# Fire in the Parks: A Case Study for Change Management

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## 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

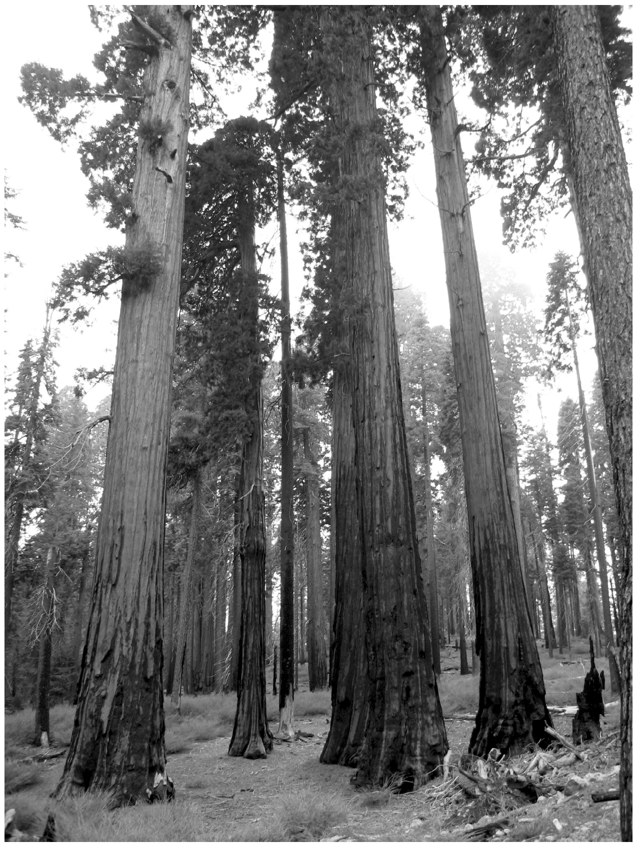

Figure 5. The aesthetic impact of occasional post-fire charring of giant sequoia bark was the most contentious issue in the prescribed burn program at Sequoia-Kings Canyon national parks. NPS photo by Tony Caprio.

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.

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 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.

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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