WILDERNESS AND HIGH INTENSITY FIRE: HOW MUCH IS ENOUGH

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During the summer of 1988, a complex of fires burned in excess of 1.4 million acres of the Greater Yellowstone Area. Nearly half of the Nation's oldest dedicated wilderness park was included within the perimeters of these fires. News reports depicted this event as a holocaust and special attention was called to the U.S. Park Service's so-called natural prescribed fire policy. Under this policy, naturally-ignited fires were allowed to burn within prescribed guidelines. Fires originating in this fashion and initially managed under this plan accounted for approximately half of the total burned area (Schullery 1989). To many commentators the stewards of this wilderness were guilty at the least of benign neglect and at the worst of playing God with fire (Bonnicksen 1989).

What was special about the 1988 fires? While Yellowstone burned, nearly 1.5 million hectors of wilderness burned in Alaska with virtually no public notice. Over the past century scores of similar-size fires have burned throughout the Western Cordillera (Pyne 1982). Indeed, much of the landscape northwest of the Greater Yellowstone Area burned in a fire of similar magnitude in 1910. Furthermore, dendrochronological research by Romme and Despain (1989) clearly indicates that fires of similar magnitude burned across the Yellowstone Plateau a mere 250 years ago.

The 1988 fires were unique because of the context in which they burned. Because they burned in one of the "crown jewels" of our national park system, they attracted media attention that gave the event the trappings of a celebrity scandal (Smith in press). More important to the issues discussed in this volume, these fires occurred on the heels of twenty-five years of largely unresolved discussion, debate, and transition in wilderness management philosophy. The events of 1988 make a thorough discussion of wilderness management issues in the context of high-intensity fire quite timely.

WILDERNESS MANAGEMENT OBJECTIVES

Explicitly or by default, wilderness managers must answer 3 general questions (Christensen 1988). 1) What should be preserved? 2) In what state should preserves be maintained? 3) How should management be done? I shall assert here that answers to each of these questions are conditioned by our views of the role of natural disturbance in ecosystems.

What Should Be Preserved?

This question must be address in both philosophical and practical terms. Managers must first determine the categories of items they wish to preserve (e.g., genotypes, populations, ecosystems, etc.). It is then necessary to determine which specific items within a category are worthy of preservation. Resources for designation of wilderness preserves will likely always be limited so that priorities must necessarily be assigned to such a shopping list.

In What State Should Preserves Be Maintained?

This is the central focus of the area of preserve design and includes such issues as size and boundary configuration and location. Given the extent of past, present, and potential future human alteration of nearly all landscapes, we must also decide what ecosystem or landscape states are acceptable within a preserve; i.e., what should it look like.

How Should Management Be Done?

I shall argue that constraints set by the manner in which questions 1 and 2 have been answered, coupled with the ubiquitous human influence on landscapes, make intervention on wilderness landscapes unavoidable. What sorts of interventions are proper?

MODELS OF NATURAL DISTURBANCE IN WILDERNESS ECOSYSTEMS AND ANSWERS TO MANAGEMENT QUESTIONS

The Classical Ecological Strawman

For the first half of this century management strategies with respect to natural disturbance were largely shaped by a theory of recovery of ecosystems from natural disturbance posited by Frederick Clements (1916, 1928, 1936). Although this theory has become a favorite strawman for ecologists interested in disturbance, it deserves attention here if only because of its impact on the way in which managers answered the above questions during its heyday.

In this model, succession following disturbance is viewed as a stepwise, directional process driven by competition and "biotic reaction" or environmental alteration by plants (Christensen 1988). Early invading pioneers alter the environment in such a manner that they cannot effectively compete with later invading species. This process of change continues until the site is occupied by a climax community of organisms that modifies their environment in such a way as to perpetuate themselves. Composition and structure of early successional communities was argued to be determined by local site conditions such as moisture status and soil resources. However, biotic reaction was alleged to decrease variability in starting conditions and within a given regional climate communities would converge to a single, climatically determined climax.

The climax community was reckoned to be the most stable possible community structure on a particular site (Clements 1936). Odum (1969) argued that successional trends towards climax include, among other things, increasing stability, species diversity, fertility, net primary production nutrient retention, and nutrient cycling efficiency. Large-scale disturbances such as fire were viewed as setting this process back and areas altered by chronic fire referred to as disclimaxes. It was implied that if fire could be excluded from such areas, they would succeed to the climatic "euclimax." Watt (1947) argued that disturbance plays a role in virtually all landscapes, but its spatial scale changes with succession. Large-scale disturbance such as fire may initiate successional change, but climax communities are maintained by small-scale events such as wind throw.

Much of the success of Clements' theory rested in the clear guidance it provided land managers. What should be preserved? Obviously climax communities should be important objects of preservation. Furthermore, because succession leads inexorably to particular climatic climaxes, a natural classification of such communities is possible. Nature has provided the shopping list. In what state should preserves be maintained? If the climax state is most stable, diverse, productive, etc., then it could be argued that would be most desirable state. Furthermore, if climax communities are maintained by disturbance processes operating on a relatively small scale, then the spatial design of a preserve matters relatively little in this regard. Finally, how should management be done? If disturbance deflects successional trajectories or is destabilizing, then it follows that disturbance should be excluded.

During the past two decades, virtually every tenet of the Clementsian model has been challenged (e.g., Drury and Nisbet 1973, Pickett 1976, Connell and Slatyer 1977, Egler 1977, and Peet and Christensen 1979). Most plant community ecologists agree that ecosystems vary continuously along environmental gradients, making clear definition of what ought to be preserved much more difficult. Furthermore we now know that successional change occurs by means of a diverse array of mechanisms (Connell et al. 1987) and that now a specific pattern of convergence or divergence is the rule (Christensen and Peet 1984, Pickett and McDonnell 1989).

A number of observations have led ecologists to reinterpret the role of natural disturbance in ecosystems. Even during Clements' time it had become clear that many organisms are not just simply resistant to fire, but possess features that make them dependent on fire. Celebrated examples include serotinous cones, heat stimulated germination, and postfire flowering. All of these adaptations seem to argue that fire had been an important natural selective force long before human alteration of fire cycle.

By the publication of the first proceedings of this conference, the potentially undesirable consequences of fire exclusion in wilderness ecosystems had become clear. In some cases, such as the sequoia-mixed conifer forests of California, fire suppression allowed invasion of a shade and fire tolerant species and inhibited successful reproduction of species of central preservation interests (Biswell 1963, Kilgore 1972, Harvey et al. 1980). In grasslands and savannahs, reduced fire frequency may diminish production and reduce species diversity (e.g., Walker and Peet 1983). In many shrublands, fire exclusion may not drastically alter species' relative abundances, but does lead to accumulation of dead debris.

Most important, it is now obvious that ecosystems do not necessarily become increasingly stable as succession proceeds. Indeed, in many fire-prone ecosystems just the opposite is the case. When decomposition does not keep steady pace with production, as in many arid or nutrient-limited systems, succession may lead to fuel accumulation and increased flammability. Invasion of shade tolerant species into forest understories may have the same consequences. Such invasion not only increases the likelihood of fire, but also alters fire behavior. Thus, in the 1960s, wilderness managers realized that well-intentioned policies had in some locations created "unnatural" tinder boxes.

The consequences of fire exclusion in western wildlands were summarized eloquently in the Leopold report (Leopold et al. 1963).

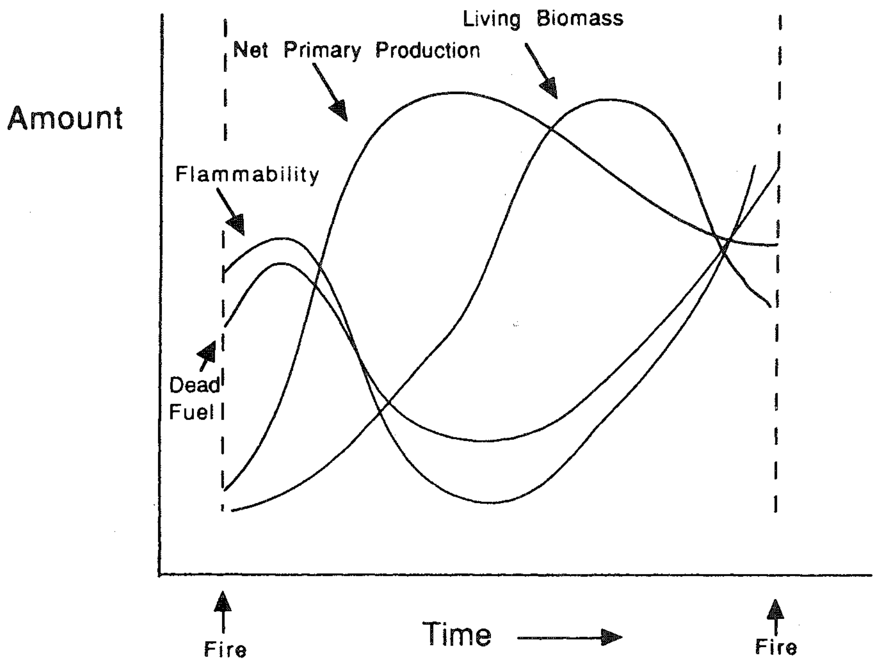
> When the forty-niners poured over the Sierra Nevada into California, those that kept diaries spoke almost to a man of the wide-spaced columns of mature trees that grew on the lower western slope in gigantic magnificence. Deer and bears were abundant. Today much of the west slope is a dog-hair thicket of young pines, white fir, incense cedar, and mature brush—a direct function of overprotection from natural ground fires. Within the four 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 animal life is meager, wildflowers are sparse, and to some at the vegetative tangle is depressing, not uplifting.

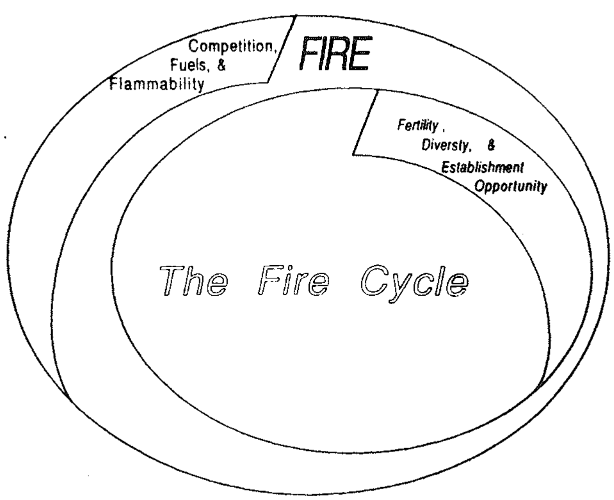
Pulse Stability—The Neoclassical Ecological Strawman

A central tenet of Clements' model was that controls on ecosystem structure become increasingly autogenic through succession and that climax communities could be viewed as highly self-regulated cybernetic systems. As it became accepted that natural disturbances such as fire were inevitable on many landscapes, it was suggested that control of such process might also be autogenic in some sense. If changes in an ecosystem increase the likelihood of a disturbance which in turn facilitates species regeneration, one could view the system as being "pulse stable" (Loucks 1970). Such a pulse stable system is illustrated in Figure 1 for a hypothetical shrubland ecosystem. The beauty of this model is that it allows us to retain the notion of stability in the context of disturbance. Except for me in my graduate student years, I am not aware of anyone really suggesting that fire cycles were this simple.

The fire cycle illustrated in Figure 1 puts this in tidy perspective. Conditions for successful reproduction of most plant species are most favorable

Figure 1. Changes in ecosystem features during the fire cycle. Flammability may be high immediately following a fire owing to residual fuels. Decomposition may lower fuel loads, however, accumulation as succession proceeds results in increased flammability. In such systems, patterns of production and diversity are often correlated with this cycle.





immediately following fire owing to increased fertility, removal of potential sources of allelochemicals, reduced competition, etc. Successional change makes conditions less favorable for reproduction but increases flammability. Mutch (1970) suggested that such situations might even select for plant characteristics that would improve flammability (but see Christensen 1985, Snyder 1984). With this view of the world, what should we preserve? Quite clearly the focus of our attention should be processes rather than structure per se. The goal cannot be to preserve a particular part of the cycle. Instead we should preserve the process, i.e., fire, that keeps it moving.

In what state should preserves be maintained? In the context of pulse-stable systems, preserve design is critical. Ideally, preserves should be sufficiently large to include a mosaic of stages in the fire cycle. This requires a reasonably good understanding of areal extent and frequency of fire. Certainly preserve boundaries should be placed with consideration to patterns of fire behavior.

How should management be done? Most wilderness management stewards agree that, where fire has played an important role, the fire cycle should be reproduced and maintained. The simplest and most naive strategy to accomplish this goal would simply be to "let it be," and assume that the resulting pattern of disturbance is natural. Hopefully, no judicious manager would accept liability for such a policy. Furthermore, given the extent of human activity on and alteration of most landscapes, we have no reason to believe that such a policy would necessarily restore natural fire cycles. Consequently, wilderness managers have adopted various combinations of two strategies of prescribed fire. The term prescribed fire is used here to refer to fires that are allowed to burn according to preestablished guidelines of behavior with a clear plan for containment or control. A natural-ignition prescribed fire program assumes that lightning or other ignition sources occur with sufficient frequency to maintain typical fire cycles. Resulting fires are monitored to see that they remain within prescriptions to prevent danger to life or property. Planned-ignition prescribed fire programs have been initiated where it is unlikely that natural ignitions will provide frequent enough fire, where liability risks are too great, or to restore fuels to loadings that are considered to be more "natural."

Patch Dynamics and the Complexity of Fire Regimes

The fire cycle paradigm provides an important pedagogical device for discussing the role of fire in ecosystems. However, in the simple form presented above, this model fails to capture several important characteristics and consequences of fire in wilderness landscapes that must be considered in fire management plan development.

Multiple Stable Points

In a simple computer model of ecosystem change in fire-prone ecosystems such as chaparral, jack pine forests, or Florida sand pine scrub, one might have a subroutine which burns the ecosystem when fuels accumulate to some particular loading. Some of the variability in fire frequency might be simulated if the likelihood of ignition was also conditioned by year-to-year variations in climatic conditions. It is now clear that such cycles are stable in some ecosystems only so long as this variability remains within certain bounds; that is, fires burning at sufficiently short or long intervals can result in changes in patterns of succession and subsequent fire behavior.

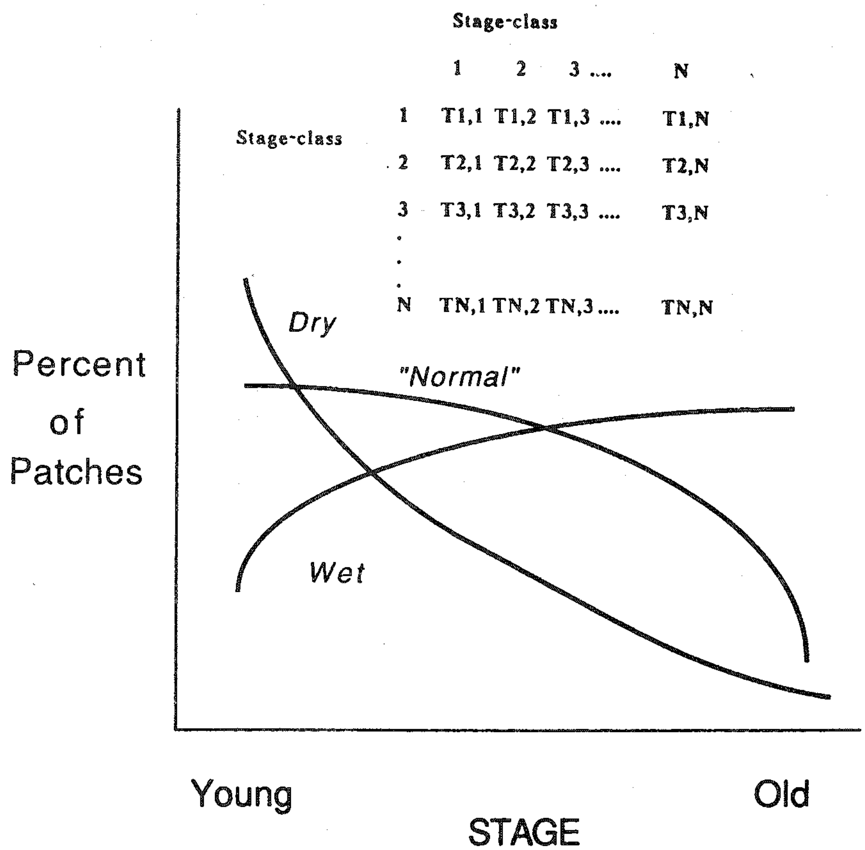
A classic example of such a situation involves the distribution of longleaf pine-wiregrass sandhill, sand pine scrub, and xeric hardwood hammock ecosystems in central Florida. Until recently, the distribution of such ecosystems was reckoned to be determined by soil variation (Laessle 1958, Christensen 1981). However, recent work by Kalisz and Stone (1984) and Myers (1985) indicates that the mosaic distribution of these ecosystem types is determined in large part by fire history. The savanna-like structure of sandhill vegetation favors frequent low-intensity fires. Climatic conditions that diminish ignition probabilities, such as a series of wetter-than-normal years, may favor invasion of sand pine scrub species. Such an invasion may diminish flammability even if climate returns to normal. Scrub favors and is maintained by less frequent (30-50 years), crown killing fires. Repeated fire can result in reestablishment of sandhill, whereas prolonged fire-free intervals favor succession to comparatively nonflammable hardwood hammock. Fuels in each of these ecosystem types tend to favor the fire cycle that maintains that type, but variation can result in successional change. Similar mechanisms have been proposed for vegetation mosaics in chaparral (Keeley and Keeley 1988) and southeastern wetlands (Kologiski 1977, Hamilton 1984).

Patch Dynamics

Landscapes can be viewed as a collection of patches undergoing successional change (Paine and Levin 1981, Pickett and White 1985). The character of such a landscape will be determined by the frequency, intensity, and spatial extent of disturbances creating patches, as well as the rate and nature of processes that result in patch succession.

In this model landscape dynamics might be modeled in terms of a demography of patches characterized by a matrix of transition probabilities (Figure 2). Patches in any particular state have some probability of being transformed by successional change or disturbance into some other state. Assuming these transition probabilities are fixed, the equilibrium frequency distribution of states on landscapes could be predicted with some relatively simple matrix algebra. One could argue that wilderness preserves should be sufficiently large so as to include a full complement of transitions. No one has suggested that such a model actually be used to guide wilderness preserve design, but it does serve as a useful device to discuss the complexity of patch dynamics on fire-prone landscapes and the management problems posed by such complexity.

Figure 2. A matrix of transition probabilities from one patch or state to other stages or states. The graph indicates the frequency distribution of states or stages on landscapes that might result as climate changes. See text for explanation.



First, the assumption that transition probabilities remain constant through time is clearly wrong. The likelihood of fires occurring depends on climatic conditions that vary on time scales from years to centuries. For example, such variation is clear in dendrochronological records for the giant sequoia (Swetnam in press). Where such change occurs the frequency distribution of landscape states shifts from time to time (Figure 2). Given the potential for future climate change owing to human activities, debates over the distribution of communities in the absence of human interference may be moot.

Transition models such as that depicted in Figure 2 assume a large number of patches on a very large landscape. As patch size begins to approach the scale of an entire landscape, frequency distributions of states may change in a periodic fashion. Such changes appear to characterize landscapes such as the Yellowstone Plateau (Romme and Despain 1989).

The actual transition probabilities in any particular patch depend heavily on the characteristics of surrounding patches, a fact recognized in most fire spread models (e.g. Rothermel 1972, Kessell 1976). Thus, a flammable old-growth forest patch is much less likely to burn if surrounded by nonflammable early succession vegetation. This problem is especially important where human activities have altered patterns of fire spread in ways that are not fully understood. The potential complexity of such neighborhood effects was demonstrated in the 1988 Yellowstone fires where variable weather altered the likelihood of the fire spread between patches on a daily basis. The structure and composition of adjacent patches also affects successional changes within a patch. For example, Myers (1985) found that fire exclusion resulted in succession of sandhill to sand pine scrub only if scrub vegetation was nearby to provide seed.

High-intensity fire creates ecologically important variation at nearly every spatial scale. The ecological impacts vary considerably among and within fires. Harvey et al. (1980) showed that variation in ash deposition at scales of 1 m greatly influence patterns of giant sequoia regeneration. The mosaic at scales of hundreds and thousands of meters is one of the most celebrated consequences of the 1988 Yellowstone fires.

From an evolutionary standpoint, variability in fire regimes may be more important than average properties. For example, Christensen and Wilbur (in manuscript) found that small scale variation in fire behavior in shrub bogs increased variation in limiting nutrients such as phosphorus. This variation was, in turn, highly correlated with patterns of species post-fire abundance. Christensen (1985) proposed that species diversity in many ecosystems may depend on such variation. Fires often generate significate, if ephemeral, redistribution of resources that may greatly influence patterns of seed germination and seedling success. Such patterns are clearly displayed in many plant communities long after resource pattern has returned to prefire conditions. Thus, the "regeneration niche" (Grubb 1977) may play a significant role in the diversity of many fire-prone plant communities.

FIRE REGIME COMPLEXITY AND MANAGEMENT

What Should We Preserve?

Fire behavior is clearly a landscape phenomenon. If we wish to preserve elements dependent on maintenance of fire regimes with the least amount of management intervention, we should attempt to preserve functional landscapes. Given that economic and political constraints often dictate preserve boundaries, our goal will necessarily focus on how to preserve critical processes within these constraints.

In What State Should Preserves Be Maintained?

As indicated above, preserve boundaries should be defined by the functional properties of landscapes that regulate critical processes. In the case of fire, preserve boundaries should coincide with landscape features that regulate fire behavior. Furthermore, in the best of all worlds preserves would be large enough to include the full range of diversity associated with the disturbance regime. The reality wilderness managers face is that most preserve designs were determined by political and economic considerations with little regard to meaningful ecological divides. Furthermore, few preserves are likely to be large enough to encompass the full range of natural disturbance-caused diversity.

There has been considerable recent discussion regarding the role of ecosystem restoration in the development of fire management protocols (cf. Bonnicksen 1989; Bonnicksen and Stone 1982, 1985; Christensen 1988; Parsons et al. 1986). In the extreme view, the Leopold committee's (1963) assertion that wilderness parks should provide a "vignette of primitive America" could be interpreted as a mandate to restore ecosystems to some particular past structure and composition. Because of nearly a century of fire exclusion, there has been considerable concern that fuels may have accumulated to "unnatural" amounts and that fires in such systems would be atypical. It has been argued that a program to restore ecosystem structure to a state typical of presuppression times is necessary before natural fire can be reintroduced in some ecosystems. Indeed, many national parks distinguish between fuel reduction burns in which special care is taken to prevent "abnormal" or extreme fire behaviors and fires prescribed to simulate natural fire conditions.

A knowledge of past ecosystem structures and their relation to fire is critical to formulating fire policy. Certainly, we cannot reproduce or simulate natural fire regimes with the understanding that data on the past provide. However, specific past ecosystems or landscape structures cannot be considered appropriate models for the future. Over the last several millennia most wilderness landscapes have undergone constant change and have never looked the same twice. The fact that frequent fires during a particular time created a certain frequency distribution of patch types does not justify a short return interval fire policy any more than climatically caused fire-free periods justify a century of fire exclusion.

The U. S. Department of Agriculture and Department of the Interior Interagency Fire Management Policy Review Team (1988) indicated that a major goal of wilderness policy was to "restore fire to a more natural ecological role. 'Naturalness' is defined as those dynamic processes and components which would likely exist today, and go on functioning, if technological humankind had not altered them." This may be a worthy goal, but given our current understanding of the chaotic nature of ecosystems processes, it would be incorrect to assume that there is some preordained structure or configuration that landscapes would attain in the absence of technological human intervention. Put another way, within the realm of what is natural using the above definitions, an infinite array of ecosystem states is possible. However, not all that is within this domain of naturalness will necessarily be acceptable given the constraints of preserve designed with little concern for the ecological issues discussed above. Add to this the additional constraints of "multiple use" and the inescapable if unpredictable impacts of humankind and I submit that a policy such as described above cannot be made operational.

Reference to "technological humankind" raises that issue of what role alteration of fire regimes by Native Americans should play in setting fire management policy. I feel that strong arguments can be made pro and con and wish only to mention here two difficulties inherent in including such burning in management plans. First, while acknowledging the important role of Indian-set fires in most North American landscapes, we know very little of the specifics of their impact on fire regimes. Thus, it is not clear how to include such burning in management plans. Second, use of fire by Native Americans as well as its consequences must surely have changed over the past ten millennia. We cannot begin to guess what the land management strategies of Native Americans would be today had technological humankind not intervened.

While I do not advocate a strict restorationist policy, our uncertainties regarding the past, present, or potential future states of wilderness landscapes do not excuse us from setting explicit operational management goals. We have not established wilderness preserves in order to manage fire. Put another way, fire cannot, in and of itself, be the desired end product of wilderness management. Rather, we should prescribe or withhold fire to accomplish specific management goals which will likely need to be articulated in terms of a range of acceptable landscape configurations. Monitoring programs focused on those goals are necessary in order to evaluate management effectiveness.

How Should Management Be Done?

It is generally accepted that prescribed fire programs represent the only viable option for managing fire in most wilderness preserves. Such programs may involve planned ignitions or may rely on natural ignitions. Each type of program has its advantages, but each also has potential flaws which must also be understood.

Planned-ignition prescribed fires allow managers to set the timing and spatial extent of burns in advance of the event. Where risks of liability are high or landscapes have been modified to such an extent that natural ignitions are unlikely to restore fire regimes, such programs are clearly preferred. However, four general issues must be considered in developing such a program. 1) Is it feasible? Rather vocal critics of the fire management policies of the agencies managing the Greater Yellowstone area suggested that the impacts of the 1988 fires could have been diminished had a judicious planned-ignition prescribed fire program been employed to reduce fuel loadings and create fuel breaks. Ignoring the question of whether such fuel management is a proper wilderness management goal, it is clear that the technology to execute planned-ignition programs in heavy fuels such as the lodgepole pine forests of the Yellowstone Plateau does not exist. Forests and shrublands subject to crown fire are notoriously difficult to ignite within assuredly safe prescriptions and virtually impossible to contain or control under conditions typical of when fires "naturally" occurred. 2) Are the environmental impacts acceptable? Where fires can be contained by natural divides or boundaries, fire management impacts may be minimal. However, where control depends on fire lines or active suppression, managers much weigh the costs of these activities in terms of wilderness values against their potential benefits. 3) Are planned-ignition fires "natural?" This question encompasses two categories of concerns. First, where historical management strategies have altered fuel conditions, fire behavior may be considerably different than that on pristine landscapes. In such situations managers may use fire as a restoration tool, but should not proceed under the illusion that such fires simulate the natural process. Special care or additional fuel manipulation may be necessary to minimize potential negative impacts of such fires. Second, and I believe more important, wilderness fire prescriptions should be consistent with the true character of the process we wish to simulate. Prescribed fire techniques have their origins in silviculture and wildfire control. In these contexts management goals usually include getting a complete, homogeneous burn as quickly as possible in order to minimize risks. Fire managers must be cognizant of the fact that natural disturbance processes are often heterogeneous and that such heterogeneity may be critical to the preservation of many wilderness elements. 4) What about spatial scale? It is implicit in many fire management programs that many small prescribed fires will have the same net ecological consequences as a single large fire. In truth, we know very little about the ecological trade-offs that are made as we change the spatial scale of management.

Natural-ignition prescribed fire programs have been most often used on large, unaltered landscapes where there is little reason to believe that likelihood of ignition has been altered by human activities and when natural features or climate tend to limit fire size. Prescriptions for such fires are generally set after the event has begun and usually include guidelines for containment or suppression should fire behavior exceed prescribed guidelines. Three general problems confront such programs on the context of wilderness management. 1) Is the knowledge base sufficient? The natural-ignition strategy in effect substitutes knowledge for intervention; it presumes we know enough about fire behavior to assume risks and set limits. This is true in some landscapes but was certainly not the case with regard to the 1988 Yellowstone fires. 2) When should natural-ignition fires be suppressed? We must acknowledge that, even when plans for suppression are in place, wilderness fires are not always controllable. At one extreme of fire behavior we can manage with great precision, at the other extreme of natural behavior we control fires about as well as we control hurricanes. A promise to contain fires when they reach some critical thresholds may in some cases be hollow. 3) How meaningful are prescriptions? By allowing only those natural ignitions that fit constrained prescriptions to persist, have we truly simulated the range of fire regimes necessary to achieve management goals?

SUMMARY

Wilderness is, in many ways, a uniquely New World concept. Our concepts of wilderness grew in parallel with our nineteenth century notions of frontier, the contrast of landscapes conquered by humans versus those free of human intervention. In the sense that management implies intervention and wilderness implies its absence, the phrase "wilderness management" is an oxymoron.

The fallacy is of course in the assertion that wilderness has, can, or should exist totally absent of human activities. No landscape is free of human impacts. Furthermore, some assert that exclusion of impacts such as burning by Native Americans may have undesirable wilderness consequences. We have chosen to preserve precious little of the world's wilderness. Furthermore, the borders we have defined for these preserves generally bear little relationship to the ecological processes such as fire necessary for their preservation. On such landscapes we have learned that not managing can be the most potent and unacceptable form of intervention. Indeed, we have created a world in which there is not such thing as not managing.

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