None identified
Callippe fritillary (*Speyeria callippe*)	None identified
Papilio pale swallowtail (*Papilio eurymedon*)	None identified
Arroyo chub (*Gila orcutti*)	Large fires may increase siltation in the rivers and streams inhabited by this species
Western pond turtle (*Clemmys marmorata*)	None identified
Western toad (*Bufo boreas*)	None identified
California treefrog (*Hyla cadaverina*)	Giant reed (*Arundo donax*) infestations increase ability for riparian vegetation to carry fire and could increase mortality for this species
Red diamond-back rattlesnake (*Crotalus exsul*)	This species prefers dense brush and fire would negatively affect this species by opening up brush areas
Golden eagle (*Aquila chrysaetos*)	Only 5 nesting pairs of golden eagles remain in coastal areas of San Diego. Nesting pairs in this area would benefit from fire, which would open dense brushy habitats and increase foraging efficiency
Yellow warbler (*Dendroica petechia*)	This species prefers dense thickets and would be negatively affected by a fire that opens riparian vegetation. Giant reed (*Arundo donax*) infestations increase ability for riparian vegetation to carry fire
Oak titmouse (*Baeolophus inornatus*)	None identified
California quail (*Callipepla californica*)	Prefers a mosaic of dense the open habitat and would benefit from small patchy fires near water sources
Dusky-footed woodrat (*Neotoma fuscipes*)	None identified
Badger (*Taxidea taxus*)	Fire may increase some fossorial rodent populations such as California ground squirrel (*Spermophilus beecheyi*), increasing food supplies for badger
Mountain lion (*Puma concolor*)	Burning chaparral would increase foraging areas for deer (*Odocoileus hemionus*) and would benefit mountain lions. Contiguous brush between the Palomar and Santa Ana mountains is needed to encourage dispersal by young lions into the Santa Ana Mountains

for cougars to move through this linkage, the species faces extinction in the Santa Ana Mountains because the range provides less than half the area required to allow cougar populations to persist (Beier 1993). Absence of cougars will trigger a wave of change, permanently altering predator–prey and herbivore–plant interactions throughout the range and on the reserve as well. Managers must carefully consider the distribution of dense vegetation needed by dispersing cougars in burn plans.

Managers should take into account the wide variety of effects that fire could have on species within a natural area. For example, SMER comprises approximately one-third of the territory for a nesting golden eagle (*Aquila chrysaetos*) pair—one of only five remaining breeding pairs in coastal San Diego County (D. Bittner, Wildlife Research Institute, personal communication). Feeding areas are declining in the territory as agriculture and urbanization encroach on natural habitats. In this case, fire can play a key role in opening densely vegetated habitat on the reserve to increase prey availability. A burn plan conducted solely to benefit golden eagles could be detrimental to cougars, which prefer dense, brushy habitats.

Some species may even be locally extirpated by fire and managers need to clearly identify the locations of populations that can recolonize burn areas. Under natural conditions, populations fluctuate in response to changes in the habitats and their own intra- and inter-population interactions. As a result, there have always been naturally occurring local extinction events. In the past, such local losses were balanced by reinvasion from other sites. In a fragmented landscape, reinvasion of some native species is reduced or prevented. Management practices will need to address recolonization needs if regional losses of biodiversity are to be avoided.

Broad regional processes such as decreases in air quality, exotic species invasions, and climate change should also be included in fire planning. Concern has arisen over the impact that air pollution can have on terrestrial nitrogen loads (Bytnerowicz and Fenn 1996) and the potential synergistic effects between air pollution and wildfire on vegetation structure (Padgett et al. 1999). As exotic species frequently are better able to exploit increased levels of nitrogen in the soil, and because many exotic species thrive as well or better than natives in the post-fire environment, it is possible that increased fire frequency or untimely fires could foster the advance of exotic species at the expense of natives in the human-modified environment (Padgett et al. 1999). Another example is potentially synergistic effects of increased fire frequency on invasive species. Fires at short intervals can have devastating effects on species composition (Zedler et al. 1983), and the degradation of vegetation caused by frequent fires has been documented in California and elsewhere (D'Antonio and Vitousek 1992, Haidinger and Keeley 1993).

What approaches do we take to incorporate this broad array of biological objectives in fire management planning at the reserve? If we conduct prescribed burns in the wrong place or in the wrong way, fire can eradicate species that are unable to recolonize from other natural areas. Conversely, if we don't burn at all, we may also cause local extinctions since the seeds of fire-dependent species can senesce in a seed bank waiting for cues such as smoke or increased light to germinate (Keeley and Fotheringham 1998). We don't have solutions to these challenges, but we have taken two first steps toward addressing them.

First, because existing vegetation maps were too general to adequately represent important variation, we conducted a detailed vegetation survey of the project area. We mapped how dominants and co-dominants varied within each Holland vegetation type (Holland 1986), mapping to at least 5-acre units of accuracy. With vegetation mapped as a GIS layer, we will explore the feasibility of designing a prescribed burn plan that maintains dominants at various age groups, including old-growth. This approach is based on the testable assumption that spatial variation in the dominant plant communities reflects spatial variation in other species distributions. Using detailed vegetation descriptions in designing prescribed burn plans may help to prevent against permanently altering environmental processes that are unknown or poorly understood.

Second, we hosted a series of workshops to identify that role that the reserve plays in maintaining regional biodiversity. The workshops engaged regional biologists and land managers from more than 40 universities, organizations, and agencies to discuss habitat connections between the Santa Ana and Palomar mountains. Though we recognized that ecosystem processes must be kept in mind, we adopted the tractable approach of studying the natural history and population viability requirements for a diversity of focal species. We considered habitat requirements, predator–prey relationships, reproductive biology, dispersal patterns, and other natural history variables for 20 plant and animal species sensitive to fragmentation in the linkage (Table 1). Wildfire emerged as an important factor affecting population viability for most of these species. This planning process revealed how much we have to learn about even reasonably well-studied species and challenging problems where managing for one species may conflict with managing for another. Prescribed burn plans need to evaluate how a variety of species may fare under alternative fire scenarios.

Research Opportunities

Fire research is often restricted to sites that happened to burn during a wildfire or that were burned for other purposes (e.g., prescribed burn for increasing safety). As such, the needed comparisons for rigorous field experiments that can control for slope, aspect, fuel loading, vegetation type and other variables cannot be made. Because field stations are charged with providing research opportunities, many consider developing long-term replicate burn plots of varying ages and with known burn histories that serve as resource and attractant for fire research. Field stations are one of the few land management groups that can afford to conduct a 10- to 20-year research project. Although notable exceptions exist, this approach is rarely undertaken due to the limited size of available lands, the relatively large replicate areas needed for these studies, and conflicts with other current or future research projects. SMER's approach is to consider burn plots when a specific research project is proposed.

If designed appropriately, data can be obtained from prescribed burns that inform managers of the effectiveness of land management actions. If assumptions of the prescribed burn plan are clearly stated (e.g., fuel reduction increases the ability of firefighters to control a fire at the site for up to 10 years, fuel reduction increases foraging efficiency of golden eagles, or burning maintains native species diversity), prescribed burns can be designed to assess the effect of fire-related habitat alteration and determine whether the burn achieves the desired goal. This kind of rigorous approach requires that statistical analyses be considered when designing prescribed burns and that replicate plots be established to estimate the means and variances of target variables. A university field station is an ideal place to involve both researchers and managers in a collaborative venture to address these questions.

Safety

Fire is a safety hazard to reserve users and staff. Researchers, classes, docent-led members of the public, and staff regularly drive or hike in remote areas of the reserve, sometimes on rugged trails through the gorge and chaparral in the course of research and learning. Access roads on the reserve are unpaved and some areas are impassible up to 3 days after a rain. Staff and users also stay overnight in reserve facilities located on the north and south sides of the reserve. All of these factors put reserve visitors at risk during a wildfire. To reduce threats to lives and facilities, we have taken a variety of approaches in community outreach, resource information development and sharing, infrastructure development, and fuel load modification.

Neighboring homes and human activities increase the risk of a fire starting. In 1998, a homeowner using a weed-whacker in the middle of summer started a local fire on the north side of the reserve that was contained before it reached reserve lands. Through workshops, neighborhood meetings, and community events, we have identified risky fire behaviors and reporting avenues, and dispensed information materials to neighbors. The general approach was to identify ignition sources as a mutual responsibility. To reduce risk of ignition from trespassers, we collaboratively developed a docent program with a local land conservancy to educate our local communities about research activities and fire risk and to develop support for these activities.

At least 13 agencies, districts, and community groups (Table 2) have legal responsibilities or have expressed interest in lands included within SMER. To begin dialogues with these groups on fire management issues, we developed a GIS database comprising environmental (topography, vegetation, drainages, surface water, potential habitat for threatened or endangered species, and archaeological sites) and logistic resources (structure locations, fire hydrant locations, access routes, road condition, drafting locations, staging areas, and helispot locations). Pertinent information was produced in formats identical to information resources housed in the fire engines and brush trucks that firefighters use when responding to a fire. We also developed a flow chart that organizes and summarizes how fire management planning (here shown as an example for a prescribed burn) can include all of the groups with interests at the reserve (Figure 1).

Using the GIS database, we worked with fire response agencies to identify key weaknesses in our infrastructure that would compromise firefighting response. Two projects were undertaken to remedy these weaknesses: We developed a 17,000-gallon water supply in one of the most remote areas of the reserve, and we installed a remote access weather station to provide Internet-accessible data on weather and fuel temperature and humidity. Reserve buildings

Table 2. Entities that have expressed interest or have responsibility concerning fire management at the Santa Margarita Ecological Reserve, a San Diego State University Field Station in Riverside County, California.

Agency or institution	Interest in fire management	Management priority
San Diego State University	Reserve administrator, land owner, Federal Emergency Management Agency (FEMA) grant recipient	Maintain natural ecological processes for the purposes of research and education
Fallbrook Public Utility District	Land owner, FEMA grant recipient	Provide reliable high-quality water and wastewater disposal to the community of Fallbrook
Bureau of Land Management	Land owner	Sustain the health, diversity and productivity of public lands for the use and enjoyment of present and future generations
California Department Fish and Game	Land owner	Manage California's diverse fish, wildlife, and plant resources and the habitats on which they depend, for their ecological values and use and enjoyment by the public
The Nature Conservancy	Land owner	Preserve plants, animals, and natural communities by protecting lands and waters they need to survive
Metropolitan Water District of Southern California	Right-of-way holder	Provide adequate, reliable, high-quality water to the service area
Federal Emergency Management Agency	Funding agency	Reduce loss of life and property through emergency management, mitigation, preparedness, response, and recovery
U.S. Fish and Wildlife Service	Administers Endangered Species Act and reviews federal projects	Conserve, protect, and enhance fish, wildlife, plants, and their habitats for continuing benefit of the American public
California Department of Forestry and Fire Protection	Fire response agency	Protect the people of California from fires, respond to emergencies, and enhance forest, range, and watershed values
North County Fire Protection District	Fire response agency	Safeguard the health and welfare of the community and mitigate the effects of hazards to life, property, and the environment
Mission Resource Conservation District	FEMA grant recipient	Disseminate information on natural resource conservation issues involving agriculture, environmental quality, and wildlife
Neighbors	Wildfire concerns	Personal safety

were also brought up to fire safety codes and navigation signs were installed on remote roads.

Road access became a difficult management issue. Grading reserve roads to achieve width and condition standards disturbs habitat, natural drainage patterns, and research projects, and increases avenues for invasive species (Zink et al. 1995). One road is located within the flood plain of Stone Creek and would involve substantial recontouring of the stream bank. To develop an approach that would minimize environmental disturbance while achieving access goals, we began a collaborative project with an interdisciplinary (civil engineers, soil scientists, hydrologists, and wildlife and fishery biologists) and multi-agency (U.S. Forest Service, other federal agencies, state agencies and organizations) group that uses techniques and treatments for minimizing the effects of dirt roads on riparian vegetation. During an initial assessment of the reserve, we identified problem areas. Treatments at these areas will become a demonstration site for showcasing a variety of techniques that minimize environmental impact.

We manually cut back or reduced native vegetation at least 130 m from all reserve facilities to decrease the chance of structures burning during a wildfire. Prescribed burns can also be used to reduce fuel loading near facilities. On the reserve, our approach is to understand the biological consequences of safety burns and determine whether these consequences are acceptable. Studies are badly needed to figure out ways to maintain areas at reduced fuel loading without favoring the aggressive exotic grasses and forbs that tend to dominate open areas.

PRACTICAL, REGULATORY, AND SOCIAL REALITIES

Any plan that deals with fire must be conceived in the full context of social, economic, and political as well as biological factors. In this section, we return to the question of how to incorporate political and social realities with the already diverse reserve goals discussed above.

As mentioned above, protected natural areas are becoming increasingly important to provide habitat for species in decline. This problem can become a catch-22 if fire is needed to create high-quality habitat but potentially causes the death of individual animals. Burning habitat occupied by a species of special concern to improve the area for future generations requires a take permit from the U.S. Fish and Wildlife Service, which is not always granted. Prescribed burn plans that try to maximize species richness in general or maintain natural environmental processes come under even greater scrutiny if endangered or threatened species are involved.

Fire response agencies have developed guidelines for protecting structures in fire-prone areas. High fuel volume vegetation is required to be cleared to 130 m from the structure's foundation (Gilmer 1996). In cases where homes are closer than 130 m from the property line, county regulations state that the neighbors are responsible for clearing vegetation on their properties. Thus, the boundaries of the reserve are compromised. In an extreme case, a home built on the boundary of the Santa Rosa Plateau Ecological Preserve would have required land managers to clear vegetation in vernal pools that contained threatened and endangered species (Carole Bell, Santa Rosa Plateau Ecological Preserve, personal communication).

If wildfire occurs on the reserve, firefighters will respond using standard firefighting practices (e.g., bulldozing fire breaks, using fire retardants, and wet water). The reserve sought to minimize the effects of these activities so that fire effects themselves could be studied after the fire without the confounding effects of human activities. In addition, bulldozers and high nitrogen content of fire retardants favor invasion by exotic European grasses. A proposal to limit bulldozing and fire retardants to a north–south firebreak in the reserve was met with skepticism and alarm from the firefighting community. The lands in the reserve have steep slopes, support dense fuels, have poor access, and are located within only a few kilometers from major urban centers in Temecula and Fallbrook. If standard firefighting techniques were not used and the fire eventually burned homes or took lives, both fire agencies and the reserve would be vulnerable to lawsuits. Thus, as homes increase near wildland areas, ability to vary wildfire response strategies decreases, and biological objectives are replaced by safety objectives irrespective of the mission of the land management agency.

Even if modifications to firefighting techniques are agreed upon, fire management actions may not be carried out. During fire season, fire response personnel may be transferred to large fires in other parts of the country. Should a fire break out at the reserve while local personnel are on assignment elsewhere, firefighters unfamiliar with the fire management plan would be responsible for containing the fire. We have attempted to address this problem by using appropriate signs at our boundaries and incorporating information about the plan into fire response procedures used by the fire response agencies.

Natural areas are beautiful as open space and living in these areas offers great appeal. Homes at the wildland–urban interface are often quite expensive. Once on-site, however, people begin to view natural areas as the fire hazard that they are, placing increasing pressure on land managers of adjacent properties to conduct prescribed burns to achieve safety rather than biological objectives. Although under no legal obligation to protect adjacent homes (but see previous example in this section for a notable exception), wildland managers often succumb to social pressures since public perception can have far-reaching effects on a wide variety of management activities. Fueled by the concept that fire is "good" for "fire-adapted" habitats, specific biological objectives are rarely considered. The eventual consequence is a halo of burns at the edges of natural areas.

WHERE DO WE GO FROM HERE? A VISION FOR FIRE MANAGEMENT IN THE 21ST CENTURY

The experience at SMER is not unique. Biological needs overlain by social and political pressures from the urban–wildland boundary is a general challenge that exists throughout the region and the world where wildfires pose a risk to life and property. Because our field station is an extension of San Diego State University, we feel strongly that we should take a broad heuristic approach rather than finding the quickest solution to our particular problems. Thus, we see our unique fire problem as a test case for exploring approaches that will inform management throughout the region. We believe that further research and trial programs are needed in the following areas: combining science and management, collaborations and shared information, policy, and education.

Returning fire to the ecosystem as a natural process has rightfully gained great popularity among biologists and firefighting personnel. Simply burning at historic frequencies, however, does not ensure that the ecosystem will flourish. Managers need to acknowledge in prescribed burn plans the wholesale environmental changes that have occurred in the last century, the bio-regional importance of the site being considered, and the complexity of biological responses to fire. We must develop fire policies that are based in sound science, not merely plausible expert speculation or oversimplified assertions that fire is "good" or "bad." If the assumptions inherent in prescribed burning are clearly stated, prescribed burns can be designed to allow us to rigorously test our assumptions. Fire management planning can become a fluid, adaptable process, with goals being adjusted as new information and new problems come to light.

In urbanizing areas, fire management is highly collaborative. Agencies and organizations are motivated by a variety of institutional goals. We must find effective ways to facilitate multiple management goals. Establishing ourselves as an information resource and sharing information on biological effects of fire with our partners and their constituencies can help. Natural areas can be used to encourage participation by local communities in planning and fire activities.

The concept that landowners adjacent to natural areas have responsibilities as well as rights must be established. When fires are burning, the emphasis is on NIMBY ("not in my back yard"). Citizens often demand that public money be spent to ensure the safety of their homes. But between fires, living next to a natural areas is seen as a good thing, a fact reflected in the greater value of homes near natural areas (Standiford and Scott 2002). Thus NIMBY becomes PIMBY—"please [I want a natural area] in my backyard." An analogy applies: Airlines ask those seated in exit rows to accept special responsibilities for the good of all and to change seats if they are unwilling or unable to do so. Similarly, we must ask those living next to fire-prone natural areas to accept certain responsibilities. Educating home-buyers about fire risk and the need to maintain natural processes in remote areas must be institutionalized as part of the home-purchasing process. Ordinances must allow management to work with natural processes rather than to contravene them.

We acknowledge that the reserve management also has a responsibility to work with its neighbors. Many of those who live in southern California have moved from other parts of the country and have limited direct experience with the natural rhythms of a semi-arid landscape. Education is necessary to help people understand the problems that are unique to their region. But education will be most effective if it is supported by land-use regulations that mandate sensible accommodations to life next to chaparral.

We need programs that build public understanding and support for biologically sensitive fire management. We must be able to provide convincing evidence that will change public attitudes. At the heart of the issue is how to assist the public to understand the kind of probabilistic and speculative thinking that is natural to scientists but which can seem to a lay audience to be maddeningly equivocal. We accept also that education is not all one way—we must approach this problem with the objective of establishing a fruitful dialogue between the reserve and the public.

ACKNOWLEDGMENTS

This study would not have been possible without the funding from the Hazard Grant Mitigation Program administered through the Governor's Office of Emergency Services and the cooperation of SDSU Field Station Programs, Fallbrook Public Utility District, and Mission Resource Conservation District. The manuscript was improved by the comments of Todd Engstrom and two anonymous reviewers.

LITERATURE CITED

Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. Conservation Biology 7:94–108.

Bytnerowicz, A., and M.E. Fenn. 1996. Nitrogen deposition in California forests: a review. Environmental Pollution 92:127–146.

D'Antonio, C.M., and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23:63–87.

Davis, F.W. 1999. Gap analysis of mainland California: an interactive atlas of terrestrial biodiversity and land management. California Gap Analysis Project, California Department of Fish and Game, and Environmental Systems Research Institute. http://www.biogeog.ucsb.edu/projects/gap/gap_cdrom.html

Dobson, A.P., J.P. Rodriguez, W.M. Roberts, and D.S. Wilcove. 1997. Geographic distribution of endangered species in the United States. Science 275:550–553.

Gilmer, M. 1996. Landscaping the I-Zone. Pages 194–203 *in* R. Slaughter (ed.). California's I-Zone: urban/wildland fire prevention and mitigation. California Resources Agency, Sacramento.

Haidinger, T.L., and J.E. Keeley. 1993. Role of high fire frequency in destruction of mixed chaparral. Madroño 40:141–147.

Holland, R.F. 1986. Preliminary descriptions of the terrestrial natural communities of California. California Resources Agency, Sacramento.

Keeley, J.E., and C.J. Fotheringham. 1998. Smoke-induced seed germination in California chaparral. Ecology 79:2330–2336.

Keeley, J.E., C.J. Fotheringham, and M. Morais. 1999. Reexamining fire suppression impacts on brushland fire regimes. Science 284:1829–1832.

Minnich, R.A. 1995. Fuel-driven fire regimes of the California chaparral. Pages 21–27 *in* J.E. Keeley and T. Scott (eds.). Brushfires in California wildlands: ecology and resource management. International Association of Wildland Fire, Fairfield, WA.

Myers, N., R.A. Mittermeler, C.G. Mittermeler, G.A.B. da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858.

Padgett, P.E., E.B. Allen, A. Bytnerowicz, and R.A. Minnich. 1999. Changes in soil inorganic nitrogen as related to atmospheric nitrogenous pollutants in southern California. Atmospheric Environment 33:769–781.

Standiford, R.B., and T. Scott. 2002. Value of oak woodlands and open space on private property values in southern California. Pages 835–836 *in* R.B. Standiford, D.D. McCreary, and K.L. Purcell, technical coordinators. General Technical Report PSW-GTR-184, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

Stephenson, J.R., and G.M. Calcarone. 1999. Southern California mountains and foothills assessment: habitat and species conservation issues. General Technical Report GTR-PSW-172, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

Zedler, P.H., C.R. Gautier, and G.S. McMaster. 1983. Vegetation change in response to extreme events: the effect of short interval between fires in California chaparral and coastal scrub. Ecology 64:809–818.

Zedler, P.H., and L. Seiger. 2000. Age mosaics and fire size in chaparral: a simulation study. Pages 9–18 *in* J.E. Keeley, M. Baer-Keeley, and C.J. Fotheringham (eds.). 2nd interface between ecology and land development in California. U.S. Geological Survey, Western Ecological Research Center, Sacramento, CA.

Zink, T.A., M.F. Allen, B. Heindl-Tenhunen, and E.B. Allen. 1995. The effect of a disturbance corridor on an ecological reserve. Restoration Ecology 3:304–310.