THE GEORGE WRIGHT FORUM

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GEORGE WRIGHT SOCIETY
1980–2005
25 years of service

Origins

Founded in 1980, the George Wright Society is organized for the purposes of promoting the application of knowledge, fostering communication, improving resource management, and providing information to improve public understanding and appreciation of the basic purposes of natural and cultural parks and equivalent reserves. The Society is dedicated to the protection, preservation, and management of cultural and natural parks and reserves through research and education.

Mission

The George Wright Society advances the scientific and heritage values of parks and protected areas. The Society promotes professional research and resource stewardship across natural and cultural disciplines, provides avenues of communication, and encourages public policies that embrace these values.

Our Goal

The Society strives to be the premier organization connecting people, places, knowledge, and ideas to foster excellence in natural and cultural resource management, research, protection, and interpretation in parks and equivalent reserves.

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FORUM

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On the cover: Human fire use is an important economic and ecological management tool in many parts of the world. In Kakadu National Park, Australia, prescribed fires, similar to those set by Aboriginal people for thousands of years, are used to maintain selected native plants and animals and limit more severe wildfires.

SOCIETY NEWS, NOTES & MAIL

Diamant, Toothman win seats on GWS board; Emory re-appointed

Rolf Diamant and Stephanie Toothman emerged as the victors in the 2005 election for the GWS board of directors. The largest field of candidates ever was vying for seats being vacated by Bruce Kilgore and John Reynolds. In close contests, Diamant beat out John Donahue, Elaine Leslie, and Mike Tranel for one seat, while Toothman bested Brad Barr and Bert Frost for the other. Diamant is superintendent of Marsh–Billings–Rockefeller National Historical Park in Vermont, while Toothman (who returns for a second stint on the board) is head of cultural resources in the National Park Service's Seattle office. The results were tabulated at the 2005 GWS board meeting in early November. At that same meeting, the board re-appointed Jerry Emory to a second three-year term. Emory is a communications specialist with the Moore Foundation.

Looking ahead to 2006, two more elected seats on the board will come open, as both David Parsons and Dwight Pitcaithley will be reaching the end of their second terms and thus serving their final year on the board. Details on the election and a call for candidates will appear in the next issue of the *Forum*.

Revised GWS by-laws approved

As reported in the last *Forum*, earlier this year revisions to the GWS by-laws were proposed and a comment period for members was offered. No objections to the revisions were received, so at its 2005 meeting the GWS board approved the revisions. Most of the changes were minor editorial adjustments to bring the by-laws into conformity with our current membership categories and executive office structure.

New books

- ***The Urban Imperative: Urban Outreach Strategies for Protected Area Agencies.*** Almost half the world's people live in cities and this proportion is steadily growing. Protected areas provide important benefits to cities; conversely, conservationists depend on support from voters, leaders, and opinion-shapers largely concentrated in urban centers. This book's message is that conservationists' success will depend increasingly on taking these urban connections seriously. Edited by Ted Trzyna, *The Urban Imperative* brings together 34 authors from 11 countries on 6 continents to discuss the multifaceted interdependence of cities and protected areas; innovative roles for conservation organizations in educating urban people about nature, greening cities, and bridging divisions in urban society; and the partnerships essential to working in urban settings. Case studies focus on cities as diverse as Cape Town, London, Los Angeles, Paris, Mumbai, and Sydney. Ordering information at http://www.interenvironment.org/cipa/tui.htm.
- ***Pilgrim Places: Civil War Battlefields, Historic Preservation, and America's First National Military Parks, 1863–1900.*** This illustrated 32-page study, which will form the basis of a chapter in author Richard West Sellars' forthcoming benchmark history of

cultural resource management in the National Park Service, is a history of the creation of Civil War battlefield parks, including Gettysburg, Antietam, Shiloh, and Vicksburg, as well as the genesis of national cemeteries, veterans' organizations and reunions, and the African American role in the conflict. Ordering information from Eastern National, 1-877-NAT-PARK, or www.eParks.com.

- ***Drift Smoke: Loss and Renewal in a Land of Fire.*** Author David J. Strohmaier, a historian and former firefighter, offers this first-person narrative of the damage and renewal brought on by wildfire. Living with fire, he says, is a matter of "seeing the connection between loss on a personal scale and loss on a landscape scale: in relationship with persons, and in relationship to and with the land." Ordering information from University of Nevada Press, www.nvbooks.nevada.edu. Another new Nevada title is ***Black Rock*** with photos by Peter Goin and literary commentary by Paul F. Starrs. The Black Rock is a little-known desert realm the size of Delaware located north of Reno. This forbidding landscape embraces mile-high mountains and one of the world's most barren salt pans; the book explores the natural forces that have shaped the region. Ordering information as above.
- ***Communities and Forests: Where People Meet the Land.*** Natural resource sociologists Robert Lee and Donald Field have edited this collection of 16 articles on the how North American forestry is changing by increasingly focusing on the integration of communities into decision-making about forests. With this new involvement come changes in the social meaning of forests, especially those on the fringes of urban communities. Ordering information from Oregon State University Press, 1-800-426-3797.
- ***Earth Repair: A Transatlantic History of Environmental Restoration.*** Following in the footsteps of George Perkins Marsh, historian Marcus Hall compares the paths environmental restoration has traced in Italy and the United States to answer the question of which ecosystems need restoring, to what states should they be restored, and what methods should be used to achieve the restoration. Ordering information from the University of Virginia Press, www.upress.virginia.edu.

Brief bits

- The United States recently was elected as a member of the World Heritage Committee. Secretary of the Interior Gale Norton said the U.S. would use its seat to promote President Bush's "Cooperative Conservation" approach and to "restore the credibility" of the World Heritage Convention in Congress.... The steering committee of IUCN's World Commission on Protected Areas (of which GWS Executive Director Dave Harmon is a member) has completed a strategic plan to cover its activities over the next four years. Focal areas will be conservation of biodiversity, science and management of protected areas, capacity-building and awareness-raising, and governance and equity.... Bruce Kilgore, who is completing his final year on the GWS board, received a Lifetime Achievement Award from the Association of Fire Ecology at its 2005 meeting, held in Bartlesville, Oklahoma, in October. The AFE recognized Kilgore for his career-long efforts to enhance the understanding of the role of wildland fire, especially in relationship to protected areas.

Thanks for the Memories

Jean Matthews

Ed. note: To cap our 25th anniversary year, we invited the first editor of *The George Wright Forum,* Jean Matthews, to share her thoughts on the evolution of the GWS, starting with the creation of the organization in 1980. Jean edited the *Forum* throughout much of the 1980s, and helped set a tone of forthrightness and candor for the journal—one which we have tried to maintain ever since. Trained as a journalist, Jean worked as a newspaper reporter before beginning a government writing career in 1962. Initially a speech writer for Secretary of the Interior Stewart Udall and Ladybird Johnson, she also produced several highly regarded yearbooks on the work and staff of the Department of the Interior. In the early 1970s, Jean began writing speeches for NPS Director George Hartzog and served on an environmental education task force that sought to integrate natural systems concepts into NPS interpretive media. Jean's idea to publicize the marriage of science and resource management came about in 1980 when she launched the journal *Park Science*, a project she oversaw until her retirement in 1994. A year later Jean was named a co-winner of the Society's highest honor, the George Melendez Wright Award for Excellence. As you'll see, although "retired," Jean maintains her passion for bringing the best science to bear on park management.

WHAT A RARE AND WONDERFUL OPPORTUNITY—to walk down memory lane back to the days of the giants, when it was possible to start such an enterprise as the George Wright Society. These are the larger-than-life people who were not just "present at the creation," but were responsible for what grew out of that moment.

I had been standing waist-deep in a veritable slough of despond, assaulted by one depressing message after another about what was happening to our nation's precious national parks, forests, and preserves. The *New York Times* was editorializing about the desperate efforts of National Park Service personnel to prevent our holiest places from being turned into cash registers. My depression had deepened so alarmingly that I had booked a four-day retreat at a Trappist abbey and was about to leave for it when Dave Harmon's invitation reached me: an offer to do a quarter-century backward look at how the George Wright Society began and what it has accomplished. It seemed an opportunity I was in far too low a frame of mind to tackle.

I arrived at the abbey with the latest issue of the *Forum,* settled into my little room, and found the New Testament on the bedside table, open to a passage describing the voice of God, speaking to Moses from the burning bush. "Take off your sandals," was God's command. "You are standing on holy ground."

The picture that passage brought up was of Bill Brown at Harpers Ferry, after heading the director at that time, Ray Nelson, describe his vision of the national park mission. Brown's response was to rush up to the podium and demand, "Where are my sandals?"

So much for "taking them off." When holy ground is at stake, you put them on and get to work.

What transpired back them was only possible because we were backed by giants.

First, there was Stewart L. Udall, John F. Kennedy's secretary of the interior. Udall had just read George Perkins Marsh's *Man and Nature*—a 100-year-old classic that begged to be updated. Among Udall's first acts as interior secretary was to bring Marsh's case for environmental stewardship up to date. The result was *The Quiet Crisis.* It may have started out as "quiet," but its gospel was a ringing challenge to take up a new task.

The call was for "an end to fragmentation" and presented a "whole earth" approach to stewardship. Udall's vision and leadership naturally attracted the men and women who would begin to implement it, and the rest of the giants began to emerge. I was incredibly lucky to have a small part in the movement and to reap the benefits it afforded. Stan Cain, an assistant secretary for fish, wildlife, and parks, first made me aware that every action we take with relation to the earth has *effects,* and that "there are no *side* effects." Bill Pecora, then director of the Geological Survey, introduced me to Loren Eiseley, whom Pecora described as "the scientists' poet." Thanks to Pecora, the speech drafts I wrote afterwards were laced with elegant Eiseley quotes.

And then came one of Udall's truly inspired appointments—George B. Hartzog, Jr., one of the two greatest directors the National Park Service has ever had (the other being Stanley Albright). It was Hartzog who hired outstanding photographer Wayne Miller (who, along with Edward Steichen, helped create the famous exhibit "The Family of Man," for which Carl Sandburg wrote a beautiful prologue). Miller was not content merely to photograph the parks. He saw the possibilities for making them purveyors of environmental education, and set about devising such a program. (It wasn't what Hartzog had in mind when he hired Miller, but Hartzog's intuition told him the direction was right, and he backed the project to the hilt.)

This is the point at which I first remember Bob Linn—another of the top-flight people the new movement was attracting. Miller and his fledgling environmental education corps were meeting in the library at Harpers Ferry and attempting to recruit Linn into their ranks. "We want to use the national parks as classrooms to show park visitors the ways in which man and nature interact and work," Miller said.

I still remember the bemused look on Linn's face as he processed that information, finally observing, "I always thought that man was a *part* of nature." I left that meeting with more speech draft material: man as *a part of,* rather than *apart from,* nature. It sounds pedestrian now, but at the time, what a concept!

Another player in the pantheon of those days was Ted Sudia. The latest *Forum*, which I had with me in the abbey, featured a piece by Ron Engel (of which more later). In it, Engel pays tribute to Tommy Gilbert (of Man and the Biosphere accomplishments, and the first president of the GWS) and Sudia, who did his level best to start an Institute of Domestic Tranquility, which he saw as encompassing the great natural areas, art, and the natural and social sciences.

Alas, some pieces of the future are too huge to be chewed and digested at the level of enlightenment where they are first introduced, and the Institute of Domestic Tranquility was one of those. But some are destined to survive, and one of Sudia's ideas did make it. The George Wright Society was Sudia's brain child, and he was lucky enough to birth it in a world where people like George Hartzog were available to approve of it, bless it, and help get it off the ground.

The first meeting of the GWS was in the auditorium of the General Services Administration, just north of the Main Interior Building in Washington, D.C. Among those present were Sudia, Linn, and the two generous daughters of George Wright, dedicated to establishing am organization worthy of their father. No one at that meeting could fully realize how important a mission the GWS would undertake, how impressively it would evolve, or how mightily it would be challenged as they days of the giants waned.

As the grand vision faded and the visionaries were replaced, Bob Linn never flagged in his determination to keep the Society on track and the *Forum* as a written record of its triumphs and on-going work. I remember growing anxious as the climate of stewardship slackened, and several times calling Linn and saying, "I feel an editorial coming on." He was ever the generous publisher and allowed me to rail against the stealing of our language and the subverting of its meanings. What had me up in arms in particular was the Sagebrush Rebels renaming themselves the "Wise Use Movement." That linguistic travesty was only the beginning, of course, and led increasingly to such misnomers as "Clear Skies" and "Healthy Forests." This deliberate bastardizing of language was more than "a cloud on the horizon no bigger than a man's hand"—it *was* a man's hand. And it meant no good.

A recent editorial writer in the *Oregonian* was appalled at the Forest Service putting out bids for helicopter rides around Mount St. Helens and predicted a flood of concessionaires peddling trashy souvenirs. A follow-up editorial in the *New York Times* detailed the work of the wrecking crew and noted with great alarm the political "loyalty oath" the Park Service proposed to require of its top management. Where was the old vision of preserving our treasured natural and cultural heritage, perpetuating it, undiminished, for future generations? Why were our holiest natural temples being peddled to the highest bidders?

Today, the George Wright Society is carrying forward the use of parks and preserves as laboratories for scientific research into the natural systems of earth and how they work. We're building a future on the past, when we set ourselves enthusiastically to decipher "tongues in trees, books in running brooks, and sermons in stones"—to read the age-old wisdom of continuing creation. Today we watch while science is suppressed or ignored. Visitors to the Grand Canyon—that great testimony to evolution—are able to purchase pseudo-scientific readings in Intelligent Design, a.k.a. Creationism.

I see the George Wright Society more and more as a keeper of the flame, much like the monasteries that kept the light of learning alive through the Dark Ages. Our mission becomes more critical as the darkness deepens. Bob Linn's spirit is alive and well as the *Forum* continues to pursue scientific knowledge and make it available to park management—just as though the inmates weren't currently in charge of the asylum.

Reading the latest *Forum,* I was struck with its theme of geodiversity, a concept full of insight and promise. (My spell check underlines *geodiversity*—it's too new an idea to merit a word in my computer's brain, but the idea is now loose and researchers will run with it.) Congratulations to Vincent Santucci for a splendid issue.

Most important to me was Ron Engel's keynote address to the IUCN's last plenary

FIRE MANAGEMENT IN PARKS & PROTECTED AREAS

GUEST EDITOR: BRUCE M. KILGORE

Fire Management in Parks and Protected Areas: Introduction and Summary

Bruce M. Kilgore

When national parks were originally established in the United States in the late 1800s and early 1900s, most people thought you simply needed to protect them as they were, with no changes over time, to achieve the objective of preserving parks for future generations. While this may work for cultural resources, we have learned that changes in vegetation, wildlife, and other natural features are part of the way natural ecosystems function. The original, somewhat simplistic, and static concept of "park preservation" has since been expanded into a broader concept of perpetuating natural park resources and natural park processes over time. Only in this way can the National Park Service (NPS) and other agencies with responsibilities for protected areas really succeed in restoring, maintaining, protecting, and preserving the resources and resource values for which the parks and protected areas were established.

In this issue of *The George Wright Forum,* we present several articles that address how "fire management" in parks has evolved during the 89 years since the 1916 establishment of the National Park Service. While many aspects could be considered, we will focus on changes in the accepted role of fire in parks, and the relationship between fire management, forest health, and biodiversity.

Over the past 42 years, since the 1963 Leopold Report (Leopold et al. 1963) was delivered to Secretary of the Interior Stewart Udall, the National Park Service has been wrestling with how best to respond to that report's conclusions and recommendations that dealt with fire management. The report's recommendations were incorporated into NPS green book policy in 1968 and implementation began at Sequoia-Kings Canyon and other national parks in that year.

A major change was made in the National Park Service's philosophical approach to fire management. Moving well beyond the traditional suppression-only policy, Superintendent John McLaughlin of Sequoia-Kings Canyon allowed lightning-ignited fires to burn in certain high-elevation zones in the park beginning in 1968 (Kilgore and Briggs 1972). And prescribed fires were also ignited by park rangers in red fir and lodgepole pine forest (1968) and giant sequoia–mixed conifer forests (1969). These programs grew in many parks, particularly in Sequoia and Yosemite. As early as 1974, some 9 NPS units allowed 74 lightning fires to burn on 15,000 acres of park wildlands, and 5 NPS units used 46 prescribed burns that covered 11,000 acres of National Park Service forest and grasslands (Kilgore 1976).

A major review of these programs at Sequoia-Kings Canyon and Yosemite was undertaken in 1986 by a seven-person panel of scientists, headed by Norman Christensen of Duke University. That review was presented to Director William Penn Mott and served to guide the future actions of resource management and fire staff at both Sequoia-Kings Canyon and Yosemite (Christensen et al. 1986). Within two years, Christensen was called upon again by the NPS to chair a panel to review the controversial 1988 Yellowstone fires. Those fires posed a major challenge to NPS fire programs throughout the country. The panel review (Christensen et al. 1989), as well as an interagency review team's report (USDA/USDI 1989), led to significant changes in the way the NPS fire management programs were implemented.

As chair of these two panels, Christensen played a major role in evaluating the progress made by the National Park Service in implementing the 1963 Leopold Report recommendations and in suggesting what changes would be appropriate in future fire and resource management programs at Sequoia-Kings Canyon, Yosemite, and Yellowstone National Parks. Christensen summarized the story of these two scientific reviews of NPS fire and resource management policy in his plenary presentation at the March 18, 2005, session of the George Wright Society Conference in Philadelphia. We have the pleasure of presenting the written version of that analysis/paper in this issue of the *Forum.*

Recent (2004) legislation and management plans have emphasized the relationship between forest health, fuels management, and fires. While this legislation deals primarily with non-wilderness Forest Service lands, Bureau of Land Management lands, and private lands in the West, these programs have the potential to strongly impact the health of adjacent forested lands in national parks and other protected areas. Greg Aplet and Bo Wilmer describe the Wildland Fire Challenge across America as a result of extremely large forest fires that have burned millions of acres—including hundreds of homes—in recent years. They discuss how we need to evaluate our programs aimed at dealing with these fires and the fuel build-up that contributes to them, and what ecological restoration programs and community actions are appropriate.

Christensen then summarizes the results of a five-person panel (comprising James Agee, Bruce Kilgore, Nathan Stephenson, Jan van Wagtendonk, and Carol Miller) who discussed "Forest Health and Fire in the National Parks" at the 2005 GWS Conference in Philadelphia. While debate surrounding the Healthy Forests Restoration Act has focused on national forests, there are many implications for national parks. The goal of this workshop was to explore the challenges to forest health and restoration of natural fire regimes provided by park mandates that provide for both conservation and public use.

The National Commission on Science and Sustainable Forestry, a group chartered by a consortium of foundations including the Doris Duke Charitable Foundation, the National Forest Foundation, Surdna Foundation, and the Packard Foundation, held its second annual symposium in Denver in December 2003. It focused on "Fire, Forest Health and Biodiversity." Christensen has prepared a summary of the conclusions of that 16-paper session for this issue of the *Forum,* including a summary of the keynote presentation by Jerry Franklin of the University of Washington. He then summarizes the four major themes of that symposium as "Fire as an Ecological Process" (Michael Huston, Andrew Hansen, and Daniel Brinkley), "Inter-regional Variation in Fire Regimes and Fire History" (Jim Agee, Tom Swetnam, Jon Keeley, William Romme, and Joan Walker), "Perspectives on Fire Management" (Penelope Morgan, Wallace Covington, and Christensen), and "Perspectives of Managers and Stakeholders" (Rick Cables, Gary Roloff, Greg Aplet, and David Parsons).

For a broad national policy perspective, we have included a recent paper on "Federal Forest Fire Policy in the United States" by Scott Stephens and Lawrence Ruth. This article was originally published earlier in 2005 in *Ecological Applications* and is republished in this issue of the *Forum* by permission of the Ecological Society of America. It stresses the important point, made earlier by Franklin and Agee (2003), that despite many policy revisions, plans, and special healthy forest initiatives, "there is no comprehensive policy to deal with fire and fuels" and "few indications that such a policy is in development." It also makes the point that "policy-making depends on technical and scientific information, but the choices made are inherently political ones." The public and homeowners must be involved in whatever solution is developed, and that solution will depend on long-term commitment to maintenance of ecosystems and fuel levels that lead to low-to-moderate fire behavior around communities at risk.

Finally, to take an even broader look at the role of fire in ecosystems worldwide, we are including a paper by Jeff Hardesty, Ron Myers, and Wendy Fulks, all of The Nature Conservancy's Global Fire Initiative, that presents a preliminary assessment of fire as a global conservation issue. The Nature Conservancy notes that ecosystems and people have been living in a world of fire for perhaps millions of years. Yet it notes that ecologists believe that fires are behaving differently now from any other time in history. The assessment uses a classification of the earth into 132 major terrestrial habitat types. And it divides fire regimes into three major categories: fire-dependent/influenced ecosystems, fire-sensitive ecosystems, and fire-independent ecosystems. It presents a preliminary assessment of how altered such fire regimes have become in recent years and an overview of the possible role of communities, governments, and scientists in future fire management actions to benefit both people and park and protected area resources.

We hope this summary of changes in fire management ideas from the March 2005 GWS Conference in Philadelphia, plus several additional assessments and discussions, will be useful to managers of parks and other protected areas, as well as of interest to the many other readers who depend upon such areas for their recreational, scientific, and other values.

Acknowledgments

I am grateful to David Parsons and Norman Christensen for developing the 2005 GWS Conference sessions that are included in this issue and for their review of various aspects of the content of this issue. In addition, Bob Mutch, Steve Botti, Jim Agee, Jan van Wagtendonk, and Dave Harmon offered valuable review comments and suggestions. We acknowledge the special assistance of Ayn Shlisky and Wendy Fulks of The Nature Conservancy's Global Fire Initiative as well as the special permission to use previously published materials granted by The Nature Conservancy, the Wilderness Society, and the Ecological Society of America.

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Fire in the Parks: A Case Study for Change Management

Norman L. Christensen

Introduction

From the time of my doctoral studies in the early 1970s up through 1985, I had considered myself a botanist—a plant ecologist to be precise—who just happened to be interested in the effects of fire on plant growth and survival. I suppose I might be able to count myself among the first generation of folks who would brand themselves as fire ecologists. Chairing two reviews of National Park Service fire management programs in 1986 and 1988 catalyzed my interest in the applications of basic science to natural resource management and profoundly altered the course of my career. I appreciate this opportunity to reflect on those experiences.[1]

Background

In 1872, our nation's first national park, Yellowstone, was "dedicated and set apart as a public park or pleasuring ground for the benefit and enjoyment of the people." The anthropocentric mission of this first park is clear, and there was in 1872 little indication that this dedication was intended to inaugurate what would become the world's most ambitious national park system. The development of an actual system of parks did not really begin until the 1890s and early 1900s with the creation of Yosemite, Sequoia, Crater Lake, Mount Rainier, and Glacier National Parks. Although conservation of nature was a more explicit part of the mission of these new parks, "people pleasuring" remained the highest priority (Mackintosh 1991). The growth of the system was largely driven by opportunity and public appeal, as opposed to what today we might call a strategic conservation plan.

There was in these very early park system years virtually no scientific framework to guide park managers with regard to the conservation of natural elements. The scientific discipline of ecology was in its early infancy—the first scientific journal dedicated specifically to this topic would not appear until 1916. There was certainly no scientific context for integrating notions of natural disturbance such as fire and successional change into management.

In the early years of the national parks, comparatively stiff guidelines were adopted for protection of national forest reserves and parks from fire; but they were vigorously debated by some. H.J. Ostrander attacked fire control policies as worse than ineffective because they allowed hazardous fuels to accumulate, while John Muir viewed fire as "the master scourge and controller of the distribution of trees" and staunchly defended those policies (Pyne 1982).[2]

Virtually all argument on this matter ceased following the so-called Great Fires of 1910 (Pyne 2001). Complete suppression of fires regardless of ignition source (lightning or human-set) became *de facto* national policy, and that was codified in 1935 as the "10 AM Policy" which stated that every fire should be controlled by 10 AM the day following its report. It is one thing to promulgate a policy or rule, and quite another to enforce it. There is no question that this policy was effective in relatively accessible areas and where fuels were light. However, in inaccessible areas with heavy fuels, i.e., much of the montane West, this policy had little effect on fire regimes until about 1940 with the advent of smoke-chasing and -jumping (Pyne 1982).

The National Park Service (and the notion of a national park system) was formally inaugurated in 1916 and charged in its organic act to "conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." Although enjoyment of the parks by people is explicit in this organic act, priority was clearly given to the conservation of nature and history.

The scientific basis for National Park Service fire management (indeed, management of all public lands) over the next five decades also had its origin in 1916 with the publication of Frederic Clements' landmark paper "Plant Succession: An Analysis of the Development of Vegetation."[3] Disturbance such as fire, Clements argued, set in motion a directional and deterministic process of vegetation change (succession) culminating in the climax community, the most stable assemblage of organisms possible in a particular climatic regime. Clements' notion of change had a myriad of implications for management, and three are particularly relevant here.

First, Clements argued, it was large expanses of climax prairies, shrublands, and forests that dominated presettlement landscapes on which natural disturbance was, at most, infrequent. "Under primitive conditions, the great climaxes of the globe must have remained essentially intact, since fires from natural causes were undoubtedly both relatively infrequent and localized." He went on to argue that preclimax communities "became universal features only as man extended his dominion over nature through disturbance and destruction…" (Clements 1935).

Second, this theory implied inexorable increase in ecosystem stability with succession. Clements and his advocates, despite evidence to the contrary,[4] were unwilling to imagine successional change in which ecosystems actually became less stable or more prone to disturbance.

Third, Clements' model of change had significant implications with regard to managers' view of the importance (or lack thereof) of spatial scale. Although human-caused disturbances might occur at large spatial scales, Clements and others (e.g., Watts 1947) argued that the scale of processes necessary to perpetuate a community, such as tree falls, diminished with succession. This notion provided no incentive for consideration of spatial scale or boundaries in park design or management.

Evidence that fire might play a positive, even essential role in some ecosystems such as prairies and southeastern pine forests began to appear between 1920 and 1950 (e.g., Hensel 1923; Wells 1928; Chapman 1932; Garren 1942); however, serious concerns that fire suppression policies were having negative effects on park ecosystems were not expressed until much later. In his 1960 monograph on

Figure 1. This photo, dating from 1890, and Figure 2 (opposite) were taken eighty years apart in the Confederate Group, Mariposa Grove, Yosemite National Park. They illustrate the thickets of white fir that develop in the absence of fires. (Photo by George Reichel, courtesy of Mrs. Dorothy Whitener, historical documentation by Mary and Bill Hood).

southwestern ponderosa pine forests, Charles Cooper warned that cattle grazing in the late 19th century followed by fire suppression had facilitated forest changes, specifically the development of dense understory thickets of pole-size pines, which would favor abnormally large and intense future fires. Soon after, similar concerns were expressed regarding a number of western forest landscapes (e.g., Biswell 1961, 1967; Hartesveldt 1964; Weaver 1964).

This matter became a central Park Service issue with the publication of the Leopold Report in 1963 (Leopold et al. 1963). Although wildlife management was the central focus of this report, its authors called particular attention to problems created by fire suppression in many forest types.

> When the forty-niners poured over the Sierra Nevada into California, those that kept diaries spoke almost to a man of the wide-spaced columns of mature trees that grew on the lower western slope in gigantic magnificence. The ground was a grass parkland, in springtime carpeted with wildflowers. Deer and bears were abundant. Today much of the west slope is a dog-hair thicket of young pines, white fir, incense cedar, and mature brush—a direct function of overprotection from natural ground fires. Within the four national parks—Lassen, Yosemite, Sequoia, and Kings Canyon—the thickets are even more impenetrable than elsewhere. Not only is this accumulation of fuel dangerous to the giant sequoias and other mature trees but the animal life is meager, wildflowers are sparse, and to some at least the vegetative tangle is depressing, not uplifting. Is it possible that the primitive open forest could be restored, at least on a local scale? And if so, how? We cannot offer an answer. But we are posing a question to which there should be an answer of immense

Figure 2. 1970—Note how, in 80 years without fire, white fir had obscured all but the fire-scarred sequoia on the left. Such thickets provide ladder fuels that can support a high-intensity crown fire fatal even to mature sequoias. NPS photo by Dan Taylor.

concern to the National Park Service (Leopold et al. 1963).

In 1968, recognizing negative impacts of fire suppression on the very elements that it was charged to conserve, the National Park Service became the first federal agency[5] to break formally from the 10 AM policy. In that year, it released new policy guidelines to allow natural fires to burn where feasible, to allow the use of artificially set prescribed fire as a surrogate for natural events, and to suppress any fire not advancing management goals. In that same year, it inaugurated two rather different prescribed fire programs—one for subalpine forests and the other for the giant sequoia–mixed conifer forests—in Yosemite and Sequoia-Kings Canyon National Parks.

In high-elevation forests, lightning-set fires would be allowed to burn so long as they posed no threat to human life and property; these rugged, rocky landscapes provided abundant natural breaks in fuel cover that limited fire spread (Kilgore and Briggs 1972).[6] Park managers assumed, with some justification, that exclusion of fire from these ecosystems in recent decades had not produced major changes in fuels and that this approach would restore natural fire regimes to this landscape.

This *laissez faire* approach to fire restoration was deemed inappropriate for the more spatially contiguous middle-elevation mixed conifer forests, where threats to human life and property were high and where fire exclusion had resulted in heavy fuel loads. Because of particular concerns about their future (Hartesveldt and Harvey 1967), the giant sequoia–mixed conifer groves were the central focus of a so-called artificial-ignition prescribed fire program in which all wildfires were suppressed and prescribed fires were intentionally set at times and in a manner that would ensure control and safety. The stated objective of this program was also restoration of natural fire regimes, although optimism

Figure 3. In high-elevation forests, lightning-set fires are allowed to burn in many park and wilderness areas so long as they pose no threat to human life and property. NPS photo by Bruce M. Kilgore.

about doing this was early on tempered by doubts that these artificially set fires truly mimicked the natural process, particularly in the context of prevailing fuel conditions (Kilgore 1973).

Over the next few years, fire management programs were begun in other national parks, but none so notable as Yellowstone's natural prescribed fire program started in 1972. In its general outlines, this plan was similar to that for the high-elevation Sierra Nevada, i.e., lightning-set fires would be allowed to burn so long as they did not threaten human life or property, or compromise other park management objectives. Although centered on the park, the Yellowstone program was also notable for the memoranda of understanding with adjacent national forests that recognized that the forested landscape across which fires naturally occurred extended beyond the park boundaries and provided guidelines for allowing fires to burn across those boundaries.

These management plans were not without controversy. In 1976, public unhappiness with a smoldering prescribed fire in the Tetons that created smoky conditions in the national park and nearby Jackson Hole catalyzed a review of Park Service fire management and the formulation of more specific guidelines for its conduct. Concerns about the aesthetic effects of burning in the giant sequoia groves catalyzed a similar review of the Sierra Nevada artificial ignition prescribed fire programs in 1986–87 (discussed below). The fires that burned across Yellowstone National Park in 1988 brought the Park Service's fire policies fully into the public spotlight and were the occasion for reviews of both the science and management protocols underpinning those policies. I had the great privilege of chairing reviews associated with these latter two programs, and my reflections on those reviews follow.

The giant sequoia–mixed conifer fire program

In 1986, the prescribed fire program for the giant sequoia groves of Yosemite and Sequoia-Kings Canyon National Parks was in its eighteenth year. Each year, "compartments" of 50–75 ha were artificially ignited and allowed to burn with the specific goal of restoring fire to its natural role in these ecosystems (Kilgore 1972). Early in 1986, I received a call from David Parsons, then research scientist for Sequoia-Kings Canyon, asking if I would be willing to lead a team of fire experts in a review of this program. The team[7] was to review the full range of impacts of the fire program, but we were charged particularly with responding to concerns regarding the aesthetic impacts of the prescribed fires. To deal with this latter matter, the team included two individuals (Lynn Cotton and Joseph McBride) expert in landscape architecture and design. The review team met several times over the summer and fall of 1986, including a two-day public hearing and field trip at the Giant Forest in Sequoia National Park, and we delivered our report (Christensen et al. 1987) to the director of the National Park Service early in 1987.

There was, by 1986, relatively little argument over whether fires had played a significant ecological role in presettlement giant sequoia forests or, for that matter, whether the suppression of fire had produced significant changes in these forests that threatened their future (Kilgore 1972; Harvey et al. 1980). That said, relatively less was known about the historic frequencies and behavior of fire in these groves. Concerns were being raised about the extent to which prescribed fires set in understory fuels that had been modified by fire exclusion were representative of the natural process they were intended to mimic. Bonnicksen and Stone (1982) argued that pre-

Figure 4. Each year at Sequoia-Kings Canyon National Park, compartments of 50–75 ha were artificially ignited and allowed to burn with the specific goal of restoring fire to its natural role in the sequoia–mixed conifer ecosystem. NPS photo by Bruce M. Kilgore.

scribed fires would not behave naturally unless presettlement forest structure was restored. Others (e.g., Parsons et al. 1986) responded that restoring forests to a particular presettlement structure was arbitrary and did not reflect the significant variations in climate and fire regimes to which they are adapted. In their view, fire could and should be restored by reintroducing fire at presettlement intervals, intensities, and seasons. These differences in approach distilled down to an argument (sometimes quite heated) over whether the proper goal for management should be to maintain particular *structures* that might have existed in the past or to conserve *processes* such as fire that are critical to ecosystem functioning (Parsons and van Wagtendonk 1996).

By far, the most contentious issue associated with the sequoia burn program was the aesthetic impacts of blackened debris and post-fire charring of the bark of the sequoias. Written input and public testimony to the review panel were passionate on this matter. It was the view of critics that, regardless of whether prescribed fires mimicked natural processes, the Park Service was neglecting its fundamental responsibility to conserve these "natural and historic objects for the enjoyment of the people" (Cotton and McBride 1987).

Among the review findings, the following issues were most significant: (1) goals and objectives must be articulated in operational terms, and they may not be the same in all areas of a park; (2) artificial-ignition prescribed fires are not identical to the process (i.e., natural fire) they are intended to restore; (3) we must be clear about the appropriate role of historical information in setting park goals and management protocols; (4) management must be adaptive.

1. Goals and objectives. It was clear to the review team that, although natural process restoration might pertain in some areas, the fire management goals could and should differ in different parts of sequoia groves. In the lexicon of the 1916 Organic Act, giant sequoia

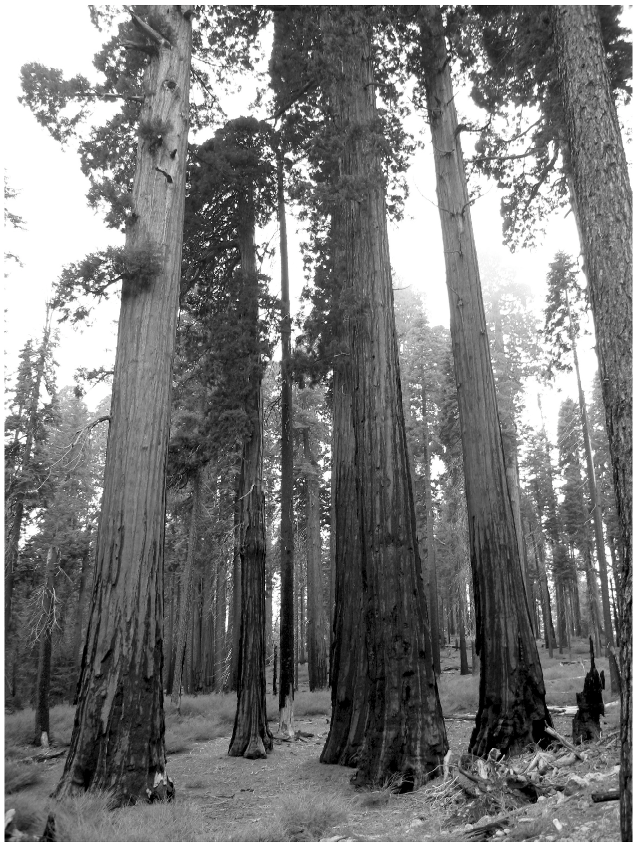

Figure 5. The aesthetic impact of occasional post-fire charring of giant sequoia bark was the most contentious issue in the prescribed burn program at Sequoia-Kings Canyon national parks. NPS photo by Tony Caprio.

groves are historical as well as natural "objects." Probably the most obvious evidence for this view is the sizeable number of large trees or groups of trees that have been formally named (the General Sherman Tree, the General Grant Tree, the Robert E. Lee Tree, the Senate Group, etc.). In many areas, aesthetic and historical values are central to the interests of many park visitors, and the team felt that fire managers should pay attention to those values. We recommended that charring of the tree trunks of large trees in high-visitation areas could be minimized by raking fuel away from tree bases. It was our view that this would have little effect on the ecological goals of the prescribed fire program, although we also felt that that view should be verified with future monitoring. Where fuel accumulation was judged to be excessive (e.g., dog-hair thickets of shade-tolerant fir or incense cedar), the prescribed fire program goal should be restoration, and the program might include pre-fire manipulations such as mechanical thinning.

Above all else, goals and objectives are the benchmarks against which management success should be measured, and to serve this purpose it is critical that they be stated in operational and measurable terms. "Restoring fire to its natural role in the ecosystem" provides neither operational nor measurable guidance. "Natural" process behavior was defined under National Park Service management policies at that time as the range of behavior that would have occurred in the absence of human interference.[8] Putting aside for a moment the dilemma of separating humans from naturalness (see point number 4 below), this definition presents two important challenges. First, the range of variation in fire behavior within and among fires over the past millennia is so large as to provide little constraint on management—virtually any fire event could be judged as natural by this definition. Second, although we might constrain this definition to mean fire behavior in relation to specific spatial and temporal variations in climate, topography, and fuels, our actual understanding of these relationships (while improving) is limited. The review team felt that fire should not itself be the goal of fire management. Rather, the focus should be on specific structure and process elements that depend on fire. In the case of the giant sequoia groves these elements include such features as understory fuels, nutrient cycling, giant sequoia reproduction, and forest floor biodiversity.

2. Artificial prescribed fire is just that. Although prescribed fires set in sequoia groves shared many features with naturally occurring fires, they were also different from them in several ways that might be ecologically significant, including spatial scale, intensity, and variability. Almost by definition, prescribed burn programs exclude extremes of fire size and severity, and thereby minimize variance both within and among fires. Weather, air quality concerns, and available human resources often set limited time windows for prescribed burns; often, burns must be completed within the span of a day. In order to complete burns within the necessary time frame and to achieve uniform results (usually a desirable goal), sequoia burn units were usually burned by igniting a grid of spot fires set 20–30 m apart and allowing the resulting rings of fire to burn into one another. Naturally occurring fires in these ecosystems were likely variable over a range of spatial scales, sometimes slowly creeping along the forest floor, some times torching up ladder fuels into the forest canopy, and often leaving various size patches unburned. Such fires may have burned for days, weeks, or even months, producing a mosaic of post-fire environments.

Figure 6. Monitoring of both fire behavior and ecological effects is needed to understand how prescribed burns differ from natural fires, including impacts on biodiversity, fuels, and visual effects. USDA–Forest Service photo by Steve Sutherland.

Much of this behavior is outside of typical prescription bounds. Furthermore, prescribed fires are typically not set at those times when natural fires would be most likely to occur. The review team felt it was important for the Park Service to assess the importance of these differences between artificial prescribed and natural fires and, if significant ecological benefits were being compromised, to make adjustments in the prescriptions.

3. The role of history. Much of the rationale for the sequoia fire plan as well as a considerable amount of the criticism of that plan were based on a rather limited understanding of the history of fire (dendrochronological analysis of a few trees in a single sequoia grove; Kilgore and Taylor 1979) and changes in forest structure on this landscape. Bonnicksen and Stone (1982a, 1982b, 1985) argued that historical forest structure—specifically the structure that existed in the late 19th century, immediately prior to the establishment of the parks—should be the basis for the fire management program. Only by returning forests to that particular structure could the Park Service justify reintroduction of fire. It was the view of the review team that a much more detailed understanding of the history of fire and forest change was needed as a context for understanding the role and behavior of fire in these ecosystems. However, the team saw a genuine danger in using a particular historical structure as a rigid model for future management. It was our view that, over the millennial life times of individual sequoia trees, climates have varied enormously with concomitant variations in fire behavior and forest structure. Climatic conditions today are likely to be significantly different from those of any arbitrarily selected past time. We interpreted the

Leopold Commission's phrase "vignettes of primitive America" to refer to a moving picture rather than a snapshot. The National Park Service goal for its wilderness parks should not be to "curate" historical landscapes as static museum pieces, but rather to ensure that the dynamics that were central to sustainability of historic landscapes continue into the future.[9]

4. Adaptive management. Our understanding of roles of fire and the ecological changes it produced in mixed conifer forests had certainly changed enormously in the 70 years between the promulgation of the Park Service Organic Act and our 1986 review. Nevertheless, there was considerable uncertainty regarding key elements of the fire ecology of these ecosystems and little doubt that our understanding of those elements would continue to change. The review team recommended that the Park Service invest in research to reduce those uncertainties and that it modify its monitoring programs to reflect revised goals and ensure adaptability to new information. We recommended priorities for research to improve our understanding of historical variations in fire regimes over the past several millennia and to assess the public's understanding of the fire program and their concerns regarding its visual impacts. Up to our review, monitoring of the fire program had been confined to the behavior of the fire itself (extent of burn, flame height, weather conditions, etc.). The review team recommended that monitoring be expanded to focus explicitly on the goals of the program, and that it include assessment of such elements as biodiversity, fuels, and visual effects.

The Yellowstone fire program and the 1988 fires

No event did more to raise public consciousness of the challenges to restoring fire to wilderness areas than the 1988 fires on the Yellowstone Plateau. This was actually a complex of several fires, some naturally ignited by lightning in late spring and allowed to burn under the park's natural prescribed fire policy and others originating from careless campfires and national forest timber activities and escaping aggressive suppression efforts. By late June of that year, the distinction between prescribed fire and wildfire had become academic; these fires had burned over 12,000 ha of forest, more than had burned over the previous sixteen years of the natural prescribed fire program. In an action more important for its symbolism than its effect, the director of the Park Service declared Yellowstone's natural prescribed fire policy non-operative and ordered all-out suppression of all fires. Nevertheless, with the dry, windy conditions over the remainder of the summer, these fires eventually burned over nearly half of the park. They were declared under control in early September and then only after the onset of wet weather. In the aftermath of these fires, a moratorium was placed on all Park Service fire management plans pending park-by-park reviews based on guidelines formulated by an interagency panel (USDA/USDI 1989).

In late August of 1988, I was asked by John Varley, then chief of research at Yellowstone, to chair an interdisciplinary committee of scientists[10] in an assessment of the near- and long-term ecological consequences of the fires. The park particularly wanted advice on two near-term questions. First, should the Park Service take extraordinary steps on behalf of wildlife? In particular, should feeding programs be implemented for large ungulates (elk and bison) to compensate for the loss of winter range? Second, should the Park Service take actions such as artificial seeding and installation of hydrologic barriers to minimize post-fire erosion? The panel was also asked for its evaluation of the longer-term ecological impacts of the fires and for any recommendations regarding future management actions. We were not asked to evaluate the natural prescribed fire management program *per se*, but some reflection on the program was implicit in our charge.

We began our deliberations with a discussion of the general mission of Yellowstone National Park. Although particular locations (e.g., Albright Visitor Center at Mammoth and Old Faithful Lodge) have historical significance, the park's primary mission is the conservation of its natural landscape. Furthermore, we agreed that maintenance of natural ecosystem processes was central to the success of that mission.[11]

Having agreed on the central importance of maintaining natural processes, the panel considered whether or not the extent and intensity of 1988 fires were within the range of natural variation for this ecosystem. We concluded that they most certainly were. Very early research by none other than Frederic Clements (1910) had established that crown-killing fires are important to long-term dynamics and maintenance of lodgepole pine forests. Furthermore, work by Romme (1982) had shown clearly that fires matching the magnitude and intensity of the 1988 fires had burned over the Yellowstone Plateau during the period 1700–1740. Although fires of this magnitude were unprecedented in the 100-plus-year history of the park, there was growing evidence that they had been a regular feature of this landscape on cycles of 300–400 years (Millspaugh et al. 2004). Thus, although some of the 1988 fires were ignited from unnatural causes, the overall complex of fires was within the range of what might have occurred naturally, and there was no reason to doubt that the ecosystems on this landscape would fully recover naturally just has they had done in the past.

Figure 7. The Yellowstone fires of 1988 burned over nearly half of the park. Dry, windy conditions led to intense stand-replacement fires. But mosaic patterns of burned and unburned forest are still clearly visible in this aerial photo. (Bark-beetle-killed forest appears in the lower right.) Photo from Yellowstone National Park Archives.

It was the general conclusion of the panel that the Park Service should intervene with artificial remediation measures only if (1) there was clear evidence that natural ecosystem process were impaired so as to prevent normal recovery, and if (2) remediation measures were likely to be effective and that any negative impacts would be minimal. Based on these conclusions and on our consensus regarding the park's mission and the naturalness of the fires, the panel's responses to the park's near-term questions regarding artificial feeding of wildlife and erosion prevention were emphatically "no" and "no."

There was little doubt that the fires had significantly reduced the quality of winter range for elk, in particular, and that mortality

Figure 8. Fires of this magnitude and intensity were unprecedented in the 100+-year history of Yellowstone. But Romme (1982) found that similar fires had burned over the Yellowstone Plateau between 1700 and 1740. There is growing evidence that such fires were a regular feature of this landscape on cycles of 300–400 years. (Note bison in foreground.) NPS photo by Bruce M. Kilgore.

would likely spike during the 1988–89 winter, especially if conditions were harsh.[12] There was also little doubt that elk forage would quickly recover beyond pre-fire levels. The elk herd in 1988 was at an all-time high, with many arguing that it was well above its carrying capacity. Thus, it was the view of the panel (which included James Peek and Jack Ward Thomas, two distinguished experts on elk biology) that short-term impacts would quickly be overcome and that whatever mortality occurred would improve the overall health of the herd in the long term. The panel was also concerned that artificial feeding programs would likely have negative impacts on ungulate population health through the spread of saliva-borne diseases.

There is considerable evidence that natural rates of erosion are variable and episodic on many forested landscapes and that those episodes are usually associated with major disturbances such as large fires (Swanson 1981; Wells 1987). The panel viewed this as a natural and important part of the long-term dynamics of Yellowstone watersheds. Not only are artificial seeding and water-flow mitigations unnecessary, but they are likely to have adverse ecosystem consequences. Artificial seeding programs carry the threat of introducing invasive exotic plants and often inhibit or delay natural successional processes. Water-flow mitigation often involves permanent alteration of surface topography.

That these two issues were at this time so controversial is itself interesting. Although the panel was not in any way lobbied by the Park Service on these issues, I am rather certain that the panel's recommendations corresponded closely to the intuition of park managers. Those managers no doubt felt that the opinions of an independent group of experts were critical to the credibility of their actions. At a somewhat more basic level, we must confess that in 1988 our understanding of the processes of ecosystem change following major disturbances on this landscape were rudimentary, and our faith in the power of natural processes was based on concepts and models still in their formative stages.[13] In the face of significant uncertainties, that faith was severely tested by persistent entreaties from the media and the public: "For Pete's sake, aren't you going to do something?"

The 1988 fires raised several significant questions about natural-ignition prescribed fire programs. First, can we really set meaningful prescriptions on expansive landscapes? By definition, a fire prescription sets the conditions of space and intensity within which a fire can be contained or, if necessary, suppressed. The fire management program inaugurated in 1972 assumed that the natural variability in forest stand structure creates natural breaks in fuels that limit natural fire size, and experience up to 1988 supported that assumption. In 1988, we learned that extreme drought and high winds make otherwise heterogeneous landscapes look uniformly flammable (Turner et al. 1989). Thus, we cannot rely on natural fires to define manageable burn units except in areas (such as in high elevations) where rock outcrops and natural topography create immutable fire breaks. Second, like their artificially ignited counterparts, natural prescribed fire programs exclude extreme, but perhaps important, events. Finally, once ignited, there is no difference between fires set by humans or those originating from lightning. Indeed, in a world in which fire ignition and behavior is being altered globally by climate change, increasingly fragmented landscapes and invasive exotic species, naturalness is increasingly difficult to define.

Figure 9. Park managers and visitors must understand the importance of disturbance and change in wild ecosystems and be involved in decisions that influence outcomes. (Harold Biswell conducts a demonstration burn in 1969 on a university experimental forest adjacent to Sequoia-Kings Canyon.) NPS photo by Bruce M. Kilgore.

Natural-ignition prescribed fire programs explicitly assume that the only ecologically appropriate source of ignition is lightning. Although the specific details are at best sketchy, it was obvious even in the 1980s that fire regimes over the past several millennia in the Sierra Nevada had been heavily influenced by Native Americans. As a matter of policy, however, National Park Service fire management programs explicitly excluded consideration of their activities. The Park Service rationale for this policy was not based on ignorance of the role of Native Americans, but rather on the fact that their patterns of fire use are not only poorly understood but also likely changed through time with different Indian cultures and technologies; hence, designing a fire program around a particular past pattern of use would be highly arbitrary. These are legitimate issues, but they do not blunt concerns that lightning ignition alone may produce fire regimes and, thereby, landscapes that are very different from those that prevailed in the past.

Summary Reflections

Although rather different in their specifics, these two prescribed fire programs (along with many other areas of natural resource management) have several challenges in common, and I would like to focus here on three of those challenges: goal-setting, uncertainty, and people.

Goal-setting. It is impossible to measure the success of any program in the absence of clearly articulated and operational goals. As obvious as this assertion is, articulation of goals remains a major challenge for national park fire management. Operational goals are, first and foremost, measurable. The goal of restoring fire to its *natural ecosystem role* qualifies in this regard only if we have a measurable reference for defining "natural," and that reference is most often historic range of variation (HRV). Can't we simply define natural fire as that behavior falling within the HRV of spatial scale, frequency, and intensity prior to European settlement? For at least three reasons, our answer to this question is "no."

First, most fire ecologists would answer "yes" to this question only if the natural HRV is constrained by an understanding of the variations in climate and fuels that influence fire behavior through time. Thus, large and intense fires might be judged natural if they occur during especially hot and dry times, but not so if they occurred under moister conditions. Although improving, our understanding of historic patterns of fire behavior in most ecosystems is not nearly so sophisticated.

Second, prescribed fire, whether artificially or naturally ignited, is necessarily a limited subset of the behaviors within the HRV, and prescribed fire management programs generally exclude the extremes (high and low) of spatial scale, frequency, and intensity. There is increasing evidence that many important ecosystem features and services depend on such extremes. For example, although there is considerable evidence that small-scale intense fire events are important to giant sequoia establishment, such events are not included in the prescribed fire programs for the sequoia–mixed conifer forests (Stephenson et al. 1991).

Third, because most landscapes have been significantly affected by anthropogenic factors such as fragmentation, alien species, and altered climates, events behaving within the HRV may have unnatural or undesirable consequences. For example, there is evidence that activities directed toward restoring historic fire regimes have favored invasion of alien annual plants in several western forest ecosystems (Crawford et al. 2001; Bradley and Tueller 2004; Keeley 2005).

In truth, prescribed fire, whether set by lightning or a drip torch, must be understood as a surrogate for the natural process. As such, prescribed fire cannot in itself be the end goal; rather it is a means to an end. Fire management goals should be articulated in terms of those ecosystem structures (e.g., fuels and biotic communities) and processes (e.g., hydrologic and nutrient cycles) that are affected by fire. Fire management should be judged successful if these structures and processes behave according to pre-established standards that might themselves be rooted in notions of naturalness (e.g., historic range of variation). In a world of anthropogenic change—including climate, fuel loads, land fragmentation, and invasive species—this focus on ecosystem structures and processes is all the more important; we cannot depend on fire to produce natural outcomes even when it's behaving within what might have historically been natural bounds.

Uncertainty. I once heard a colleague assert, "You cannot manage what you don't understand." That, of course, is not true. That we have only a rudimentary understanding of the dynamics and patterns of change in wilderness ecosystems does not exempt us from their management. That said, ignorance is not a free pass for management by trial and error either—management should be adaptive. Given the enormous uncertainties and variability associated with them, this is particularly true for fire management programs. Effective adaptive management includes several key elements, including clearly stated goals, models, focused monitoring, learning cultures, and understanding constituencies. Goal-setting was discussed above, and these other elements are discussed below.

Models are the frameworks that allow us to understand the connection of actions to outcomes. As Kai Lee (1993) has suggested, models are a central feature of any adaptive management program, and they are almost always wrong. Fire management protocols should be based on our best models of how fire behavior connects to those ecosystem structures and processes that we wish to sustain. We have much to learn in this area.

Fire management monitoring must focus on the specific ecosystem goals for those programs. In this sense, designing a monitoring program is somewhat like designing a dashboard for a car, where the goal is to measure with appropriate precision those elements most central to automobile functioning in a reasonably economical fashion. Models are particularly important in identifying key features that are highly correlated with desired outcomes and that are relatively easily and cheaply measured. Human and economic resources for monitoring are limited, and elements for measurement must be prioritized.

In an ideal world, management will foster learning cultures that ensure the timely feedback of information between monitors and managers, and encourage reflection, discussion, and even dissent. I know of few organizations or agencies that match the ideal in this regard—indeed, I have worked for an institution of higher learning for nearly thirty-five years, but we rarely, if ever, match this ideal for a learning culture. Nevertheless, adaptive management depends on the willingness to overcome the barriers of institutional organization and hierarchy and to dedicate the resources necessary for full discussion of the implications of new information for management directions.

The ultimate success or failure of adaptive management programs hinges on "understanding constituencies." I use this ambiguous phrase purposefully to emphasize that managers must both understand and be understood by those that they serve. In effect, managers are saying to their constituencies, "Trust me—my understanding is imperfect, but I promise to learn and adjust along the way." Those constituencies must understand both the importance of the management goals and the nature of the uncertainties. Most importantly, they must have confidence in the manager's willingness and ability to manage those uncertainties in good faith. Thus, people are central to successful management.

People. These and other case studies raise significant questions about the appropriate role of people—past, present, and future—in setting national park priorities and protocols. The dilemmas associated with whether and how to adjust fire management to account for the roles of Native Americans has already been discussed. This issue is diminished in importance if our interests shift away from the causes of fire and instead focus more on the consequences of fire.

In an ideal world, we might imagine that wilderness parks would be managed by simply allowing natural processes to operate as they might. In this ideal world, one might argue, human values would be relatively unimportant in setting management protocols or policies. Not only is such an attitude in direct conflict with the objectives articulated in the National Park Service organic act (i.e., to provide for the enjoyment of scenery and the natural and historic objects), but it implies that wilderness can itself be defined free of human values (Cronon 1997). It cannot.

In Clements' time, we imagined that, by letting nature run its course, ecosystems would develop to a single, stable climax state. We now know that a variety of ecosystem structures and composition are stable, sustainable, and natural, and human activities and management will be important determinants of which states will actually be obtained from among the various possibilities. Not only must people—park managers and visitors—understand the importance of disturbance and change in wild ecosystems, but they must equally be involved in the decisions that will influence outcomes.

My experiences in the Yellowstone and the Sierran parks not only convinced me of the importance of stakeholder involvement in fire management programs, but also that the Park Service is actually using such involvement reasonably well. This is certainly part of the reason that public opinion consistently rates the National Park Service among the most popular federal agencies and national parks among our most favored places.

Endnotes

1. In each of these evaluations, my understanding was greatly influenced by the wisdom of others. In this regard, I am particularly grateful to Jim Agee, Bob Barbee, Jack Davis, Dave Graber, Bruce Kilgore, Dave Parsons, Paul Schullery, Nathan Stephenson and John Varley. I, of course, take full responsibility for any errors or misunderstandings.

2. Although Muir was opposed to allowing fires to burn in park forests, he did have an appreciation for the behavior and possible role of fire in some forests. In his 1901 book *Our National Parks*, he describes a fire in a giant sequoia forest in poetic terms as

> creeping and spreading beneath the trees where the ground was level or sloped gently, slowly nibbling the cake of compressed needles and scales with flames an inch high, rising here and there to a foot or two on dry twigs and clumps of small bushes and brome grass. Only at considerable intervals were fierce bonfires lighted, where heavy branches broken off by snow had accumulated, or around some venerable giant whose head had been stricken off by lightning.... Fire attacks the large trees only at the ground, consuming the fallen leaves and humus at their feet, doing them but little harm unless considerable quantities of fallen limbs happen to be piled about them, their thick mail of spongy, unpitchy, almost unburnable bark affording strong protection.

3. Although many of Clements' ideas were articulated earlier in papers by Henry Chandler Cowles (Cowles 1899, 1901), it was Clements who pulled them together into a unified framework and communicated them in formats and venues accessible to managers.

4. Show and Kotok (1924), for example, argued that, in the absence of light surface fires in giant sequoia–mixed conifer forests, woody debris (fuels) would accumulate that would produce intense crown-killing fires.

5. The National Park Service actually began using prescribed fire a decade earlier in Everglades National Park with the recognition that the Everglades ecosystem depended on the interaction of fire and hydrology (Pyne 1982). This was, however, deemed an experimental program and involved no change in Park Service policy.

6. Natural prescribed fire programs such as this were often referred to as "let burn" programs, implying that fires ignited naturally were simply allowed to burn. In actuality, fires were only allowed to burn so long as they behaved within pre-prescribed guidelines for weather conditions, intensity, and perimeter. Fires burning outside prescription were designated "wildfires" and were cause for immediate suppression.

7. Team members included L. Cotton (landscape architecture), H.T. Harvey (ecology), R.E. Martin (forest fire science), J.R. McBride (forestry/landscape architecture), P.W. Rundel (ecology), and R.H. Wakimoto (fire management).

8. Current Park Service policy (codified in *Reference Manual 18;* NPS 1999) provides much more flexibility to individual parks in defining appropriate fire behavior.

9. We note that the opposite is true in historical parks, such as Gettysburg, or parts of parks dedicated to human history or values, such as Skyline Drive in Shenandoah National Park or Cades Cove in the Great Smoky Mountains National Park.

10. Committee members included J.K. Agee, P.F. Brussard, J. Hughes, D.H. Knight, G.W. Minshall, J.M. Peek, S.J. Pyne, F.J. Swanson, S. Wells, J.W. Thomas, S.E. Williams, and H.A. Wright.

11. Today, this may seem so obvious as to be taken for granted, but it is worth recalling that both the fires and our evaluation of their effects were taking place in the midst of another "firestorm" associated with the 1986 publication of Alston Chase's book *Playing God in Yellowstone*. Whatever else one may say about Chase's philippic, it certainly made the case that the Park Service's view of its mission in Yellowstone had not always centered on the "conservation of the natural ... objects."

12. That winter was, indeed, particularly harsh and elk mortality was high. Nearly 40% of the herd died in the first year following the fires. This opened the panel's recommendations and the Park Service's acceptance of them to considerable scrutiny and criticism. In March of 1989, a front-page headline in the *Washington Post* read, "Park Service abandons the 'let burn' for the 'let die' policy."

13. Indeed, the important role of the Yellowstone landscape since 1988 as a laboratory for refining our understanding of ecosystem and landscape dynamics is wonderfully documented in Wallace (2004).

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The Wildland Fire Challenge: Protecting Communities and Restoring Ecosystems

Gregory H. Aplet and Bo Wilmer

In recent summers, large forest fires have burned millions of acres and hundreds of homes across western states where drought conditions prevail. Alarmed elected officials agree that fuel loads in forests must be reduced to protect communities and restore ecosystems, but they disagree over where and how much.

In this paper, we evaluate the quality of information that feeds wildland fire policy, assess the challenge of identifying and protecting threatened communities from wildland fire, and outline the first steps in a comprehensive strategy to prioritize where fuel reduction and ecosystem restoration measures are needed.

The wildland fire crisis

Virtually every North American ecosystem has experienced fire over its evolutionary history. In regions such as subalpine forests where precipitation was high and temperatures low, fire was an infrequent visitor; periodic drought and hot weather were required to dry vegetation enough to burn. Between infrequent fires, fuels built up naturally to high levels, ensuring that when fire did return, it was big and hot. In other regions, such as southwestern ponderosa pine forests where "fire weather" is common, fire burned frequently enough to keep fuels from amassing, consuming mostly grass and other surface vegetation.

With the arrival of Euroamerican settlers, land-use patterns changed dramatically. Eastern forests were cleared for agriculture; in the West, vast herds of livestock consumed grasses; across the continent, fire suppression became the norm (Figure 1). Where fire was infrequent, these practices left vegetation and fire regimes essentially unchanged, but in areas with more frequent fire, tree seedlings grew into dense forests capable of carrying roaring crown fires on lands where surface fire once prevailed (Figure 2). More people built houses in fire's way, especially in the growing western states, where settlement encroached on some of the region's most fire-prone, low-elevation forest lands. In addition, current drought has increased both the frequency and severity of wildland fires.

In 2000 and again in 2002, western states witnessed the largest fires in more than a century. Many burned adjacent to, and sometimes in, communities, resulting in the tragic loss of homes and lives. In response, organizations and governments at all levels produced a number of policy initiatives to try to reverse the trend. The National Fire Plan (USFS/DOI 2000), developed in response to the 2000 fire season, recommended reducing fire risks, working with local communities, and improving agency accountability.

In 2002, in a process facilitated by the

Western Governors' Association, a broad-based group of state, federal, and other parties signed on to a ten-year comprehensive strategy (Western Governors' Association 2002). Like the National Fire Plan, that initiative sought to protect communities and restore fire-adapted ecosystems, but opened the fire planning process to all stakeholders through a collaborative structure, set priorities on community protection and at-risk watersheds, and recommended accountability through monitoring. In late 2003, Congress passed the Healthy Forests Restoration Act (HFRA), which reduced the level of environmental review required for fuel reduction projects and truncated public involvement in agency decision-making. The act authorized special fuel reduction projects to protect "at-risk communities" on 20 million acres of federal land.

Figure 1. Fire suppression continues as an important part of fire management policy on local, state, and federal lands in the United States. While we have made great strides in suppression technology since the early 1900s (note helicopter water drop), the largest fires in more than a century burned adjacent to, and sometimes in, communities in western states in 2000, 2002, and 2003. Photo provided by the California Department of Forestry and Fire Protection.

Protecting communities: the scope of the challenge

All of these recent initiatives have made the protection of communities threatened by wildland fire a high priority, emphasizing community involvement in fire planning and reduction of fuel loads by cutting trees and brush adjacent to communities. Exactly where these efforts and scarce resources should be focused, however, has been a subject of debate and confusion. In this section, we review one effort to identify communities at risk and show how these data can be used to estimate the scope of the community protection challenge nationwide.

Identifying communities at risk. In January 2001, the secretaries of agriculture and the interior posted a notice in the *Federal Register* that outlined the community protection issue and included a preliminary list of more than 4,000 "communities at risk," compiled from information received from some states (Federal Register 2001a). The notice provided guidance on how to recognize a community at risk and solicited a second round of names from the states, resulting in a list of 22,127 communities. Some states submitted extensive lists; others were more circumspect, submitting only

Figure 2. Extreme fire behavior: a crown fire. Photo by Kari Greer/NIFC.

those few communities in obvious peril.

Unable to resolve the differences between states, the secretaries applied a screen to include only those communities near federal land most likely to be affected by federal policies (Federal Register 2001b). Of the resulting list of 11,376 communities, 9,339 could be matched with place names in the U.S. Geological Survey's Geographic Names Information System to create a national map of communities at risk (Figure 3).

Such a process of self-nomination obviously results in an inadequate, haphazard catalog of communities at risk. Figure 3 clearly depicts disparities across state boundaries. Georgia, for example, is heavily represented, while neighboring Alabama has almost no representation, and Oklahoma and Kansas, similar both ecologically and demographically, also show large disparities. Still, Figure 3 shows those state-designated at-risk communities that could be mapped and that, in aggregate, represent a first approximation of the location of communities vulnerable to fire in the vicinity of federal land.

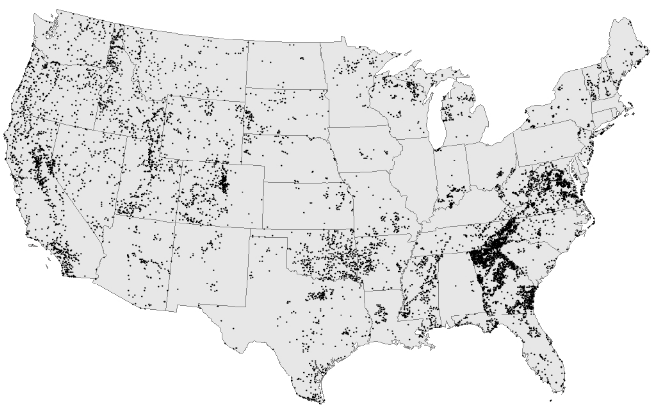

Figure 3. Designated communities at risk from wildland fire. This map was prepared by the U.S. Geological Survey from lists submitted by states and refined by the federal government to include communities near federal lands.

Defining the community fire planning zone. Despite its shortcomings, we used the data represented by Figure 3—data representing the states' evaluation of the problem—to assess the size of the community fire protection challenge. In undertaking such an analysis, it is important to determine how much land around each community must be evaluated and, if necessary, treated to reduce the risk of fire. This "community fire planning zone" (CFPZ) is a function of both the size of the community and the width of the fuel treatment "buffer zone" around each community.

To account for community size, we relied on the National Land Cover Dataset to identify "urban footprints" of towns by selecting clusters of urban "pixels" and matching them to communities on the federal list. Where the location of a listed community was more than one mile from an urban footprint, we assumed the town was too small to produce a footprint, and we mapped it as a point.

While an understanding of the outlines of a "community" is important, it does not answer the question of where to apply treatment. Protecting communities requires treating fuels some distance from structures (Figure 4), but how far should community fire planning zones extend?

It has been demonstrated that the most effective way to protect homes is to address the area immediately adjacent to structures (Figure 5). The underlying principle is simply that homes will not burn if they do not ignite, regardless of what happens to the surrounding forest, and it is a very narrow "home ignitability zone" that determines whether a home will burn.

Research by the U.S. Forest Service has shown that there are three primary mecha-

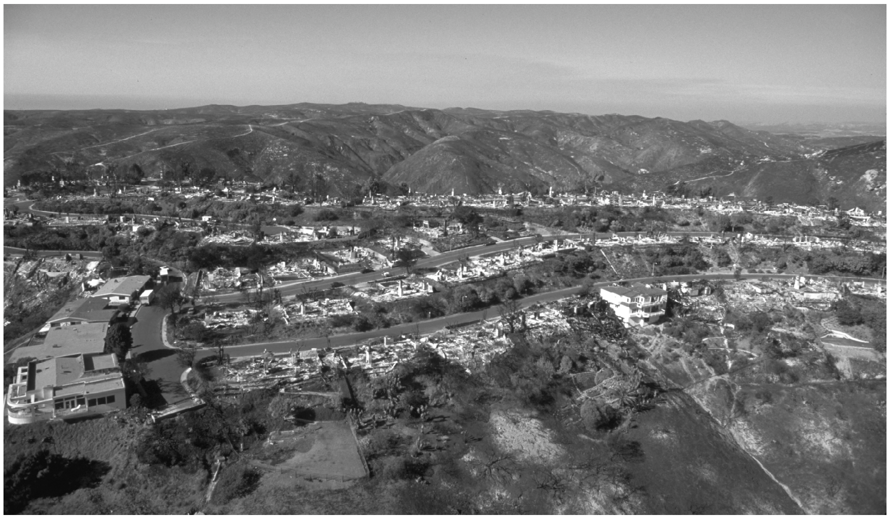

Figure 4. In southern California, during hot, dry, windy conditions in late summer and fall, chaparral fires have brought tragic loss of homes and lives. This occurs because high winds bring fire and fire brands into direct contact with flammable structures. Photo by Robert A. Eplett/OES/CA.

nisms for home ignition. First, houses can ignite when shingles and siding are exposed to direct contact with flames from adjacent fuels, particularly flames carried in fine fuels, such as grasses, needles, leaves, and small branches. The second way homes can catch fire is through radiant heat from nearby flames elevating the temperature of structures themselves above their ignition thresholds. Third, the roofs of houses can ignite when exposed to showers of lofted embers. By reducing fine fuels directly within the home ignitability zone, homeowners can prevent flames from reaching the house itself. Thinning small-diameter trees within 60 m of homes can reduce the potential for radiant heat to ignite a home, and by building rooftops out of non-flammable materials, fire risk to homes can also be drastically reduced (Cohen and Butler 1998; Cohen 2000).

Figure 5. Following "firewise" principles, the owner of this home removed fuels within its "home ignitability zone" in the West Creek Subdivision, Colorado. As a result, it survived a crown fire in the wildland–urban interface during the 2002 Hayman Fire in the Pike National Forest. Photo © Karen Wattenmaker/kwphoto.com.

Together, these three mechanisms for home ignition can only be prevented by focusing on the area directly around individual structures. Appropriate protective steps, such as pruning branches away from homes and moving woodpiles, are well described by fire protection alliances, such as the National Wildland–Urban Interface Fire Program (see www.firewise.org). If done correctly, treatment of the home ignitability zone well in advance of a fire may allow residents to stay with their property and extinguish incidental ignitions once the flaming front has passed (Mutch 2005).

While structure protection demands a focus on the immediate vicinity of the home, there are reasons why treatments may be extended beyond 60 m. Communities may wish to create "defensible space" within which firefighters may work safely, or they may wish to thin trees to reduce the probability of crown fire in order to protect scenic views or watershed quality. Fire physicists and other experts have posited various buffer distances, ranging from a quarter-mile, based on the physics of crown fire behavior, to as far as 20 miles, based on observations of fire spread. The HFRA authorized special fuel reduction projects on federal land within "an area extending ½-mile [and in some cases 1.5 miles] from the boundary of an at-risk community." Therefore, to estimate the size of the CFPZ, we applied a half-mile buffer to the outside of our estimated community footprints. For communities for which we identified a footprint, this resulted in a half-mile-wide strip around the urban core. Communities that had no detectable urban core were mapped as half-mile-radius circles around a point (Figure 6).

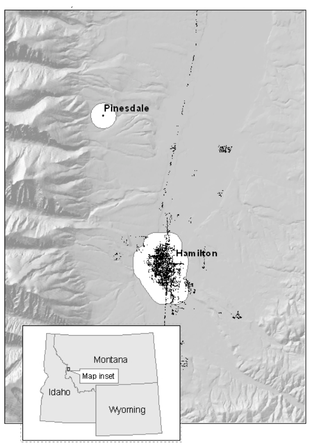

Figure 6. Sample community fire planning zones in Montana. This magnified view of our national analysis of community fire planning zones displays and labels two designated communities at risk from wildland fire and their half-mile buffer zones in the Bitterroot Valley of Montana.

It is important to emphasize here that this logic does not argue for clearing a half-mile buffer around every community. Rather, it is within this half-mile buffer that community members should look for *opportunities* to improve public safety. Within this CFPZ, assessments should be made of infrastructure needs (e.g., fire engine access, hydrants) and strategic fuel reduction (to protect homes and create defensible space). Not every type of vegetation will need to be treated, and there are some vegetation types, such as subalpine forest, within which thinning will be ineffective in lowering the probability of crown fire because fuel structure has such a limited effect on fire behavior.

The results of our analysis revealed that across the 48 conterminous states, community fire planning zones around the 9,339 mapped federal communities at risk cover 11,381,821 acres, an area approximately the size of Vermont and New Hampshire combined. Forty percent of this total is agricultural or developed land.

California ranks first among the states, with 13% of community fire planning zone acreage nationwide. Georgia, Texas, Virginia, Florida, and North Carolina rank next; combined, they account for nearly 37% of the total. Fire-prone western states—Idaho, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, and New Mexico—account for less than 15% of the total. Overwhelmingly, community fire planning zones are where people are, not where forests are.

By overlaying a public land ownership geographic information system database (DellaSala et al. 2001) on our CFPZ data, we determined that the vast majority of land in the community fire planning zones—even

Land Ownership of CFPZ	Acres	Percentage of total acreage
Private/State/Tribal	9,668,977	85.13
Bureau of Land Management	160,504	1.41
Department of Defense	229,741	2.02
U.S. Fish and Wildlife Service	54,273	0.48
U.S. Forest Service	1,097,544	9.64
National Park Service	112,775	0.99
Other Federal Lands	57,917	0.53
Total	11,381,621	100.00

Table 1. Land ownership of community fire planning zones.

for this list of communities in the vicinity of federal land—is non-federal land (Table 1). Just 9.6% of CFPZ acreage is on national forests; only 5% is found on other federal lands.

While this calculation represents the first attempt to assess the land area associated with federal communities at risk, it likely underestimates by several-fold the extent of the problem. It relies for its underlying information on a flawed national map of communities at risk that reveals reporting inconsistencies and leaves out almost one-fifth of the communities on the August 11, 2001, *Federal Register* list (Figure 3). Also, mapping communities only by their urban footprint fails to account for the vast "intermix communities" (Figure 9) where homes are scattered among wildland fuels. Still, our assessment shows the community protection challenge to involve millions of acres, the vast majority of which are private. Community protection cannot be achieved with policies, like the HFRA, aimed primarily at federal land management.

Restoring fire-adapted ecosystems: where are the priorities?

Without a doubt, the protection of homes and lives must be the highest priority of fire management. But it is not the only priority. Centuries of post-colonial land use have disrupted North America's ecological rhythms and left many ecosystems in poor shape. Eastern forests, many of them fire dependent, have been almost entirely logged at least once, and many have been converted to food or fiber farms. In the West, most of the largest trees have been cut, livestock grazing has removed grass cover from formerly productive rangeland, and fire, successfully excluded for most of the twentieth century, has returned with a ferocity unknown to many western ecosystems.

The relatively new field of ecological restoration addresses the poor condition of many ecosystems, and restoration of fire has been at the center of discussion among scientists and land managers. But which ecosystems are most in need of attention? What are the priorities, given limited financial resources and personnel, for restoration? Answers to these questions are a function of both the degree of alteration and the potential for restoration.

Fire regimes and condition classes. The timing and pattern of fire has a tremendous effect on vegetation, and species and ecosystems can be said to be adapted to particular fire regimes, defined in terms of the historical frequency and severity of fire in natural ecosystems (Schmidt et al. 2002). *Fire regime*

I (high-frequency, low-intensity forest fire) occurs only in forests and woodlands that often experience hot, dry weather, where frequent fire (occurring at least once every 35 years) consumes grass, pine needles, and other fuels of the forest floor without killing the trees. *Fire regime II* behaves similarly to fire regime I, except that it occurs in grasslands where no trees are present. *Fire regime III* produces a patchy mosaic of low-intensity surface fires and high-intensity crown fires, sometimes in the same fire event, often occurring in interior Douglas-fir, larch and sagebrush, and, in some instances, lodgepole pine and redwood forests. *Fire regimes IV and V* consist of infrequent, large crown fires that occur every 35 to 200 years (in fire regime IV) or only every 200 years or more (in fire regime V). In both cases, large patches of vegetation are burned.

In an attempt to assess how extensively conditions have been altered in each of these fire regimes, scientists at the U.S. Forest Service's Rocky Mountain Research Station produced a report called *Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management* (Schmidt et al. 2002). This study represented the first nationwide look at fire from an ecological standpoint, examining how ecosystems have changed as a result of alterations in fire regimes on a continental scale. The report identified approximately 200 million acres of federal land that are at risk due to changes in vegetation from historical conditions. Because the limited data used for the assessment made it impossible to accurately assess on-the-ground conditions, however, the authors cautioned against inappropriate use of the information and maps included in the report: "The end products were not intended to be used at scales other than a coarse scale" (Schmidt et al. 2002).

Despite such admonitions, the report has been widely cited by policy-makers in their efforts to focus attention on the fire situation. The report's focal map, called "Fire Regime Current Condition Classes," was intended to represent the current condition of vegetation across the conterminous United States. Unfortunately, the map has major shortcomings that diminish its usefulness.

The methods used in the preparation of the condition class map involved a combination of expert opinion, existing maps, and map-based data analyzed in a geographic information system. Teams of experts on vegetation ecology were assembled for each of the Forest Service's eight regions in the conterminous 48 states. Each team was asked to describe the stages of normal vegetation development for various vegetation types in each region. They were then asked to use three condition classes to rate whether current conditions, described as combinations of existing vegetation types and forest density for every square kilometer of the lower 48 states, were consistent with normal vegetation development, moderately departed from normal because of the disruption of natural fire regimes, or significantly departed from normal.

Scientists who developed the map warned of a number of weaknesses in their analysis. First, much of the process of constructing the map involved subjective judgment calls, which make it impossible to determine exactly how condition classes were assigned or to repeat the methods by which teams arrived at those conclusions. Because each regional team of scientists worked independently, identical vegetation types along regional borders were sometimes assigned to different condition classes. These edge-matching problems were later resolved through negotiation among teams, but they strongly indicate the subjective nature of the classifications.

Second, most data used in the construction of the condition class map were collected at a scale that limits their usefulness, and inconsistencies in scale from map to map generated errors, leading to an overestimation of degraded conditions. For example, one of the fundamental maps underlying the entire analysis was Küchler's (1975) map of potential natural vegetation, created at a scale of one inch to 50 miles, hardly sufficient to resolve real vegetation variation at the one-kilometer scale.

The analysis also relied on "forest density" data as a surrogate for "structural stage," warning that this was a weakness in the methodology (Schmidt et al. 2002). Structural stage information is necessary to determine if forests that once flourished in open stands of widely spaced trees have grown denser and acquired a continuous canopy of explosive fuels. Such data require a close look at every acre, a monumentally expensive task. Instead, the scientists used a readily available alternative data set that they acknowledged was not the layer "required by the methodology." Regrettably, the forest "density" data used to construct the condition class map consisted of an estimate of how much of a square kilometer is forested, not how dense the forest is. It thus cannot be used to assess structural stage. Until problems with the methodology can be worked out, the fire regime condition class assessment should not be used as an input into fire management decision-making.

Understory fire: a national priority. Despite the shortcomings of fire regime condition class assessment, fire regimes themselves can be used to help set fire management priorities. The past century of fire exclusion has had a varied effect on North American vegetation. Fire regimes IV and V, which burn infrequently, are still considered largely within their historical range of fire behavior. Grasslands that constitute much of fire regime II have been largely converted to other uses, but where grasslands still exist, the role of fire in their ecology is not well understood. Fire exclusion has likely produced some changes in vegetation in fire regime III, but the complexity of fire and vegetation dynamics obscures obvious solutions. Only in fire regime I has there emerged a broad consensus that fire exclusion has resulted in dramatic changes and that those changes must be addressed (Christensen 2003).

Examples of vegetation in fire regime I include the longleaf pine–wiregrass ecosystem of the southeastern coastal plain, shortleaf pine and pine–oak systems in the interior Southeast, ponderosa pine forests in the Southwest, and extensive oak woodlands rimming California's Central Valley. For each of these systems, studies show that fire exclusion results in dramatic changes in vegetation, including increased forest density and the failure of some species, especially grasses and oaks, to regenerate. From the interior oak woodlands of the Pacific Northwest to the pine forests and wetlands of the Southeast, vegetation that evolved with fire has been starved of a key process, and those ecosystems' composition, structure and function have been altered.

To understand the potential for restoration of fire regime I, we modified a map from Schmidt et al. (2002), removing areas of altered vegetation (agriculture and urban) because of the low potential for restoration in those areas. Our analysis determined that fire regime I accounts for 34.3% of wildland vegetation in the conterminous 48 states. Fire regimes II and III account for 27.2% and 23.4%, respectively, while fire regimes IV (9.8%) and V (5.34%) are decidedly less common.

Figure 7. In April 1994, the Boise National Forest conducted a prescribed burn beneath the green, living ponderosa pine forest shown here in the foreground. Surface and ladder fuels were consumed, leaving the overstory pine. Four months later, a wildfire burned the entire area. Note that pine in the untreated forest in the distance were killed. But when the wildfire reached the prescribed burn area, it became a low-intensity surface fire. Most large pine in the prescribed burn area remain alive. Photo © Karen Wattenmaker/kwphoto.com.

It is now evident that the future health of forests in fire regime I depends on the return of fire as an ecological process (Figure 7). In some places, this will require only the restoration of fire, either naturally or through intentional ignition, but in other places, trees need to be thinned (and fuels otherwise manipulated) to facilitate the reintroduction of fire.

Thinning is the most controversial aspect of forest restoration. Nearly all experts agree that restoration of fire to fire regime I will require breaking the continuity of the fuel ladder from the ground to the canopy and that this will mean thinning small trees (Agee et al. 2000). The controversy arises from uncertainty over how big those trees should be. Some argue that large trees (more than 14 inches in diameter) must be thinned to break up the continuity of canopy fuels, while others insist that only surface fuels, consisting of shrubs and trees less than six inches in diameter, need to be cut. Many conservationists point out that large trees are already a seriously depleted element of many forest ecosystems (Anderson et al. 1996) and should be protected. They view with skepticism any suggestion that large trees should be cut in the name of restoration.

Regardless of the size of the trees, fuel reduction as part of fire restoration is sure to be an enormously expensive undertaking. It may be possible to recover some of the costs of restoration through the sale of by-products, but it will also require substantial investment of public funds.

To gain a better understanding of which areas might be in need of fuel treatment and thus to help prioritize treatment activity and save costs, we examined the current vegetation types found within the area identified by Schmidt et al. (2002) as fire regime I. This area contains a number of vegetation types that are clearly not in fire regime I (for example, maple–beech–birch and grassland), so we eliminated them from further consideration. We then mapped the locations of remaining vegetation types to produce Figure 8. To facilitate interpretation, we distinguish between western woodlands, which are not likely to produce usable timber, and western forest types that may yield commercial by-products.

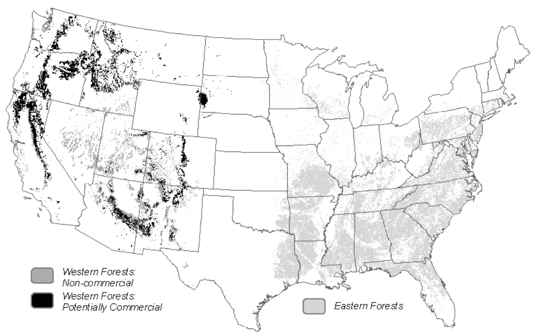

Figure 8. Forests potentially in need of fire restoration. Forests identified on this map represent a subset of forest types that may have suffered from fire exclusion. Further analyses, relying on more accurate data are required to determine if specific fuel treatments are required. These forests do not represent stands that necessarily require treatment.

Several conclusions are immediately apparent from Figure 8. First, fire exclusion is a problem not only in western forests. More than 250 million acres of fire regime I are in the Southeast where fires historically burned with frequency. In many of these forest types, fire exclusion has led to the build-up of a shrubby understory that degrades wildlife habitat and increases fire severity.

Figure 8 also suggests that much of fire regime I in the West is in open woodlands, not forests. Almost 40 million acres of pinyon–juniper and 5 million acres of hardwoods are mapped by Schmidt et al. (2002) as fire regime I. Pinyon–juniper is the most widespread forest type in the West, but wood values are low, suggesting that the sale of by-products will not offset restoration costs (Henderson and Baughman 1987). A similar story is told in the extensive non-commercial oak woodlands of the Willamette Valley in Oregon and in California, where the invasion of tree saplings threatens to carry lethal fire to the oaks.

The remaining 53 million acres of vegetation mapped as fire regime I in Figure 8 consist of dry forest types, primarily ponderosa pine (43 million acres), interior Douglas-fir (10 million acres), and larch (200,000 acres), that may yield commercial by-products through thinning.

As Figure 8 shows, much of the fire restoration challenge lies in the East, not in the western forest types that have been the focus of the debate over forest thinning. Even in the West, much of the area of concern is in woodland types that will not likely yield commercial by-products through restoration, although some thinning may be necessary. Out of the approximately 350 million acres of fire regime I in the conterminous 48 states that likely would benefit from the restoration of fire, only about 15% is in western forest types that may produce usable timber through thinning, and not all of those forests will need thinning.

Conclusions and recommendations

Our analysis identifies almost 100 million acres of fire regime I in the West alone that may benefit from the restoration of surface fire. Recent research (Barbour et al. 2001) shows that the cost of such treatment generally runs from $500 to $1,500 per acre for mechanical thinning and $100 to $500 per acre for prescribed burning. At $100 per acre, it will cost $10 billion dollars just to burn the backlog of fire regime I lands in the West. If 10% of that area requires mechanical treatment prior to burning, that adds another $10 billion, and mechanical treatments in community fire planning zones, even the narrowly defined CFPZ identified here, will cost several billion more. In addition, every acre treated accrues a long-term maintenance need, as both thinned and burned areas must be regularly cleared of regrowth every 5 to 10 years.

There is clearly not enough money to treat every acre. Priorities must be set using the best possible data, and community protection must come first (Figure 9). It is also necessary to identify which parts of the landscape should be the highest priority for fire restoration, whether through prescribed burning or natural fire.

Community protection. A simple half-mile zone around urban footprints of communities at risk exceeds 11 million acres, most of it private, state, and tribal land. Inclusion of surrounding "intermix" communities will likely increase that amount several-fold. Federal policy aimed at logging and thinning (treating fuel loads) on national forests and other federal lands will not address the majority of land associated with communities at risk from wildland fire.

Recommendations:

- Individual homeowners must take action to protect themselves. Simple steps, such as the installation of metal roofs, moving firewood away from the home, and keeping yards clear of fine fuels can dramatically lower the probability of home ignition.
- Funding must be directed to communities for the design and implementation of community-based fire plans. In some cases, money will be needed only for homeowner education or the development of sensible zoning regulations or covenants; in other cases, the less affluent will need assistance to do their part treating fuels.
- Better information, especially derived from remote sensing and geographic information systems, must be developed to help set priorities for community protection, and funding is needed to gather that information.

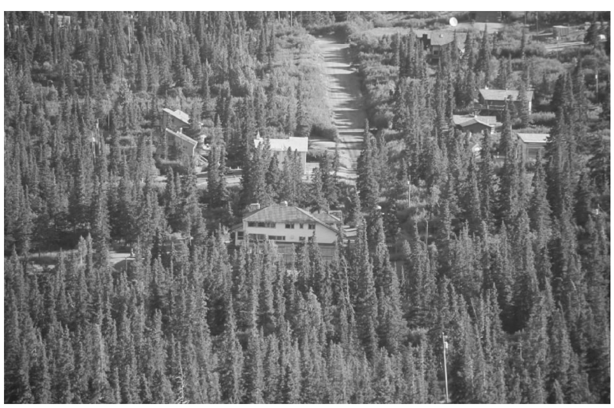

Figure 9. In this intermix community, structures are scattered throughout the surrounding wildlands. There is no clear line of demarcation, thus creating perfect conditions for catastrophic loss of property during a wildland fire. USDA–Forest Service Pacific Northwest photo by Tom Iraci.

Ecological restoration. Our analysis of the Forest Service's condition class map shows that the data needed to assess the condition of America's forests are not yet available. Too little is known about historical and current forest conditions, especially forest structure, and the scale of available data is too coarse to produce accurate and meaningful results.

Nevertheless, our analysis suggests that as many as 350 million acres may benefit from restoration planning in fire regime I alone. Other fire regimes also merit eventual attention. Over such a vast area, restoration cannot be successful unless approached rationally and efficiently. Where restoration is undertaken, we recommend that it be based on the following three principles, developed during a two-year collaborative process involving forest scientists, rural community advocates, and forest activists from across the nation (DellaSala et al. 2003):

- Enhance ecological integrity by restoring natural processes and resiliency. Actions may focus on individual species or the structure of ecosystems, but restoration should aim to repair ecological processes, such as fire cycles and hydrologic regimes, wherever possible.
- Provide economic incentives to encourage ecologically sound restoration. Economic incentives that drive the degradation of forests must be replaced with restoration incentives that protect and restore ecological integrity.
- Make use of or train a highly skilled, well-compensated work force to conduct restoration. Effective restoration depends on strong, healthy, and diverse communities and a skilled, committed work force.

This paper has been adapted by the authors from their original science report "The Wildland Fire Challenge: Focus on Reliable Data, Community Protection, and Ecological Restoration," published in October 2003 by the Wilderness Society. The original paper can be downloaded at: www.wilderness.org/Library/Documents/WildlandFireChallenge.cfm.

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Forest Health and Fire in the National Parks: Workshop Summary

Norman L. Christensen

Much of the dialogue and debate surrounding forest health and the implementation of the Healthy Forests Restoration Act has focused on national forests, but the implications for our national parks are considerable. The parks' mandates for conservation and public access create particular challenges for forest health restoration, as well as the restoration of natural fire regimes. The goal of this workshop [which was convened by the author at the 2005 George Wright Society conference—ed.] was to explore those challenges.

James Agee (University of Washington, College of Natural Resources) provided an overview of factors affecting variability in fire regimes and an evaluation of the effects of past, current, and likely future management on wildland ecosystems. He emphasized the importance of recognizing the variability among forest fire regimes. High-severity fire regimes prevail in moist-to-mesic forest types where fire return intervals are long (hundreds of years) and post-fire succession extends over centuries. Fires are often associated with extreme events such as extended drought or other catastrophes. Because fire return intervals are long relative to the period of active fire suppression (the past century), there is no forest health problem in these forest types.

Mixed-severity fire regimes, as the name implies, are characterized by spatially and temporally heterogeneous fire behavior with patches of severe fire separated by unburned or low-severity burned areas. This pattern produces spatial heterogeneity that is important to the diversity of these landscapes. Fire suppression in these systems has produced homogeneous fuels that are now supporting intense and homogeneous fires with the loss of landscape-level diversity. Restoration activities in these forests should focus on restoration of diverse landscape patterns.

It is the low-severity fire regime forests that have been most affected by fire suppression activities. Fire regimes in these forests were historically typified by low-intensity surface fires at relatively short return intervals (often less than 10 years). In the absence of fire, herbaceous surface fuels have been replaced by dense understory tree and shrub in-growth and the development of fuel ladders that facilitate crown-killing fire. In some areas, prescribed fire can be used to restore healthy conditions, but in many areas the threat of catastrophic fire is too great. Here, mechanical treatments are necessary. Such treatments should, in priority order, reduce surface and ladder fuels, and thin crown density. It is important that big trees be retained. These trees are fire resistant and important to maintaining conditions under which prescribed fire can then be used to maintain healthy forest conditions.

Agee argued that a national fire policy

was needed that extended beyond fire suppression, fuels management, and protection of the wildland–urban interface. A meaningful national policy would recognize the variability among forest types and regions, and the variability in current and desired future conditions. It would focus on the use of appropriate management tools in the context of a changing world. Such a policy would recognize the variability in management goals and options among different categories of public and private lands. Based on these differences, such tools as prescribed fire, prescribed natural fire, and mechanical thinning need to be selected to fit the specific situation found on site. Such a policy would recognize the reality of natural and human-caused variation in climate and the importance of forests to the global carbon cycle.

Bruce Kilgore (National Park Service, retired) suggested that, while many forests have too much fuel, healthy forest legislation and actions lack clear objectives. Current approaches assume a simplicity that does not exist—just cutting logs, piling brush, and burning will not restore forest health. Decision-makers must clarify which forests are in need of treatment, set priorities for protecting human life and property, and articulate clear guidelines for restoration activities. Such managers need to establish desired outcomes and trajectories of change, and ensure that sufficient funding is available to accomplish goals. The original goal for fire management in the national parks of restoring natural processes may still be a useful guide, but is probably not sufficient given variability in conditions and uncertainties regarding future change.

Kilgore warned that, thus far, projects undertaken under the rubric of healthy forest restoration have focused too much on short-term outcomes and number of acres treated rather than on the quality of outcomes or long-term maintenance strategies. Healthy forest legislation is more focused on limiting the public appeals process under the National Environmental Policy Act than on facilitating the sort of adaptive management needed in the context of variability and uncertainty. Agreeing with the undersecretary of agriculture that "it all boils down to a matter of public trust," he saw little in the current process to engender that trust.

Nathan Stephenson (U.S. Geological Survey, Sequoia-Kings Canyon National Park) outlined three issues that are critical for fire management in the national parks. First, what are the consequences of not being able to restore fire at landscape scales? Data indicate that current prescribed fire programs fall far short of the total area in need of restoration. Furthermore, air quality constraints, weather, difficult burn conditions, and limited financial resources will likely perpetuate this situation into the future. We should acknowledge this reality and be sure that we maintain pre-settlement fire regimes in those areas where we can. We should also focus on other strategically placed prescribed fire and restoration projects (e.g., SPLATS), and burn remaining areas when possible, so long as benefits outweigh risks. Monitoring is critical in all areas.

Second, what are the consequences of rushing maintenance burns (i.e., fires intended to mimic the natural fire regime)? Given excessive fuel accumulation and in-growth in many areas, prescribed fire or thinning aimed at restoration may be necessary to avoid risks of unnatural severe fire.

Finally, what are the consequences of using the past as a model for healthy forest restoration? Stephenson warned that, in an era of unprecedented change in climate, human development, and landscape structure, "natural" conditions defined by historical norms may no longer be resistant to or resilient from otherwise natural fire events. This may require creation of innovative ("unnatural") forest structures that provide such resistance and resilience.

Concerns regarding the constraints placed on park management by change and development outside park boundaries were echoed by *Jan van Wagtendonk* (U.S. Geological Survey, Yosemite National Park). Urban and industrial growth in areas often far removed from parks have created air quality challenges within the parks themselves. These may have direct effects on both visitors and ecosystems, but they also directly limit the flexibility of fire managers to prescribe and manage fires. Development near park boundaries creates potential liability that further limits that flexibility. Successful execution of Park Service fire management programs depends on increased collaboration and communication among the Park Service, regulatory agencies such as the Environmental Protection Agency, and the land planning community.

To meet the challenges of managing fuels and wildland fire, *Carol Miller* (U.S. Forest Service, Aldo Leopold Wilderness Research Institute, Missoula, Montana) argued that we need a process-based understanding of the ecological dynamics involving fire and the consequences of management actions. Wilderness and parks are critical for providing that understanding because they contain the best approximations of natural functioning ecosystems. That said, the challenges of managing fuels and fire are not merely ecological in nature; arguably, they are largely social issues. In addition to altering ecosystem structure and function, fire suppression has helped to distort human perceptions of natural systems. The orientations toward wilderness fire management that are held by the public and government agencies need to shift away from fire suppression as the dominant fire management strategy and toward a stewardship of the process of fire that includes natural, i.e., wildland fire use (WFU), and prescribed fire. To support this shift, we need to understand the individual, social, and organizational factors that support and maintain the existing orientation toward suppression. These include:

- *Incentives/disincentives.* Currently, the only reason or incentive for a manager to allow fire to visit the landscape is his/her personally held belief that "it's the right thing to do." Incentives for fire use must replace the existing disincentives. For example, managers need to have confidence that they and their careers will be protected when they make a well-reasoned, but risky decision (Figure 1).
- *Organizational culture.* In a few regions and units, there exists an orientation toward fire use, and the default decision is not necessarily suppression. These places usually have a history of relatively successful WFU programs. We need to better understand the factors responsible for differences among organizational cultures and use this information to foster cultures that are more accepting of fire use.
- *Language.* Our current vocabulary tends to reinforce the orientation that fire is undesirable. For example, we often talk in terms of managing risks from fire, but much less often in terms of creating opportunities for its benefits. We use the word "severity" to describe fire's effects, and that word inherently carries a negative connotation (have you ever heard of "severe" wealth or "severe" happiness?). We should be very careful and selective when we use a

Figure 1. Currently, the only incentive for a manager to allow fire to visit the landscape is his/her belief that "it's the right thing to do." Incentives for fire use must replace existing disincentives. Managers need confidence that their careers will be protected when they make a well-reasoned, but risky decision about fire use. NPS photo from Everglades National Park.

phrase like "catastrophic fire." What do we really mean, and is it necessary to use the term in the first place?

- *Internal education.* There is a pervasive disconnect between land/resource management planning processes, and fire management planning processes. Improved communication within the organization will require that resource managers understand something about fire behavior and fire operations and that fire managers understand something about fire effects on particular resource values.
- *Procedures.* Recent changes in the wildland fire implementation procedures (USDI/USDA 2005) will facilitate use of fire in wilderness and parks. The initial decision-time window has been extended from two to eight hours, and the documentation now requires a justification for a suppression decision.

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Fire, Forest Health, and Biodiversity: A Summary of the Proceedings of the Second Annual Symposium of the National Commission on Science and Sustainable Forestry

Norman L. Christensen

OVER THE PAST DECADE, FIRES IN WESTERN FORESTS have generated widespread public concern and debate regarding the condition of our forested lands and their apparent increasing vulnerability to extensive and sometimes very intense wildfires. President Bush's Healthy Forests initiative and the Healthy Forests Restoration Act passed in 2003 by Congress propose efforts to restore forest ecosystems on public lands to conditions less prone to catastrophic fire. The vast majority of discussion and legislation has focused around "fuels management" with little reference to the variations in forest structure and composition—i.e., biodiversity—that comprise those fuels and often no consideration of the different trajectories in forest change that determine fuel conditions. Fuel management, whether through prescribed or natural fire or by mechanical thinning, involves manipulating elements of the biological diversity of forests. Furthermore, wildfires, their suppression, and fuel manipulations have consequences for the biological diversity of forests that extend decades, perhaps centuries into the future.

Thus, the goals of this symposium were to:

- Explore the variations in forest biodiversity and associated patterns of climate and geography that influence fire regimes;
- Evaluate the influence of past and current management (e.g., fire exclusion) and land use on forest biodiversity; and
- Consider the likely impacts of fire management alternatives, including suppression, post-fire remediation, prescribed fire, and mechanical thinning for fuel restoration, on various elements of biological diversity.

E.O. Wilson (1992) defined *biodiversity* as "the variety of organisms ... and the physical conditions under which they live." The Montréal Process on sustainable forest management asserts that "biological diversity includes the elements of the diversity of ecosystems, the diversity between species, and genetic diversity in species." Within this broad vision of biodiversity necessary for sustainable management, symposium participants focused particularly on the following elements:

- Species, biological elements such as woody debris, and site and landscape structural complexity that influence fire

behavior;
- Species whose populations may be at risk from changes in fire regimes (e.g., fire exclusion, catastrophic wildfire) or fire management interventions;
- Aquatic species and habitats; and
- Invasive exotic species.

In his keynote address, Jerry F. Franklin, University of Washington, noted that we have learned much about fire ecology, forest development, and the dynamics of important forest tree species in the past two decades. But he also expressed concern that fire scientists are not communicating effectively and that we are not using existing knowledge to develop credible forest and fire management policy. Among these lessons, seven points are particularly important.

1. "One size does not fit all." The diversity of forest types is related to a diversity of fire regimes. Where low-intensity, high-frequency fire regimes were the historic norm, fire exclusion has resulted in changes in fuels that require management intervention. However, in many forest types that naturally have stand-replacement fires, fuels are not an issue. Existing plant association and habitat classification schemes can and should provide the framework for management in the context of this variability.
2. The causes of excessive fuel accumulations, where they exist, extend beyond historic fire suppression and include the impacts of grazing, logging, and the establishment of fire-prone plantations. The generation of large contiguous expanses of vulnerable forest conditions has produced "simplified" fire-prone landscapes.
3. Fuel treatments must be prioritized. Certainly areas at the wildland–urban interface must receive immediate attention. Among wildland forests, attention is often focused on climax ponderosa pine. However, the higher-productivity mixed conifer types, where shade-tolerant species create fuel ladders and enormous fuel loadings, may have been even more affected by fire suppression and may be at greater risk of catastrophic fire.
4. Fuel treatments must focus on ground fuels, ladder fuels, and the density of the forest canopy (in decreasing order of importance). Because they are resistant to fire, important in ecosystem recovery, the source of coarse woody debris, and critical for habitat, "big, old" trees must be retained. "Big, old" must be defined in the context of the dynamics and stature of particular forests.
5. We cannot get there in a single stroke; multiple treatments and continuing stewardship will be needed. Initial treatments often produce fuel conditions that require prompt follow-up. Without a long-term stewardship plan, treated areas will promptly return to flammable pre-treatment conditions.
6. Restoration goals must encompass multiple models. A single desired future condition, based on pre-settlement conditions, will not always be appropriate. The context for forest development has been greatly altered by landscape fragmentation and parcelization; invasive plants, pests and pathogens; and environmental change at all spatial scales.
7. Where large fires occur, care must be taken so that post-fire actions, such as inappropriate salvage or establishment of dense, fire-prone plantations, do not create new problems. Surviving large-

diameter trees, snags and logs, and islands of unburned and burned habitat should be retained wherever possible.

Fire as an ecological process

The relationships between fire and biological diversity within forest stands, across forested landscapes, and with respect to ecosystem processes were considered by Michael Huston (Interdisciplinary Solutions for Environmental Sustainability, Inc.), Andrew Hansen (Montana State University), and Daniel Binkley (Colorado State University), respectively. Although they have long been a matter of speculation and study among community ecologists, the relationships between disturbance and biological diversity defy simple or single-factor explanations (e.g., the intermediate disturbance hypothesis). The effect of particular fire (or other disturbance) frequencies on disturbance is clearly dependent on site productivity and the nature and rate of successional change in different fire types. The responses of different components of total plant diversity—say, trees versus herbs—may differ and even be opposite. These dynamics have significant consequences for biodiversity at the landscape scale as well.

In pre-settlement times, most—though not necessarily all—large forested landscapes in the West probably existed as "shifting steady-state mosaics" of patches representing different fire histories and stages of post-fire succession. The smallest area necessary to capture the full range of such patches and their dynamics is termed "minimum dynamic area" (MDA), and most pre-settlement landscapes are thought to have been larger than their MDA. Variability among patches in their composition of plants and animals species contributed enormously to the biological diversity of the landscape, and the long-term sustainability of that diversity depended on the maintenance of the shifting steady state.

Exclusion of fire has in many places rescaled the mosaic patches, and particular kinds of patches changed in importance; notably, conifer-dominated patches have increased in importance while aspen-dominated pieces of the mosaic have decreased. Land fragmentation and deforestation have further diminished the size of landscapes which, coupled with changes in the frequency of different patch types and increases in their size, means that most management units now do not encompass the MDA; in many areas managers must now cope with the reality of landscapes that are only a fraction of the MDA.

Today, because of landscape changes (e.g., fragmentation, rescaling) and expansion of human development into fire-prone landscapes, historic range of variation (HRV) in fire regimes on landscapes comprising a minimum dynamic area is not a realistic or socially acceptable management option. Active management is, nevertheless, a necessity to restore ecosystems and prevent the loss of biodiversity, and HRV and MDA concepts are important in selecting appropriate temporal and spatial scales to achieve ecological objectives. This will require a combination of natural and prescribed fire, silviculture, and land-use planning. Furthermore, management must be integrated across public and private lands to achieve landscape-level objectives. As discussed below, restoration efforts must be tailored to particular biophysical settings within and among regions.

The energy released by forest fire varies from the equivalent ignition of a few cups of gasoline per square meter in light understory fires to gallons of gasoline per square meter in intense canopy fires. That energy release is largely the consequence of the oxidation of large amounts of carbon. Nitrogen and sulfur are also oxidized and consequently "lost" as gases to the atmosphere. Other elements such as calcium, potassium, and phosphorus may be oxidized, but remain in the ash. Even though nutrients in ash may result in soil enrichment immediately following fire, mineral nutrient losses from fire are quite significant. In the case of nitrogen, 4.5 kilograms are lost for each ton of fuel consumed. Nitrogen is replenished between fires by input in precipitation and, to a greater extent, by the activities of nitrogen-fixing microbes and plants. For example, exclusion of nitrogen-fixing alders from successional Douglas-fir forests can result in a 50% decrease in stand production after 80 years. Many ecosystem processes depend on the activities of a diverse array of soil microbes, and the effects of fire on this component of biodiversity has received little study.

Fires affect the local hydrologic budget and soil water infiltration capacity, producing significant erosion and sediment transport. The negative effects of such erosion are well known and include the loss of nutrient capital and sedimentation of reservoirs. However, fire-related sediment transport is important in some areas to the development of features that maintain the diversity and functioning of many stream ecosystems on forested landscapes.

Inter-regional variation in fire regimes and fire history

Patterns of variation among and within the Pacific Northwest (James Agee, University of Washington), semi-arid Southwest (Tom Swetnam, University of Arizona), Sierra Nevada (Jon Keeley, U.S. Geological Survey), Northern Rockies (William Romme, Colorado State University) and Southeast (Joan Walker, U.S. Forest Service) regions were discussed. Participants in this part of the symposium were in agreement that Agee's general classification of fire regimes in the Pacific Northwest as ranging from low-severity (high-frequency, low-intensity) to mixed-severity (variable frequency and intensity) to high-severity (low-frequency, high-intensity) provided a useful framework for evaluating fire–biodiversity relationships and forest health conditions throughout the western cordillera.

High-severity regimes with fire return intervals in the hundreds of years are typical of forests in relatively warm and wet regions or high-elevation, cold areas. Such areas include the array of hemlock- and fir-dominated forests of the western Cascades, lodgepole pine forests such as those of the Yellowstone Plateau and in the Sierra Nevada, and the California coast redwoods. Although not typically considered forest, the southwestern chaparral most certainly fits into this category. In such areas, fire initiates a classical successional process that includes a long period of stem establishment, a thinning or stem-exclusion phase, with the ultimate development of old-growth forest, each with its own characteristic array of species and structural elements. The occurrence of fires in such forests is largely related to infrequent dry climatic conditions. Fire return intervals in these forests far exceed the period of active fire suppression and it was agreed that these forests are generally healthy and not in need of fuel restoration.

Mixed-severity fire regimes are typical of many western forest types, including red and white fir and dry Douglas-fir over much of their range and higher-elevation forests in the Sierra Nevada. Such fire regimes may have been important in some of the moister areas where ponderosa pine is dominant. Fires in these ecosystems are typically heterogeneous, with high- and low-intensity patches producing a mosaic of forest conditions across landscapes. Much biological diversity is associated with this mosaic. Forest health issues are complex in these regimes. Exclusion of high-intensity events can influence species such as knob cone pine that depend on such patches, as well as natural biodiversity in the mixed conifer forests. Historical patterns of logging and fire have modified the mosaic in many areas subject to mixed-severity fires and have thus altered fire behavior. Logging has potentially created even greater fire hazards than fire suppression policy: removing large trees has opened the way for creation of vast so-called dog-hair thickets that present a major restoration challenge since putting low- or mixed-severity fires back into these systems is problematic.

Fire suppression in such forests has adversely affected parts of the landscape (e.g., lower slopes, and north and east aspects) that typically experience low-intensity fires. Restoration can be important in such areas, particularly where potential impacts on human values are large. The 2002 Biscuit Fire in southern Oregon is an example of a mixed-severity event within which fire behavior was influenced by many of the factors described above.

Fire suppression and grazing have had their greatest impact on fuels in forest ecosystems that historically experienced low-severity fire regimes. This includes the drier ponderosa pine forests in the Southwest and the east side of the Cascades, and low-elevation ponderosa pine forests of the Sierra Nevada.

The dog-hair thickets of ponderosa pine in-growth in forests in parts of the Four Corners states have resulted from the historic impoverishment of grassy understories by grazing in the late nineteenth century, followed by a year or two of high seed production and seedling survival over the next few decades. Subsequent fire exclusion has permitted development of a dense understory tree cover. Although fire frequency in these forests is certainly influenced by periodic drought cycles (e.g., the El Niño Southern Oscillation) and, perhaps, longer-term climatic trends, it is clear that the magnitude and intensity—as well as impacts on hydrology, erosion, and aquatic ecosystems—of events such as the Rodeo-Chedeski and Hayman Fires are well outside the historic range of variation. Fire exclusion in the mixed conifer forests of the Sierra Nevada has facilitated the establishment of shade-tolerant incense cedar and white fir that create ladder-fuel conditions that can initiate crown-killing fires. Current conditions in many of these forests are unhealthy, the impacts of fire exclusion and the recent catastrophic fires on biological diversity at all spatial scales have been negative. Restoration in these forests is needed, and in many places this need is urgent. Restoration may involve mechanical thinning, prescribed fire, or a combination of these approaches. Thinning should be focused on reducing ground fuels, ladder fuels, and, where necessary, the density of the forest canopy (in that order). Removal of large trees, for reasons described above, will be counterproductive from both a biodiversity and fuels management standpoint. Restoration will not succeed as a one-time management intervention.

Our understanding of fire regimes and history for some western forests, such as pinyon–juniper and several higher-elevation forest types, is incomplete and appears to vary considerably among regions.

For example, fire in the southeastern U.S. plays a significant role in forest ecosystems and has a range of fire severity regimes similar to those found in the West. But climatic conditions and a long history of intensive human land use have produced patterns that are quite different than those observed in the West.

Presettlement landscapes were greatly influenced by fires set by Native Americans to clear land and improve conditions for wildlife. Extensive deforestation, land fragmentation, and subsequent reforestation over much of the Southeast during the past 300 years have further modified forests and their fire regimes. Although exclusion of fire from some southeastern forests has resulted in substantial forest change and, in some cases, loss of biodiversity, it has not produced forest health challenges similar to those described above for many western forests. Nevertheless, fire management will be important in restoration efforts for such ecosystems as longleaf pine–wiregrass savannas in the Coastal Plain and pine–heath forests in the southern Appalachians.

Perspectives on fire management

Fire and fuel management includes several actions, such as suppression and post-fire remediation, restoration using mechanical thinning of fuels, and prescribed burning. The biodiversity implications of the use of these management tools were discussed by Penelope Morgan (University of Idaho), Wallace Covington (Northern Arizona University), and Norman Christensen (Duke University).

The effects of fire exclusion on forest biological diversity at the stand and landscape scales have been discussed above. Fire suppression activities also directly affect species and habitat. Fire lines and other suppression-related disturbances can affect habitat and create opportunities for establishment and spread of invasive species. Intentionally set backing fires may be considerably more intense than the wildfire they are intended to suppress, again with locally adverse consequences. Nevertheless, where suppression is necessary, such impacts may be unavoidable and probably deserve special consideration in post-fire remediation efforts.

Post-fire remediation programs such as Burned Area Emergency Rehabilitation (BAER) are focused on the impacts of wildfire on hydrologic flows and sediment movement. They, nevertheless, have significant impacts on biodiversity that are rarely assessed. Scarification and the establishment of erosion barriers and wattles have potential consequences for habitat of some organisms and may facilitate invasion of some invasive alien species. Seeding, particularly with non-native species, may have a negative effect on establishment of indigenous plants and greatly increase the likelihood of introduction of invasive species. As a general concern, key aspects of biological diversity—for example, re-establishment of indigenous flora and invasion of non-native species—should be currently monitored as part of most restoration programs.

Forest restoration should be viewed as framework to restore forests and forested landscapes to conditions that are consistent with their evolutionary environment. From a social and political perspective, it must be based on collaborative, participatory processes. Reference conditions for restoration may or may not be presettlement landscapes, but they must be consistent with the evolutionary history of the forest and its species, and they should be developed based on converging lines of evidence from among a variety of techniques. To restore toward presettlement conditions in the low- and moderate-severity fire regimes described above, excess understory trees must be thinned and removed and trees that predate settlement as well as additional younger trees retained to re-establish presettlement forest structure. Following this, heavy fuels are raked from the base of trees and prescribed fires applied to emulate natural intensities and spatial distributions. Restoration may also require seeding with appropriate native plant species as well as vigilant control of invasive exotic species. This particular activity might be modified to accommodate particular management objectives such as habitat improvement for at-risk species, wood extraction, or livestock grazing.

Restoration efforts should be undertaken at a pace and scale appropriate to the forest health challenges in different regions. Furthermore, such restoration must be followed by careful monitoring and an integrated fire management program that will ensure that forest landscapes do not return to unhealthy states.

"Prescribed fires" are those that are allowed to burn within predetermined parameters of weather, terrain, and behavior, such that they can be controlled or extinguished. Using artificial and natural ignitions, prescribed fire has become an important tool for fuels and habitat management over the past century. It is nevertheless important to remind ourselves that prescribed fire is not necessarily equivalent to fire as a natural landscape process. Prescribed fires are generally set or allowed to burn at smaller scales and with considerably less variability in behavior than would occur naturally. There is a strong bias against extremes in fire behavior even when they are within the historic range of variation. Prescribed fires are often set in a season other than that which is typical for natural fires, and prescriptions often pay little attention to "legacies" such as snags and woody debris that affect habitat quality. These differences between prescribed and natural fire have important implications for biodiversity management.

Perspectives of managers and stakeholders

A panel of four managers and stakeholders was the centerpiece of the symposium's capstone discussion. Rick Cables, regional forester for the Rocky Mountain Region of the U.S. Forest Service, emphasized the important consequences of fire and fire management with respect to water and watershed protection. Gary Roloff, wildlife biologist with Boise Cascade, emphasized the importance of clarity regarding goals and definitions; it is, for example, not helpful to discuss the connections of fire to biodiversity without being very clear regarding the specific components of biodiversity of interest (e.g., populations of threatened and endangered species, invasive non-native species, umbrella species, etc.). Greg Aplet of the Wilderness Society presented three core principles for forest restoration efforts. First, restoration should focus on key ecosystem processes and emphasize resiliency. Second, appropriate economic incentives must be put in place to ensure this focus. Third, restoration must include training and compensation necessary to create and retain a skilled workforce. Finally, David Parsons, director of the U.S. Forest Service's Aldo Leopold Wilderness Institute, emphasized the need for institutional commitment and continuity with respect to fire and forest restoration policies.

Conclusion

Whether prescribed or wild, fires today occur in a context that is vastly different from the past. As discussed previously, landscapes have been "rescaled" and modified by human activities—the area and relative abundance of successional patches have been modified. Climates have changed, perhaps as a consequence of human activities—consider that the dominant trees in many forests were established over 200 years ago during the Little Ice Age, in some cases before that. In many areas—even in remote wilderness—air quality has been diminished in ways that affect forest health and most certainly influence our ability to use prescribed fire. The biogeographic barriers that once isolated species have through human actions have become increasingly irrelevant, so that even natural disturbances can have undesirable consequences with regard to the invasion of exotic species.

In the context of this complexity, it is important to recall that fire and fuel management—fuel manipulation, prescribed fire, suppression—is not *the* end in itself, only a means to other ends. Such management actions do not create *states;* rather, they determine *trajectories.* The primary goals of fire and fuel management may not be the protection and maintenance of biodiversity, but it is elements of biological diversity that are being manipulated (what are "fuels," after all?) and affected. Where biodiversity management is the priority, goals must be explicit and monitoring programs focused on those goals. Goals must be operational, measurable, unambiguous, and feasible. We have learned a great deal, but our knowledge base is still incomplete. Most important, these goals must form the basis for a program of management that is adaptive to variations among forest types, changes in the environment, changes in our knowledge base and understanding, and ever-changing societal needs and values.

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Federal Forest Fire Policy in the United States

Scott L. Stephens and Lawrence W. Ruth

Introduction

EVEN WITH LARGE EXPENDITURES AND SUBSTANTIAL INFRASTRUCTURE dedicated to fire suppression in the United States, the annual area burned by wildfire has increased in the last decade (USDA/USDI 2000; WGA 2000; NWCG 2001) (Figure 1). Given the current and future challenges posed by wildland fire, a review and reexamination of existing policy is warranted. This paper reviews the reasons why the area burned by wildfire is increasing, and discusses strategies for responding to an increasingly dangerous and difficult problem, with implications for communities, federal land management agencies, firefighters, and society itself.

The objective of this paper is to present specific ideas to reform and to improve U.S. forest fire policy and management. To be achieved, substantive reform requires better development, dissemination, and utilization of scientifically based information to assist in the efficient formulation and implementation of policy (Franklin and Agee 2003). The ensuing discussion will develop a conceptual agenda for this policy. Finally, the paper will consider how to enable these changes, recognizing that the mixed public and governmental context, as well as the setting of the land-management agencies themselves with their own histories and traditions, may naturally resist policy changes.

Historical context

Federal forest fire management in the United States began in 1886 when the U.S. Army began to patrol the newly created national parks (Agee 1974). Early responsibilities included patrols for fire suppression, unauthorized livestock grazing, and timber harvesting. In 1891, the Congress authorized President Harrison to establish forest reserves, later to be known as national forests (Pinchot 1907; Pyne 1982; Ruth 2000). Gifford Pinchot became the first chief of the agency that would manage

Figure 1. Even with large expenditures and infrastructure dedicated to fire suppression, the annual area burned by wildfire has increased over the last decade. The goals of fire management should be reduction of uncharacteristically severe wildfires. USFS photo.

the reserves, and under his direction, a national forest fire policy was initiated. The suppression of forest fires dominated early forest policy.

Henry Graves, the second chief of the U.S. Forest Service (USFS) initially demonstrated some openness to the cautious use of fire (Carle 2002). This idea was supported by USFS managers in California and plans were created to produce a permit system to allow private landowners to use controlled fire. However, the idea of using fire in forest management was strongly debated within the USFS. Chief Graves assigned forest examiner Stuart Show to study the issue (Carle 2002), and he reported that the agency should adopt a strong fire suppression policy (Figure 2).

Chief Graves eventually supported a strong fire suppression program, declaring "the first measure necessary for the successful practice of forestry is protection from fire" (Graves 1910; Pyne 1982). The earliest federal fire control policy was written shortly after Graves was appointed (DuBois 1914). William Greeley, the third USFS chief, took over the agency in 1920 and continued the strong endorsement of fire suppression, stating "the conviction burned into me is that fire prevention is the number 1 job of American foresters" (Greeley 1951). During Greeley's nine-year tenure fire suppression was paramount in federal and private forest management.

A scientific study was initiated in California on the merits of fire suppression versus light underburning, and its conclusions continued to support a strong fire suppression policy (Show and Kotok 1924). The concept of light underburning was modeled after earlier Native American uses of fire in northern California (Clar 1959). Passage of the federal Clarke-McNary Act in 1924 tied federal appropriations to the state first adopting fire

Figure 2. Suppression dominated fire policy from the early 1900s until the late 1960s and early 1970s when both the National Park Service and U.S. Forest Service revised their policy. Fire scientists and managers realized that total suppression was producing forests with high fire hazard, and such forests were being burned by high-severity wildfire. Photo by Kari Greer/NIFC.

suppression, and this law effectively created a national fire suppression policy.

The policy of fire suppression was debated in the southeast United States (Schiff 1962; Pyne 1982; Biswell 1989; Carle 2002) because the use of fire was culturally accepted in this area (Shea 1940; Komarek 1962; Schiff 1962). Further, several large wildfires in this region reinforced the need to consider policies that utilized prescribed burning to reduce fuel hazards. Eventually, a change in fire policy allowed the first use of prescribed fire on federal lands, with burning taking place in Florida's Osceola National Forest in 1943 (Bickford and Newcomb 1946).

Research initiated in the Southeast (Chapman 1926) and the western U.S. (Weaver 1943; Cooper 1960; Biswell 1961) began to identify landscape conditions that could be attributed to fire suppression. For the first time, significant changes in the structure, composition, and fuel loads were documented in forests that primarily experienced frequent, low-to-moderate-intensity fire regimes. The implications of these investigations were profound but not utilized by contemporary policy. The very policy of fire suppression that had been adopted decades earlier was actually producing forests with high fire hazards, and these forests were being burned by high-severity wildfire.

Figure 3. The first use of prescribed fires on federal lands in the west occurred at Sequoia-Kings Canyon National Parks in 1968 and Yosemite in 1970. Here, an NPS forestry foreman uses a drip torch to ignite forest litter under a canopy of giant sequoias and white fir to consume litter and kill understory white fir. NPS photo by Bruce M. Kilgore.

In 1962, partially in response to the results of the increasing number of scientific studies in fire ecology, the U.S. secretary of the interior requested a study on the status of federal wildlife management. The Leopold Report identified fire suppression as a policy that was adversely affecting wildlife habitats (Leopold et al. 1963). Contemporaneously, the first use of prescribed fires on federal lands in the West occurred in California in 1968 at Sequoia-Kings Canyon National Parks (USDI 1968), followed two years later by Yosemite National Park (Kilgore 1974; Parsons et al. 1986; van Wagtendonk 1991) (Figure 3). The National Park Service (NPS) continued to suppress unwanted wildfires, but fire was also used to meet resource objectives.

In 1968, the first prescribed natural fire program in Sequoia-Kings Canyon National Parks was created (USDI 1968; Kilgore 1974;

Parsons et al. 1986). This occurred because of earlier research on the effects of prescribed fire in mixed conifer forests (Biswell 1961; Hartesveldt and Harvey 1967; Kilgore and Briggs 1972) and because of the recent change in NPS fire policy. Creation of the National Wilderness System in 1964 also advanced the philosophy of wildland fire use in remote forested areas (Pyne 1982). Some USFS wilderness areas such as the Selway-Bitterroot (Idaho and Montana) and Gila (New Mexico) began a program of prescribed natural fire in the late 1960s, but similar management philosophies were rare on other national forest lands.

Shortly after the NPS revised its fire policy, the USFS did so as well. Henry DeBruin, director of fire and aviation management for the USFS, stated "we are determined to save the best of the past as we change a basic concept from fire is bad to fire is good and bad" (DeBruin 1974). While this statement represented a major shift in the philosophy of the USFS, fire suppression was still to dominate agency policy for the coming decades (Franklin and Agee 2003). The use of fire in the management of forests would remain very rare in the USFS.

Between 1960 and 2003, wildfires on Bureau of Land Management, Bureau of Indian Affairs, NPS, U.S. Fish and Wildlife Service, USFS, and all state lands averaged 1,642,000 ha annually (data from NIFC 2004). Between 1994 and 2003, the average area burned increased to 1,925,000 ha/yr; between 1999 and 2003, the average was 2,271,000 ha/yr. The amount of land burned by wildfire in the last five years is 38% larger than the average in the period 1960–2003. Federal fire suppression costs in 2000 and 2002 were $1.3 and $1.6 billion, respectively (NIFC 2004). Similar expenditures occurred in 2003, but an estimate of the final cost is not yet available.

The emerging trajectory is troubling: despite large expenditures and infrastructure (aircraft, firefighters, command centers, logistical support, etc.) dedicated to fire suppression, the annual area burned by wildfire has increased over the last decade (USDA/USDI 2000; WGA 2000; NWCG 2001).

Recent fire policies and initiatives

Federal fire policy has been significantly modified since 1995 to recognize and embrace the role of fire as an essential ecological process (USDA 1995; USDI/USDA 1995; NWCG 2001). The 2001 federal wildland fire management policy (NWCG 2001) stated that "fire, as a critical natural process, will be integrated into land and to resource management plans and activities on a landscape scale, and across agency boundaries."

One of the main objectives of the 1995 fire policy revision was to reduce fire hazards annually on 1,200,000 ha of forests using mechanical and prescribed fire treatments (USDA 1995). Progress toward this goal has been slower than anticipated (GAO 2003), due to constraints on smoke production; difficulties in plan preparation; regulatory review; potential impacts on sensitive, threatened, and endangered species; and budgetary procedures that have delayed fuels management projects. Progress has also been impaired because of the significant risks inherent in the activity, such as the individual and professional risks facing managers for the consequences of prescribed fires that escape despite proper planning and execution (Benner and Wade 1992). Another significant problem with the current system is there are few incentives or rewards for individuals that successfully produce proactive programs that use prescribed fire and mechanical methods to reduce potential fire behavior and effects.

The National Fire Plan (NFP), established in *A Report to the President in Response to the Wildfires of 2000* (USDA/USDI 2000), is now being implemented using the *Collaborative Approach for Reducing Wildfire Risks to Communities and the Environment: Ten-Year Comprehensive Strategy* (TYCS; WGA 2001). Both the NFP and the TYCS recognize that if hazardous fuels are not reduced, "the number of severe wildland fires and the costs associated with suppressing them will continue to increase." (Figure 4). Implementation of the NFP is designed to be a long-term, multibillion-dollar effort (GAO 2003). The TYCS was developed without direct federal input and recognizes that key decisions in setting priorities for restoration and fuels management should be made collaboratively at local levels. As such, the TYCS requires an on-going process whereby the local, tribal, state, and federal land management, scientific, and regulatory agencies exchange the required technical information to facilitate the decision making process. In fiscal year 2001, the first year the NFP was in effect, Congress increased funding for reduction of hazardous fuels to $401 million ($108 million was allocated in 2000) (GAO 2003). Congress continued this increased funding in 2002 and 2003.

The Healthy Forests Initiative (HFI), introduced by President Bush in August 2002, sought to address perceived difficulties in implementing fuels management projects by streamlining and shortening administrative and public review and by limiting appeals processes. The specific objectives of the HFI were to (1) facilitate timely reviews of forest health restoration and rehabilitation projects, (2) amend rules for project appeals to hasten the process of reviewing forest health projects, and (3) require prompt judicial responses to legal challenges by setting time limits for review. The new procedures were designed to allow the departments of interior and agriculture to give priority to forest thinning projects so that they could proceed within one year.

Figure 4. Current fire plans recognize that if hazardous fuels are not reduced, "the number of severe wildland fires and the costs associated with suppressing them will continue to increase." Photo by Kari Greer/NIFC.

Many of the ideas presented in the HFI were enacted as the Healthy Forests Restoration Act (HFRA 2003), including expediting environmental analysis, expediting administrative review before decisions are issued, encouraging courts to expedite judicial review of legal challenges, and directing courts that consider a request for an injunction on an HFRA-authorized project to balance the short- and long-term environmental effects of undertaking the project against the effects of taking no action. New ideas contained in the HFRA that were not in the HFI include requirements governing the maintenance and restoration of old-growth forest stands, requiring that HFRA projects maximize retention of larger trees in areas other than old-growth stands, requiring at least 50 % of the dollars allocated to HFRA projects to be used to protect communities at risk of wildland fire, and to encourage project performance to be monitored and evaluated.

The multiple legislative and administrative efforts all provide support for "fuels reduction" in response to a "wildfire problem" that is both perceived and real. Irrespective of these initiatives, there is no comprehensive policy to deal with fire and fuels, and there are few indications that such a policy is in development (Franklin and Agee 2003). While the effects of forest fires are commonly discussed and debated by the public, politicians, scientists, and land managers, a number of scientific questions about fires and their effects remain. Accordingly, scientific information pertinent to specific regional issues and situations is somewhat limited. Further, there are few policy analyses available to provide credible information on the range of possible strategies, or to provide estimates and comparative evaluations of safety, effectiveness, and environmental impacts (Figure 5).

The lack of information and analysis cripples efforts to respond appropriately to accumulated fuels and high fire hazards. Equally, a lack of systematic consideration of the relative effectiveness of the current disparate national, regional, and local strategies toward wildfire has obscured the information that we now possess. The effect has been to impede progress on two fronts: by impeding thoughtful re-emphasis of policies that are or are likely to be effective, and by preventing more comprehensive reforms that will enable federal agencies to better respond to the threats posed by wildfire. In the next section we give specific recommen-

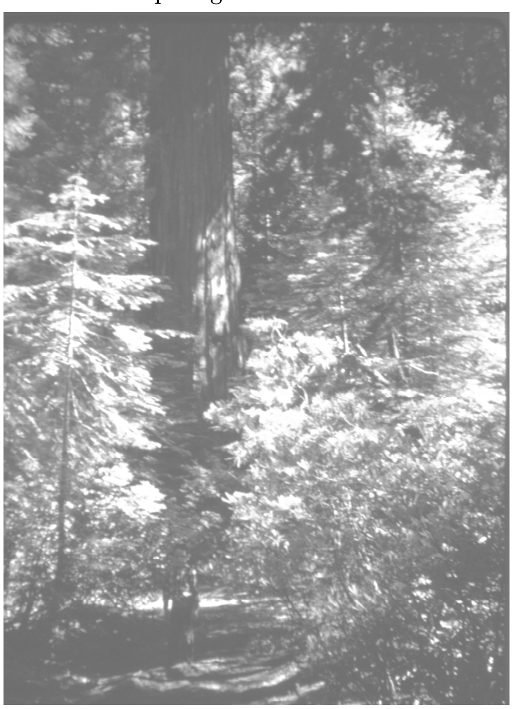

Figure 5. Various initiatives provide support for simple "fuels reduction" in response to a "wildfire problem." Yet there is no comprehensive policy to deal with fire and fuels and few indications that such a policy is in development. The complexity of problems involved are exemplified by mixed-severity fire regimes that range from low- to high-severity fire effects. These can be found in dry Douglas-fir, grand fir, juniper, and even certain giant sequoia–mixed conifer forests (see left). NPS photo by Bruce M. Kilgore.

dations on how federal forest fire policy can be improved.

Policy analysis and recommendations

Fuel types and treatment effectiveness. The primary objective of fuels management projects should be a reduction of potential fire behavior and effects, not simply the reduction of forest fuels. Recent federal fire policies and initiatives all seek to reduce fire hazard by reducing fuels. This strategy possesses an intuitive appeal, but application of the strategy may not significantly alter fire hazards. Fire behavior is not simply a function of fuels, but also of weather and topography. Fuels are the main fire behavior component that can be directly affected by management, but the type of management action and its effectiveness with respect to a particular type of fuel are critical in predicting whether the action will reduce potential fire behavior and effects. Local climate conditions can also be influenced by treatments, resulting in trade-offs between reducing canopy cover that increases air temperatures and wind speeds (van Wagtendonk 1996).

A brief introduction to the variety of wildland fuels and their characteristics is necessary to understand exactly why this knowledge and specificity is an important ingredient in achieving the overall objective. Wildland fuels are composed of four groups: ground, surface, ladder, and crown. Each of these has a different potential to influence fire behavior. Ground fuels include the duff and litter on the soil surface and generally do not contribute to wildfire spread or intensity. Surface fuels include all dead and down woody materials, grasses, other herbaceous plant materials, and short shrubs, which are often the most hazardous fuels in many forests. This is particularly likely in forests where vegetative species composition, density, and structure have been influenced by decades of fire suppression (Stephens 1998; Agee 2003). Ladder fuels are trees or tall shrubs that provide vertical continuity from surface fuels to the crowns of tall trees. Crown fuels are those in the overstory.

Reducing surface fuels will limit the intensity of fires and allow more of the forest to survive when it does burn. Thinning treatments can be directed to effectively reduce ladder and crown fuels. However, where logging residues (activity fuels) are left on site, potential fire behavior and effects may be either similar to or more extreme than an untreated forest (Stephens 1998). Finally, in forests that experienced frequent, low-intensity to moderate-intensity fire regimes prior to a long period of fire suppression, fuels treatments should focus on surface, ladder, and then crown fuels (Stephens 1998; Agee 2003). The difference between fuel types, the subtlety of their interactions, and differences in their behavior in different types of fire regimes are all important in developing fuels management strategies to appropriately reduce potential fire behavior and effects.

The USFS has used the "condition class system" to identify and prioritize areas in need of fuels treatments (Schmidt et al. 2002). This national system attempts to identify the number of fire return intervals that have been missed due to fire suppression. The assumption is forests that have missed more intervals will have higher hazards, but there are exceptions. Many ponderosa pine (*Pinus ponderosa* Laws.) and Jeffrey pine (*Pinus jeffreyi* Grev. and Balf) forests have missed 10–15 fire intervals but the effects of 100 years of fire suppression on the amounts and arrangement of fuels and potential for uncharacteristically severe fire may be greater in a mixed conifer forest, which have missed only three to four fire intervals (Franklin and Agee 2003; Stephens 2004). This occurs because mixed conifer forests are generally more productive, resulting in more rapid fuel accumulations. An index based on departures from historic fire return intervals is therefore not the best basis for setting fuel treatment priorities (Franklin and Agee 2003). The condition class system is also a coarse classification system that was never intended for use at the local level, which requires evaluation at much finer spatial scales. Federal scientists have recognized this problem and in 2003 began the "landfire project" whose objective is to produce fine-resolution condition class data for the entire country in approximately three years.

Current fire policies attempt to generate high levels of "acres treated" with minimal evaluation of treatment effectiveness. Most fuel treatments on USFS lands do not even measure fuels before and after treatment, something that would be a fundamental aspect of any evaluation program. Current federal fire policies include NFPORS (the National Fire Plan Operations Reporting System) that allows the federal agencies to record expenditures and treatment locations, but it cannot be used to determine if treatments accomplished their objectives (GAO 2002). A strong commitment to adaptive management and all-party monitoring is needed (Figure 6) to overcome this problem (see below).

Fire and landscapes. Fire itself can help to reduce the total amount of area burned by wildfire. Many fires ignited by lightning in remote areas can produce positive effects, provided that they are carefully managed and monitored. These fires could also serve to reduce fire hazards and assist in the reintroduction of fire as an ecosystem process, particularly in western forests that have experienced large wildfires in the last decade (NWCG 2001). Improved utilization of the existing wildland fire use policy provides for careful and gradual reintroduction of fire into landscapes (NWCG 2001). There is risk in such a program, of course. But unless fuels management techniques are employed in appropriate forest types (those that once experienced frequent, low-to-moderate-intensity fire regimes) at necessary spatial scales and arrangements (Finney 2001), many of these forests will continue to be subject to uncharacteristically severe fires. The USFS wildland fire use policy is underutilized: less than 5% of national forests have approved fire plans (Ingalsbee 2001). Creation of fire plans should be a priority for all forests with hazardous fuel conditions. The wildland fire use policy already provides a mechanism of addressing an important component of accumulated wildland fuels. Broader implementation would offer an unprecedented opportunity to gather valuable ecological and organizational information about the results of the experience across an array of regions and landscapes.

To be effective, landscape fuel reduction strategies should be better linked to past fire causes. Lightning strikes are stochastic, making it difficult for fire managers to forecast areas of higher ignition potential. Strategically placed area treatments (SPLATs) may be an effective strategy to reduce landscape fire behavior in large, heterogeneous areas (Finney 2001). SPLATs are a system of overlapping area fuel treatments designed to minimize the area burned by high-intensity head fires in diverse terrain. The performance of SPLATs has not been field tested, but computer simulations have produced promising results.

Human-caused fires commonly occur near transportation corridors (highways, roads, trails), campgrounds, and urban areas, making it possible for fire managers to forecast areas of higher ignition potential. Defensible

Figure 6. Current policies try to generate many "acres treated" with minimal evaluation of treatment effectiveness. A strong commitment to adaptive management and all-party monitoring is needed to determine if treatments accomplish their objective. NPS photo.

fuel profile zones (DFPZs) placed near areas of high human-caused ignitions can be used to decrease the probability of large, high-severity fires by improving suppression efficiency (Kalabokidis and Omi 1998; Agee et al. 2000). DFPZs are linear landscape elements approximately 0.5–1.0 km wide, typically constructed along roads to break up fuel continuity and provide a defensible zone for fire-suppression forces. Installation and maintenance of these structures (SPLATs and DFPZs) at appropriate spatial scales should reduce forest fire area and severity. DFPZs will be effective in reducing losses in the urban–wildland intermix only if they are used in combination with combustion-resistant homes that have defensible space from wildland and domestic vegetation. Continued growth of human populations in the urban–wildland interface is one of the most challenging issues facing fire managers because it places additional assets at risk and reduces management options.

Fire as an ecosystem process. To be effective across diverse forest types and conditions in the United States, fire policy should better recognize and respond to the diversity of fire regimes in the nation's forests. Some management activities can reduce the severity of wildfires in some forests (Martin et al. 1989; Weatherspoon and Skinner 1996; van Wagtendonk 1996; Stephens 1998; Moore et al. 1999; Fulé et al. 2001; Pollet and Omi 2002), but some forest types such as Rocky Mountain lodgepole pine (*Pinus contorta* var. *latifolia* Dougl.) are adapted to and require periodic high-severity, stand-replacement fires (Romme and Knight 1981; Veblen et al. 1994; Turner and Romme 1994; Christensen et al. 1998).

Assessment of how fire is affecting forests would be enhanced if information were provided by land management agencies about the specific type of fire and whether the particular ecosystem is adapted to it. Agencies should report the actual amount of area burned by low-, mixed-, and high-severity fire and which proportion of these categories is outside the desired conditions or trends for each forest type. Natural variations, or reference conditions derived from historical ecology, can be used to assist in the definition of desired severity categories (Swetnam et al. 1999; Stephens et. al 2003; Stephens and Gill 2005). Currently, the only wildfire data recorded on USFS lands are total area burned, dominant vegetation types within the perimeter, and fire location. Ground-based severity measurements are recorded for some fires, but these measurements cover only a small portion of the burned area. Remote sensing can assist in the evaluation of fire severity at large spatial scales. This type of analysis should be routinely done on all forest fires.

Despite the complexity inherent in local fire regimes, regional fire activity often oscillates in phase with year-to-year climate variability (Clark 1988; Swetnam 1993). For example, the area burned annually across the southern United States tends to decrease in El Niño years and increase during La Niña years (Swetnam and Betancourt 1990). In northern California, the impact of climatic change on wildland fire and suppression effectiveness is predicted to change in the inland regions of the state (Fried et al. 2004). Despite enhancement of fire suppression efforts, the number of escaped fires (those exceeding initial containment limits) is forecast to increase by 51% in the south San Francisco Bay area and by 125% in the Sierra Nevada (Fried et al. 2004). In addition to the increased suppression costs and economic damages, changes in fire severity of this magnitude would have widespread impacts on vegetation distribution, forest condition, and carbon storage, and greatly increase the risk to property, natural resources, and human life. Changing climates may necessitate creation of fire policies that are easily adaptable because of large uncertainties.

Administrative and management constraints. Many species-specific conservation strategies developed in recent years, especially those developed to comply with the Endangered Species Act of 1973 (U.S.C. 16, sections 1531–1544), or species viability requirements of public land management statues such as the National Forest Management Act of 1976 (Public Law 94-588; Statutes at Large 90:2949) or the Federal Land Management and Policy Act of 1976 (U.S.C. 43, sections 1700–1784), can be classified as fine-filter approaches. These are conservation strategies designed for individual species without strong consideration given to maintaining natural ecosystem processes (Agee 2003). Coarse-scale strategies, on the other hand, seek to preserve biological diversity of forests, primarily by maintaining a variety of ecosystems and structures across the landscape. In many forests, fire served as a natural coarse filter before suppression.

Many fine-scale strategies, such as those often employed to respond to concerns regarding the viability of threatened and endangered species, produce extensive management constraints such as the systematic exclusion of fire from fire-dependent habitat, or the restriction that prescribed fire cannot be used until a specified amount of precipitation occurs. Such constraints essentially remove prescribed fire as a management option. The fine-scale filter may achieve short-term objectives for individual species, but generally leaves the majority of the habitat at risk to large, catastrophic wildfire (Agee 2003). This strategy is likely to fail in the long term because without effective fuel reduction treatments, most wildland areas will eventually burn under severe wildfire conditions. Fine- and coarse-filter approaches, however, may be employed simultaneously. To be more effective, successful conservation strategies should emphasize the coarse-filter approach, utilizing the fine filter in carefully selected areas only when absolutely necessary (Agee 2003).

Questions have been raised about the ability of federal agencies to efficiently execute fuels management projects (HFRA 2003). A recent analysis determined that there is little evidence that fuels management projects are being significantly delayed once they are released to the public for comment (in 2001 and 2002, final decisions on 95% of the 762 fuels management projects were made in 90 days or fewer; GAO 2003). Reforms may be needed to reduce the time required to produce the necessary environmental impact statements (EISs) and environmental assessments (EAs). EISs and EAs could be improved if they focused on defining the desired range of conditions or trends instead of focusing on spatial and temporal management constraints (fine-filter approach); the latter is much more common today. We should focus on the outcomes of fuels management projects, not on the methods used to reduce hazards. Present high transaction costs are probably reducing the opportunity for successful fuel reduction projects in federal forests.

Many wildland areas in the United States have experienced an increase in area burned over the last decade (USDA/USDI 2000; WGA 2001; NWCG 2001), and active management (Agee 2003) is necessary to reduce this trend. Prescribed fire can be used to reduce fuel hazards in many of these forests. Unfortunately, multiple constraints (air quality, wildlife, weather, and personnel availability) routinely limit periods for burning operations. As a result, many fire managers may have a single week or less when burning is actually permitted. With such limitations, it is simply not possible to use fire to reduce high hazards on millions of hectares of forests. Smoke from forest fires (of appropriate severity and size) is a natural ecosystem component, and regulations should be adapted to allow more burning opportunities while also considering public health. In contrast, wildfires produce extreme amounts of smoke that can inundate large areas for weeks or months, producing a variety of effects and unwanted impacts.

Many species of wildlife have co-evolved with fire (Smith 2000), and any local or regional reintroduction of fire must be carefully monitored to ensure species viability. Additionally, adaptive management programs must be used to learn from management actions (Shindler and Cheek 1999) because there is insufficient information on the ecological effects of fuels treatments. Mechanical treatments may be appropriate for use in combination with prescribed fire (Stephens 1998), a practice that has the potential to reduce fire hazards and emissions in certain cases. Using mechanical methods in fire- hazard-reduction treatments can produce timber resources, but when this occurs, the primary objective must continue to be the reduction in potential fire behavior and effects.

Seventy percent of the funding from the NFP has been directed to fire suppression, resulting in the hiring of approximately 5,500 firefighters and the purchasing of hundreds of vehicles and aircraft. Similar investments in professional fire ecology or fuels management positions have not occurred. Large-scale fuels management programs have been planned in all western states, but implementation of these programs has been challenging. In the Pacific Northwest there are approximately 3.6 million ha of forests in need of fuel treatment. The treatment goal for this area in 2004 is 52,000 ha. At this rate it would take 69 years to treat all of the area once, a period that approximates the effective duration of fire suppression. USFS lands in California include approximately 6.2 million ha of forests that are in need of fuel treatments. The current management plan forecasts treatment of 23% of this area in 20 years. If the goal were to treat the entire area it would require 87 years. The use of SPLATs (strategically placed area treatments) should reduce the total area that needs to be treated before landscape fire behavior and effects are reduced, but the challenges to treat very large areas are formidable. The costs of treatments can be high, especially when many small trees need to be removed and there is no market for such materials. Many plans underestimate the actual costs of implementing effective fuels treatments, especially in forests dominated by small trees.

Social interactions and institutions. Sustainable fire policies must respond to complex social, political, and economic forces. Currently, there are diverse opinions among executive-branch officials, Congress, federal agencies, state and local governments, tribes, environmental groups, and commodity groups as to what should actually be done to reduce fire hazards in federal forests. Diversity and disagreement can be healthy in any debate, and may eventually strengthen any policy. Even with better collaborative efforts that occur earlier in the planning process, and the streamlined administrative review of fuels management projects provided by the HFRA (2003), satisfying legal requirements may still derail the best intentions of federal land managers, the public, and other interests. The requirements of federal law and due process may in some instances permit a single interest to override others, and derail a collaborative effort to institute a regional or local fuels management plan.

Mechanisms for collaborative stewardship should be refined and created to encourage participants to interact on how to proceed in the face of disagreements as to what policies are appropriate and effective (Figure 7). Actions that may assist this interaction include (1) initiating small projects that provide an opportunity for a local dialogue on the outcomes of fuel treatments; (2) locating projects in areas where there is substantial agreement on restoration objectives; (3) reflecting and celebrating accomplishments in order to build relationships, trust, and support; (4) creating an extensive, well-designed adaptive management program to learn from management actions; (5) initiating all-party monitoring to assure credible post-treatment data and analysis (monitoring should be coordinated by a non-federal group to ensure independence); (6) striving to distribute the costs and benefits of restoration equitably; and (7) ensuring that scientific data and other information gained as a result of the adaptive management process are actually used.

This would provide information to land managers and scientists that will help to improve future management actions, and would also provide information to federal, state, and local governments and the public regarding the effectiveness of elements of legislation and policy in achieving the overall objective of reducing losses from wildfire. In establishing and implementing collaborative projects, and utilizing experimentation and adaptive management, successes on the ground will serve as opportunities to gain knowledge and experi-

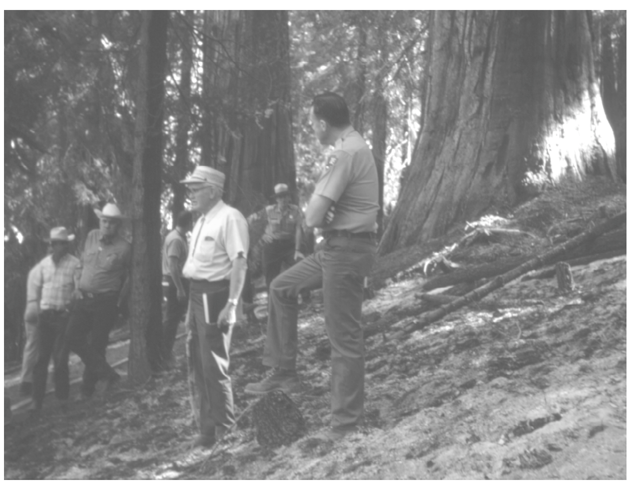

Figure 7. Sustainable fire policies must respond to complex social, political, and economic forces. These include local, state, and federal agencies, as well as environmental and commodity groups. Mechanisms for collaborative stewardship should be created to help participants work toward the common goal of reducing uncharacteristically severe wildfires. NPS photo by Bruce M. Kilgore.

ence, reflect and revise policies and prescriptions, and serve as precedents for eventual broader application at landscape scales.

Although the NFP (USDA/USDI 2000), TYCS (WGA 2001), and HFRA (2003) apply to all federal agencies (USFS, National Park Service, Bureau of Land Management, U.S. Fish and Wildlife Service, Department of Defense), each agency will implement these policies within its own institutional contexts. This will result in different aspects of the policies being emphasized in different areas. Allowing some diversity in implementation is an opportunity to learn which strategy is the most effective. Certainly the federal agencies should work collaboratively to reduce potential fire behavior and effects, particularly at shared property boundaries.

Fire suppression costs and strategies. Large fire-suppression activities in 2002 and 2003 required extraordinary emergency expenditures. Funds available for fire suppression in these years were insufficient due to the fact that the federal budget for these activities was inadequate. Additional emergency funding was secured by the rescission of funds that had been appropriated from unrelated management and research programs (GAO 2004). The federal Office of Management and Budget influenced the reallocation of these resources, forcing the USFS to use funds from non-suppression activities to pay for suppression. Ironically, the rescission removed resources from fuels management programs that were authorized by the NFP and TYCS. In 2003, according to Dale Bosworth, chief of the U.S. Forest Service, approximately 60,000 ha of USFS land were left untreated when funds were transferred to fight wildfires (Berman 2004). Another impact of the rescissions is negative impacts on collaborations with private, state, and federal partners (GAO 2004).

To prevent this pattern from recurring, Congress should provide a larger federal fire suppression budget. The present annual budget is approximately $400 million. Despite this sum, recent experience suggests that it may be insufficient, as suppression costs of more than $1 billion have occurred in three of the last four years prior to 2004. Accordingly, the president and the Congress should consider and develop more realistic budgets and multiyear funding, such as a trust fund or reserve account. Current-year fire suppression budgets could also be calculated by using a moving average of suppression costs for the previous five years. This strategy responds to trends in total area burned and associated costs, and is designed to produce a more realistic estimate of fire suppression costs. If present-year suppression costs are lower than an average of the previous five years, any unused resources could be saved to meet obligations incurred in future high-cost years. This would remove the need for future rescissions, that will help to ensure that critically needed fuel management projects move forward.

Fire suppression strategies, for reasons of effectiveness and efficiency, should recognize that each wildfire is different, and tailor strategies and tactics to the unique demands of each fire. Wildfires can be separated into general categories along a spectrum of size and complexity (Jerry Williams, personal communication). They range from the small initial attack fire to the enormous and complex megafire. During the last decade, approximately 97–99% of all wildland fires have been successfully suppressed during initial attack. The majority of these fires are less than 0.1 ha in size, and collectively, they burn a very small area.

The U.S. fire suppression system is designed to be very effective in initial attack operations because of spatially distributed suppression resources, excellent early firedetection ability, and appropriate tactics and training for these events. Fires that escape initial attack can be classified as "transition" or "extended-attack" fires. Current policy responds to such fires essentially the same as it does to an initial attack event. This strategy can produce dangerous situations because these fires can change behavior quickly due to the fact that they are actively growing and that they often burn under varying weather conditions. Among other things, the majority of firefighter fatalities in the last decade have occurred on these types of fires, which include the Storm King Mountain Fire (Colorado) in 1994 and the Thirtymile Fire (Washington) in 2002. Tactics could be revised to recognize that initial attack tactics are not safe and effective during changing fire conditions.

The largest fires, classified as "megafires" by public agencies, produce extreme fire behavior mainly because of severe fire weather and substantial accumulations of fuels. It is common for fire suppression agencies to a commit large amount of resources to fight these fires even though the probability of success is very low. In many cases fire managers continue to aggressively fight megafires because of public perception and liability concerns (e.g., you have to at least look like you are doing something or people and politicians will protest). Fire policy should be changed to reflect a more refined index of threats, potential harm, and possible effectiveness (Figure 8). This in turn would allow managers to take a defensive posture until conditions change. Suppression operations can be applied to the flanks of such fires but expending tens of millions of dollars during their peak burning periods cannot be justified. Congress will have to debate and approve this change in policy, because the federal land management agencies cannot implement this change without strong congressional support.

Summary of recommendations

Taken together, these recommendations would substantially change the course and conduct of national forest fire policy. The proposed changes are as follows:

- Restate the objectives of fuels management programs to be the reduction of potential fire behavior and effects.

Figure 8. Fire managers may continue to fight megafires because of public perception and liability concerns. National fire policy should be changed to reflect a more refined index of threats and potential harm—thus allowing managers to take a defensive posture until conditions change. © Karen Wattenmaker/kwphoto.com.

- Adopt policies and programs that are straightforward and pragmatic and also reflect awareness of and sensitivity to their environmental and social impacts.
- Improve the budgeting process for both fuels management and fire suppression to ensure funding sufficient to achieve overall and annual program objectives.
- Initiate a vigorous adaptive management program that utilizes a rigorous program of monitoring, experimentation, and research to improve fire and fuels management policies, strategies, and projects. Create a national accounting system to collect accurate information on the location, costs, and effectiveness of fuels treatments.
- Periodically evaluate particular strategies and progress toward the overall objective of reducing potential fire behavior and effects. Have independent scientific panels conduct the reviews, with the results and any recommendations transmitted to the government for consideration by the executive and legislative branches.
- Utilize and publicize the results of adaptive management to educate land managers, other agencies, elected officials, scientists, and the public.

A long-term commitment from the U.S. administration, Congress, governors, land-management agencies, tribes, and the public, is required to begin to reduce hazards and decrease the annual area burned by uncharacteristically severe wildfire. A reduction in megafires will probably only occur when fuels management projects have been installed in appropriate forest types at necessary spatial scales and arrangements. Managers cannot abandon areas of reduced fire hazards once they are created; they will have to be maintained into the future to remain effective.

Conclusion: policy and politics

Managing wildland fire in the United States has evolved considerably from the initial efforts of the USFS and other public agencies. The recent trajectory of wildland fire in the United States, however, reveals that the average annual area burned is increasing. Further, this increase is occurring despite a parallel rise in resources and funds utilized to manage fuels and suppress fire. Analysis of the effectiveness of various wildland fire policies indicates that despite scientific and widespread public concern, recent policy initiatives do not yet satisfactorily or comprehensively address certain significant and essential components of the issue.

Several recent programs, especially the National Fire Plan (USDA/USDI 2001), the Ten-Year Comprehensive Strategy (WGA 2001), and other initiatives, though perceived as essentially acceptable by federal managers, remain controversial. Individual site-specific projects, even at relatively small scales, are often problematic. More importantly, even if implemented as designed, the total effect of existing federal programs, including the Healthy Forest Restoration Act (HFRA 2003), remains a less-than-comprehensive approach to wildland fire. Other forces such as global climate change (Torn and Fried 1992; Karl 1998; Fried et al. 2004) may further complicate fire management. Climate change may lead to differences in plant distributions (Bachelet et al. 2001) and lightning frequency (Price and Rind 1994), which could increase ignitions and the length of fire seasons, further exacerbating wildfire effects.

Policy-making depends on technical and scientific information, but the choices made are inherently political ones. For this reason, even if a particular issue is relatively uncomplicated and the design of a solution may be easily understood, policy formulation is often complicated. Substantive objectives, such as fuel hazard reduction, must compete for legislative and administrative attention and resources with other worthwhile objectives and programs. Similarly, other forces can deflect the consideration of substantive objectives and priorities, even when they are supported by scientific and technical information. Budgetary concerns, for example, may override even the soundest programmatic proposals. The policy process generally responds to conflicting objectives by making choices about priorities and methods as it designs programs. Complicated arguments are often reduced to simple ones, in order to enact a program intended to address essential aspects of a particular issue. These aspects of legislative and policy processes may help those attempting to create new fire policy to further understand the gaps and shortcomings in the present policy environment.

The preceding review of wildland fire policies argues that despite recent legislative enhancements, the present amalgamation of polices remains inadequate and does not provide a comprehensive scientific framework to address the issues and problems of wildland fire. Refocusing federal and public agency efforts will require partial redirection of the missions of land management agencies. For this reason, the U.S. Congress, with the assistance of the National Academy of Sciences, should commission an independent and thorough review of wildland firefighting and fuels management objectives and strategies. The results will inform Congress and the public on the status and effectiveness of wildland fire polices and on continuing and emerging issues. The information is also likely to be useful to agencies who must ensure that their firefighting and fuels treatments strategies are effective and efficient, if for no other reasons than that they must protect public safety and maximize scarce resources. Finally, to the extent that the report confirms existing data that tend to suggest that current policies insufficiently pursue the objective of reducing fire severity, this information would provide additional support for legislative reforms to change the behavior of federal land management agencies.

The nature of the legislative and policy processes suggest that it will be difficult to successfully promote and enact major legislation to substantively reform and redirect existing fire policy. Despite recent intense attention focused on the issue in Congress in the aftermath of the fires of 2003, legislative support for the elements of the proposal will take time. While Congress's recent attention may be unlikely to extend to additional legislative initiatives, enactment of the HFRA clearly did not settle all of the outstanding fuel management issues and concerns. Indeed, budget and funding issues are likely to require on-going congressional attention (D. Bosworth, quoted in Berman [2004]). Further, even if the series of legislative and programmatic changes were enacted, the physical setting, natural variability, and large area of fuels accumulations and fire hazards that are already identified suggest that the successful implementation of such a program will require a substantial shift in agency behavior and priorities.

Many of the essential ingredients of a science-based national program are already being implemented at a variety of scales in disparate locations on federal and private lands, as small-to-medium scale fuels-management programs, research (e.g., the National Study of Fire and Fire Surrogate Treatments for Ecological Restoration), and management programs including on-going prescribed natural-fire areas (van Wagtendonk 1994; Rollins et al. 2001). Community-based efforts from the NFP are reducing fire hazards in the urban–wildland intermix using collaborative agreements. This offers an opportunity to observe the effectiveness of an overall approach aimed at reduction of potential fire severity. Employing these strategies with collaborative planning and adaptive management will point the way for a developing a science-based federal wildland policy. Experimentation and research (e.g., the Joint Fire Sciences Program) should be encouraged as tools to enable safer and more effective methods of addressing the problems caused by uncharacteristically severe forest fires.

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Fire, Ecosystems and People: A Preliminary Assessment of Fire as a Global Conservation Issue

Jeff Hardesty, Ron Myers, and Wendy Fulks

Ed. note: In 2002, The Nature Conservancy (TNC), WWF (World Wide Fund for Nature) and IUCN–The World Conservation Union formed the Global Fire Partnership and pledged to work together and with partners to address the causes and ecological and social consequences of altered fire regimes across the world. Most of the data used to develop this report were derived from a May 2004 experts' workshop convened by the partnership. Experts from six continents gathered in Sigrisvil, Switzerland, and conducted a rapid assessment of fire conditions across the earth's most biologically significant ecoregions. The data were compiled, analyzed, and summarized by TNC's Global Fire Initiative, which is responsible for this report and any errors herein. TNC published the initial document in October 2004. TNC has given permission to publish this version of their preliminary assessment in this issue of *The George Wright Forum.*

Ecosystems and people: living in a world of fire

FIRES ARE AS OLD AS THE EARTH ITSELF. For millions of years, fire has been, and continues to be, a major evolutionary force shaping the nature of life on earth.

Even in a rapidly modernizing world, fires are very common, whether naturally ignited by lightning or set intentionally or accidentally by people. Every day, somewhere on earth, thousands of hectares of forests, woodlands, savannas, grasslands, shrublands, tundra, deserts, wetlands and agricultural fields are burning, on every continent except Antarctica.

At present, scientists' best estimates suggest that, around the world, an area half the size of China burns in an average year.

Fire has many faces. For people and for ecosystems, fires can be harmful, beneficial, or benign, depending on where and how they burn. For thousands of years, human communities have benefited from fire and the burning of vegetation and other biomass to cook, heat, hunt, grow crops, manage vegetation, and produce energy. At the same time, fires can threaten human health and livelihoods.

From an ecological perspective, naturally ignited fires and fires started by people that reinforce natural fire cycles (Figure 1) are beneficial and life-sustaining in ecosystems that have evolved with fire. But fire can also be harmful, especially in ecosystems composed mainly of plants and animals lacking adaptations to withstand or take advantage of fire. Ecologically, human fire use is largely benign when restricted to agricultural fields.

Yet, ecologists believe that fires are behaving differently now than at any other time in history. Humans have become the primary source of ignitions, outstripping lightning and other natural sources. Human-induced global warming and changing patterns of rainfall and drought are likely already influencing the way

Figure 1. In fire-dependent ecosystems, prescribed fires, such as this one in the northeastern U.S., can be used to mimic natural fire and thereby achieve ecological objectives. © Jim Powers, Nantucket Inquirer and Mirror.

fires behave in many parts of the world. Coupled with other impacts like landscape fragmentation and the introduction of non-native plants that thrive on fire, ecosystems that have seldom experienced fire are burning. At the same time, in fire-dependent ecosystems that have been exposed to flames for hundreds of thousands of years, scientists believe there are fewer hectares burning now than in the past because people are directly and indirectly excluding fire.

A growing number of ecologists and conservationists believe that "altered fire regimes"—meaning too much, too little, or the wrong kind of fire—are a major threat to biodiversity conservation. They believe that if not given full due and integrated with other efforts, fires (or the lack of fires) have the potential to undo decades of progress in conservation and sustainable development. Fires and the impacts of altered fire regimes are often overlooked by conservationists for several reasons: alteration of fire regimes is almost always linked to other issues, like agriculture or forestry; alteration can be a slow and mostly hidden process, occurring incrementally and quietly over decades; and large fire outbreaks, which are episodic and largely uncontrollable, capture most of the attention and funding, which subside as the fires wane, and are largely focused on impacts on people.

A preliminary assessment of fire as a global conservation issue

Is fire a major conservation issue? A growing body of anecdotal and scientific evidence suggests that it is, but the science remains uneven. The global extent of the conservation threat is still largely undocumented. The United Nations and other bodies have made various attempts to assess the impact of fires on people and the capacity of nations to manage fire outbreaks, but none of these assessments to date have addressed biodiversity conservation and fire's changing role in the earth's ecosystems. This report is a first attempt to address the relationship between biodiversity and fires. Developed by TNC working in partnership with the WWF, IUCN, and scientists from around the world, this report provides a preliminary, coarse-scale assessment of the extent to which fire is beneficial or harmful, principally from an ecological perspective. It looks at critical ecoregions to estimate the degree to which ecologically uncharacteristic fire regimes may pose a threat to the conservation and sustainability of major habitat types, and it identifies the major sources and underlying causes of fire-related degradation. Finally, it identifies—at this point, broadly—roles for conservationists, local communities, governments and scientists.

Assessing fire: overview of methods

This initial assessment was conducted using a classification of the earth's 13 major terrestrial habitat types (Olson and Dinerstein 1998). Geographically, the assessment was performed on a subset of the WWF Global 200 ecoregions (Olson and Dinerstein 1998) plus additional ecoregions identified by TNC, that taken together, comprise some of the richest, most representative, rarest, and most distinctive examples of the earth's major habitats. Future versions of this assessment will include additional ecoregions.

Developing socially and ecologically acceptable and sustainable solutions to conservation problems depends on a sound understanding of ecosystem dynamics and human actions, including the role of fire. Understanding fire regimes is essential to determining whether and how human actions are beneficial, benign, or harmful from an ecological perspective. Ecosystems can be described in terms of typical fire regimes that operate within known or expected ranges of variation in key fire regime attributes or characteristics. Attributes include frequency (including the absence of fire), severity, intensity, spatial scale, seasonality, and predominant ignition source. Ecosystems and major habitat types can generally be classified as belonging to one of three broad fire regime types: fire-dependent/influenced (Figure 2), fire-sensitive, or fire-independent.

Figure 2. Fire is an essential process in fire-dependent/influenced ecosystems. Wildflowers and grasses thrive in a burned, fire-dependent lodgepole pine forest in Yellowstone National Park. National Park Service photo / Jim Peaco.

Fire regime alteration can be defined as the extent to which current patterns of fire have departed from the natural, historical, or ecologically acceptable ranges of variation in key fire regime attributes (e.g., fire frequency, severity) associated with and characteristic of different ecosystems. "Ecologically acceptable" fire regimes may be influenced by people, while still acting to maintain the associated plant and animal populations and ecological processes characteristic of a particular ecosystem (or major habitat type, in this assessment). Thus, altering key attributes of a fire regime is assumed to create current or long-term conditions that threaten the persistence of native plant and animal populations associated with that fire regime. From this perspective, altering one or more fire regime attributes stresses or degrades an ecosystem by significantly changing composition, structure, or function, which in turn can establish a trajectory toward a fundamentally different ecosystem type and fire regime. Evidence from a variety of ecosystems suggests that once a new trajectory is established, halting or reversing change can be very difficult or impossible.

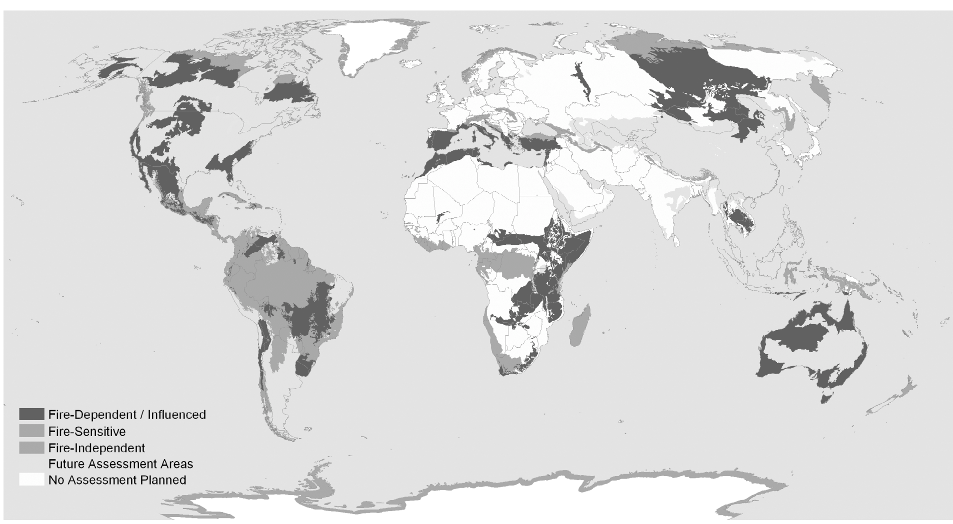
For each ecoregion and major habitat type, experts were asked to determine alteration by describing current fire regimes and the departure from an ecologically acceptable range of variation in key attributes. (Later iterations of this report will document the key attributes used in classifications and rankings, including a summary of related results.) Current status and trend were inferred by assessing how far key fire regime attributes have departed from what is considered to be ecologically acceptable and sustainable, and is the basis for identifying underlying causes and the human sources of altered fire regimes. This assessment will be updated as new and better information and data become available.

Fire regimes: the role of fire in ecosystems

Based on ecoregions assessed in this report, experts classified 46% of the global area of major habitat types as fire-dependent/influenced; 36% as fire-sensitive; and 18% as fire-independent (Figure 3).

In fire-dependent/influenced ecosystems, fires—either wildfires or fires set by people that mimic wildfires—are as fundamental to sustaining native plants and animals as are sunshine and rain. Many of the world's ecosystems, from the taiga forests of Siberia to the savannas of Brazil's Cerrado and the eucalyptus forests of Australia, have evolved with fires that occur within the bounds prescribed by annual and seasonal climates, vegetation types, lightning, fuel accumulation, topography, and a variety of other factors. Where ecosystems have evolved with fire, fires maintain a characteristic ecosystem structure and composition. Not all fire-dependent/influenced ecosystems burn the same way. For example, many forest, grassland, woodland, savanna, and wetland ecosystems are characterized by frequent, low-intensity surface fires that act to maintain an open structure with numerous grasses and forbs. On the other hand, some fire-dependent/influenced shrubland and forest types experience infrequent, intense, "stand-replacing" fires. What characterizes all of these ecosystems, though, is the resilience and recovery of their plants and animals following exposure to fires occurring within the range of variation characteristic of that ecosystem's fire regime type. In fact,

Figure 3. Priority ecoregions and dominant fire regions. Of important conservation ecoregions, experts estimated that 46% are predominantly composed of fire-dependent/influenced fire regimes, 36% are fire-sensitive, and 18% are fire-independent. Ecoregions almost always include multiple fire regime types, but were assigned to only one dominant type. © The Nature Conservancy: I. Levshina, Conservation Systems Office.



excluding fire often results in wholesale and ecologically and socially undesirable ecosystem changes. In some parts of the southwestern U.S., for example, fire exclusion has converted native grasslands important for both wildlife foraging and livestock grazing to closed canopy pine forests with few grasses, fueling very intense and damaging wildfires.

In fire-sensitive ecosystems, frequent, large, and intense fires were, until recently, rare events. In these ecosystems, most plants and animals lack adaptations that allow them to respond positively to, or rapidly rebound after, fire. These areas are typically cool or wet and consist of vegetation and an ecosystem structure that inhibits the start or spread of fire. Human-induced fires in a fire-sensitive ecosystem can influence long-term ecosystem structure and relative abundance of species, and/or limit an ecosystem's size. Examples of fire-sensitive ecosystems include the tropical moist broadleaf forests of the Amazon Basin (Figure 4), Southeast Asia, and the Congo Basin. These ecosystems are vulnerable to even mild fires that can trigger a cycle of more frequent and larger fires, leading to ecosystem conversion and creating conditions that favor fire-prone vegetation, including non-natives.

Figure 4. Many of the earth's tropical moist broadleaf forests, including those in the Amazon Basin, are vulnerable to fires. Initial low-intensity fires are followed by cycles of more fires of increasing severity. © Gustavo Gilabert/CORBIS SABA.

In fire-independent ecosystems, fire is largely absent because of a lack of vegetation or ignition sources, such as in Africa's Namibian Desert or tundra ecosystems on the coast of Antarctica.

Altered fire regimes: a preliminary estimate of status and trends

Experts concluded that some 84% of the area of ecoregions identified as being critical to biodiversity conservation and assessed in this report are at risk from altered fire regimes. In only 16% of these critical ecoregions (by area) was fire thought to be occurring within ecologically acceptable bounds (Figures 5–7).

Overall, fire-sensitive ecosystems—that is, ecosystems such as tropical moist broadleaf forests consisting primarily of plants and animals lacking adaptations to significant fire—were the most threatened, with more than 93% of the area judged as having altered fire regimes. Fire-dependent/influenced ecosystems—that is, ecosystems such as African savannas or boreal forests—while in relatively better condition, were still very much in trouble, with more than 77% of the area classified as having altered fire regimes.

Finally, although climate change was identified as a highly ranked threat in fire-dependent/influenced habitat types, the experts we consulted recommended that it be pursued separately, because of its complexity and scope. Thus, the impacts of climate change may be underestimated in this assessment and its ranking may change in future iterations of this report.

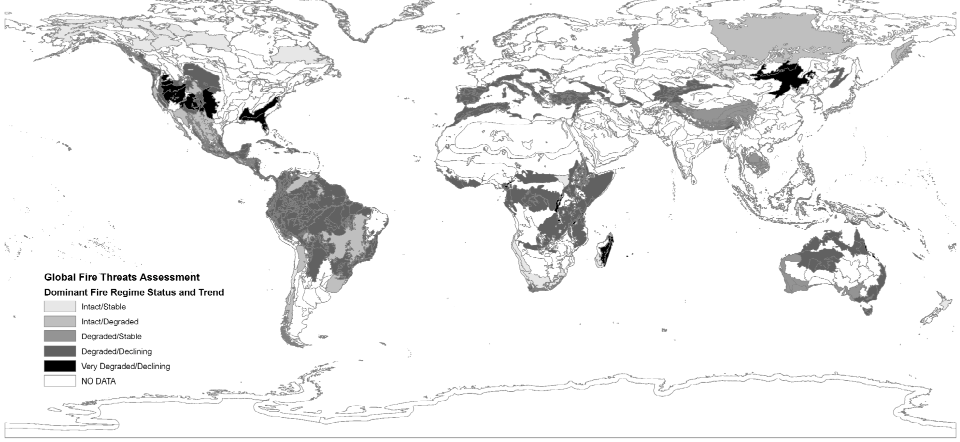


Figure 5. Current status and trends of fire regimes for major habitat types. They were derived by expert comparison of current fire regime attributes (e.g., fire frequency, severity) to ecologically acceptable regimes for that habitat type. © The Nature Conservancy: I. Levshina, Conservation Systems Office.

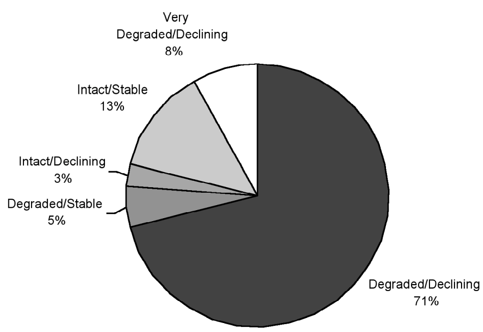


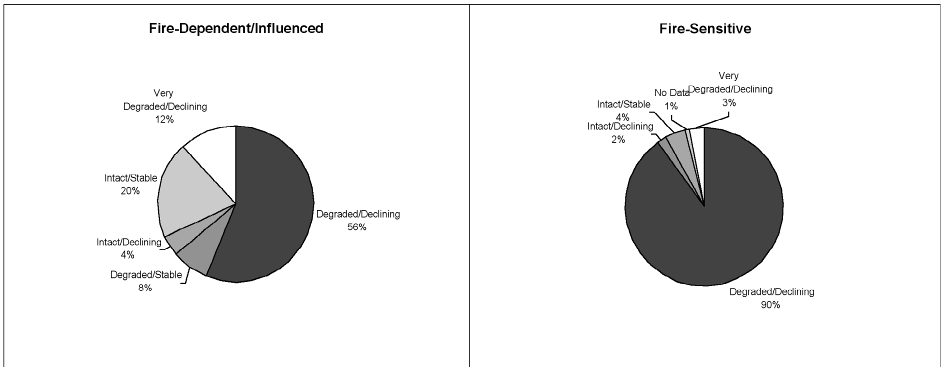
Figure 6. Fire regime status and trend for all terrestrial habitat types combined. A preliminary estimate of the overall status and trend of fire regimes indicates that an estimated 84% of major habitat types and ecoregions is degraded.

Sources of fire regime alteration

When fire ecologists review conservation and development plans, or the aftermath of catastrophic fire events, they are often puzzled as to why conservationists, local communities, and governments failed to integrate ecosystem fire dynamics in plans, or missed the warning signs of pending disasters. One answer, confirmed by this assessment, is that in many ecosystems fire regime alteration is a slow and incremental process, sometimes occurring over decades, and is often linked to multiple sources of degradation related to the many ways that people exploit ecosystems. Until some critical threshold is passed, change may not be noticed. Capturing the attention of the public and decision-makers often requires a triggering event, like a prolonged drought and uncharacteristically severe fires, even though by then it may be too late to avert catastrophic social and ecological consequences.

Understanding the linkages among alterations and sources of alteration is an essential step in identifying appropriate solutions. The sources of alteration identified by experts in this assessment were as different as grazing practices, climate change, and arson related to civil unrest.

In many fire-dependent/influenced ecosystems, experts identified declines in fire fre-



National Policies	11%	Forestry Practices	12%
Climate Change	11%	Rural Growth	11%
Grazing	9%	National Policies	11%
Rural Growth	9%	Fire Management Capacity (lack of)	10%
Arson	9%	Traditional Fire Use	10%
Fire Management Capacity (lack of)	8%	Illegal Forestry	9%
Crop Production	6%	Ecosystem Conversion	8%
Cultural Attitudes	6%	Arson	8%
Ecosystem Conversion	5%	Crop Production	8%
Invasive Species	4%	Climate Change	3%
Traditional Fire Use Cessation	3%	Other	11%
Mining, Oil, Gas Development	3%		
Fire Suppression	3%		
Urban Growth	3%		
Other	7%		

Figure 7. Status and trend of terrestrial habitat fire regimes and the major sources of alteration were estimated by experts. They considered the historical influence of people, including ecologically benign or beneficial uses of fire. Status was determined by the proportion of a given fire regime's key attributes (e.g., fire frequency, severity) that had departed from what experts judged to be ecologically acceptable.

quency and resulting fuel accumulation as the alterations that are causing uncharacteristically large, severe, and destructive wildfires, such as those now occurring in the western U.S. and southern Australia. In these two cases, the principal source of alteration is well-meaning national fire suppression policies aimed at protecting people, and which, in the U.S., is coupled with forest management and grazing practices.

Alternatively, in fire-dependent/influenced ecosystems fires also can be too frequent, such as those now occurring in Siberian taiga forests. Fire ignitions have increased as a result of rural population growth triggered by the decline of the Russian economy; the ecological result has been forest loss and declines in fire-dependent keystone species, such as larch, and the rapid liberation of millions of metric tons of stored carbon.

In fire-sensitive ecosystems, large, spectacular, and destructive outbreaks of fire tend to occur sporadically, such as those in Central America and Mexico's moist broadleaf forests in 1998 and 2000. These fires were triggered by large-scale logging, road-building, and increased human settlement in and near protected areas over time, coupled with a prolonged and severe El Niño-induced drought, which, in turn, was thought to have been exacerbated by global warming.

This assessment also indicates that the way that fire is directly used and managed by people—culturally and institutionally—is also a major influence, on par with other sources of alteration. For example, in fire-sensitive ecosystems, traditional fire use and escaped fires, combined with the lack of fire management capacity, was judged by experts to be just as significant a contributor to ecosystem degradation as the indirect fire impacts of legal and illegal forestry, which tend to capture much more attention.

A call to action: broad overview

Experts convened by TNC, WWF, and IUCN identified altered fire regimes as a major conservation issue, affecting an estimated 84% of the area of ecoregions recognized by conservationists, scientists, and many countries as being critical to global biodiversity conservation. This assessment reinforces the urgency of accounting for fire regimes when assessing threats and developing socially acceptable and ecologically appropriate conservation strategies. Durable solutions are not as simple as suppressing unwanted fires or allowing beneficial fires. Managing an ecologically and socially acceptable role for fire will require investing in science, finding common goals, creating innovative approaches, and building institutional resolve. Collaboration across government, private, academic and community sectors will be critical. As a starting point, we recommend the following.

For communities. This preliminary assessment of underlying causes identifies a critical role for local communities and people. Rural population growth and local land uses, such as grazing, agricultural practices, and traditional fire use, can be both major sources of alteration as well as of ecologically appropriate maintenance of both fire-dependent/influenced and fire-sensitive ecosystems. In all nations, effective and integrated community-based approaches need to empower local people and institutions by engaging them in documenting and understanding the fire-related dynamics of local ecosystems; establishing socially and ecologically acceptable goals for ecosystems; integrating cultural and economic issues; addressing underlying causes, not symptoms; reinforcing, modifying, or finding alternatives to traditional fire uses; and building the capacity to plan for and manage fires effectively.

For government. Government policy emerged as an important source of fire regime alteration, ranking first and second in fire-dependent/influenced and fire-sensitive ecosystems, respectively. Government policies are an indirect driver of many sources of fire alteration, including rural and urban growth, rural abandonment, legal and illegal logging, and ecosystem conversion. And agreements between governments, for example those dealing with climate change, are critical. Governments can ensure that laws and policies result in equitable sharing of costs and benefits related to fires, recognize community-use rights, and remove incentives that encourage industry and local people to start harmful fires or suppress ecologically beneficial fires. In many nations, government economic and social policies are key drivers of rural development and resource use, and in an increasing number of countries, government agencies are major players in fire management. Governments, industry, and other landowners will need to invest in fire management, educate resource managers, and assist in developing local capacity for effectively managing both unwanted and desired fires.

For scientists. Scientists have a critical role to play. Building the case for action at global, country, and local levels requires credible assessments of fire regime types and underlying causes of fire-related problems. As is evidenced by this report, many data gaps still exist. Often even basic information on the ecological role of fire, fire impacts, and the relationships among biodiversity, fire, and

Fire Facts

- In Ghana, 29% of the gazetted forest estate, or about 320,000 ha, has been deforested, principally due to repeated forest fires since 1983. A further 55% has been partially degraded. It is estimated that an amount equivalent to 2% of Ghana's potential gross domestic product (US$100 million) is lost annually to fires, significantly reducing funds that could have supported schooling, health services, and poverty reduction.
- The 1997–1998 fires in Southeast Asia burned more than 9.7 million ha, resulted in US$10 billion in economic losses, severely damaged many fire-sensitive tropical forests in protected areas, elevated Indonesia to the upper tier of global greenhouse gas producers, and affected the health of more than 100 million people.
- Large fires in the U.S. in 2000 resulted in property losses of more than US$9 billion and suppression costs of $3 billion. Scientists estimate that 51 million ha of U.S. federal lands containing fire-dependent ecosystems are undergoing major shifts in composition, structure, and function because of nearly a century of fire suppression, especially in the interior West. Unless actively restored through prescribed fire and increased natural fires, augmented by judicious forest thinning, many natural communities and species identified as targets for biodiversity conservation will be imperiled. In 2001, U.S. federal agencies treated less than 1% of the total acreage necessary to reverse these changes.

A Call to Action

Communities
- Adopt integrated ecological fire management
- Document fire-related ecosystem dynamics
- Evaluate traditional fire use
- Establish ecosystem goals
- Identify and address underlying causes of altered fire regimes
- Integrate cultural and economic issues
- Build fire management capacity

Governments
- Ensure equitable distribution of fire costs/benefits
- Recognize community-use rights
- Remove perverse incentives related to fire ignition and suppression
- Invest in fire science, management and education
- Build local and national fire management capacity

Scientists
- Conduct research to broaden understanding of fire regimes and biodiversity
- Elucidate causes of altered fire regimes
- Conduct monitoring at local, regional and global levels
- Investigate complex relationships among fire, climate change, land use, and invasive alien species
- Assess and predict ecological implications of proposed strategies

Figure 8. Fire-loving alien plants can drastically change the fire regimes of both fire-dependent and fire-sensitive ecosystems. Here, non-native cheatgrass *(Bromus tectorum)* is invading sagebrush steppe in the western U.S. © John Randall, TNC.

land uses is lacking. Investment in basic research and rapid assessments is essential. At present, no credible estimates of regional burned area are available, nor is it easy to infer from remotely sensed data whether individual fires are beneficial, harmful, or benign from either an ecological or social perspective. Understanding the complex interrelationships among fire, climate change, land use, and invasive alien species (Figure 8) will be critical in order to understand long-term trends and develop adaptive conservation and development strategies. Lastly, practitioners need tools that help them envision long-term and landscape-level alternative scenarios and outcomes.

To download this document, graphics and subsequent versions, go to http://nature.org/initiatives/fire/science. For more information on TNC's Global Fire Initiative, see http://nature.org/fire.

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