Evolution of the Natural Fire Management Program at Sequoia and Kings Canyon National Parks[1]

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ABSTRACT: The Sequoia and Kings Canyon National Parks' natural fire management program is the oldest of its kind in the United States. Past fire suppression practices had produced an unnatural accumulation of fuel, increasing the risk of high-intensity fires. Subsequent research showed fire was important to many park ecosystems and that fire could be reintroduced without harm under prescribed conditions. Each Park must define the goals of its natural fire management program, monitor its effectiveness, and continuously reevaluate goals, objectives, and methods.

INTRODUCTION

Fire has played a major role in shaping ecosystems of North America (Pyne 1982). In many areas, the presence or absence of fire controls vegetation succession, wildlife habitat, and nutrient cycles, as well as regulating biotic productivity, diversity, and stability (Heinselman 1978). It is now recognized that if examples of natural ecosystems are to be preserved it will be necessary to perpetuate fire as a natural process (Parsons 1981a). Because of fire's importance in preserving wilderness ecosystems, natural fire management programs have expanded greatly in the past 15 years. For example, lightning-caused fires are now allowed to burn in portions of 34 National Park or Forest Service areas (Kilgore 1982). Prescribed burning to reduce unnatural fuels so that lightning-caused fires can be allowed to burn is also used in some National Park Service natural areas.

To carry out any effective natural fire management program, it is first necessary to define the goals of the program. This might include protecting certain species, perpetuating a given scene or point in time or, as has evolved in recent years in National Park Service natural areas, perpetuating natural

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processes such as fire (McCool 1983)[2].

For example, in Sequoia and Kings Canyon National Parks the goal of the natural fire management program is to preserve or restore fire as a natural process where it does not threaten human safety m property or to escape from these Parks. This goal is accomplished by permitting natural fires to burn in certain areas and by substituting prescribed burning where the effects of fire suppression must be reversed or mitigated before natural fires can be alloved to burn. The emphasis is on preserving or restoring the dynamic character of the Parks' ecosystems, not on restoring a historic scene.

Before the program's goals can be implemented, a variety of ecological information must be collected so managers can fully understand the role and impact of natural fire. This information should include fire history and behavior as well as the effects of varying fire frequencies and intensities on ecosystems. An important use of these data is to assess changes in the role and behavior of fire caused by fire suppression and to aid the manager in deciding whether prescribed burning will be needed.

To be fully effective, a natural fire management program must also include monitoring to evaluate its effectiveness in achieving the stated goals (ideal ends or effects) and objectives (specific conditions that can be met). Natural fire management programs are dynamic and continually need refinement. By default or direct action, managers continually affect ecosystems' integrity, virtually always on the basis of less than complete informatian. New data, thoughtfully analyzed, can warrant program changes. The purpose of this paper is to review the evolution of the natural fire management program at Sequoia and Kings Canyon National Parks and the types of ecological information needed to develop, implement, and refine it.

PAST PRACTICES

Sequoia and Kings Canyon were the first national parks in the United States ta institute a natural fire management program that included natural ignitions and prescribed burning (Kilgore and Briggs 1972). To implement this complex program, information on the historical and ecological role of fire in the Parks was required. Today, after 15 years and some 236 prescribed natural fires (22,062 acres [8,932 ha]) and 107 prescribed burns (23,277 acres [9,424 ha]), information still is being collected to fully evaluate and refine the program.

Vegetation in Sequoia and Kings Canyon National Parks ranges from chaparral and oak woodlands at the lower elevations, through ponderosa pine, giant sequoia and mixed conifer forests at the middle elevations, to subalpine forests and barren rock at the higher elevations (Vankat 1982). Each of these communities has evolved under a specific combination of fire frequencies, intensities, and patterns, called a "fire regime" (Heinselman 1978). For example, chaparral is thought to have evolved with short-return-interval, stand-replacement fires; sequoia-mixed conifer and panderosa

[2] Editors' note: Please refer to the Foreword for comments on prescribed fire terminology.

pine forests with frequent, low-intensity surface fires; and subalpine forests with infrequent, low-intensity surface fires (Kilgore 1981).

In recent presettlement times, lightning-fire frequency was augmented by Indian burning in certain areas. Indians are thought to have burned for variaus reasons, such as increasing growth of food-producing plants and browse for wildlife (Vankat 1977). It is difficult to distinguish the effects of Indian fires from those of lightning fires on park ecosystems, although burning by Indians probably was more important in influencing ecological patterns than in developing specific adaptations to fire.

Following the displacement of the Indians in the 1860's, European settlers began to have a significant impact on the area. Extensive livestock grazing was accompanied by burning to increase forage. This burning, like Indian burning, probably increased fire frequency. Much of the settler burning was of unnaturally high frequency and intensity (Muir 1877). Such destructive fires eventually led to an era of fire exclusion.

The establishment of Sequoia and General Grant National Parks in 1890 called for the suppression of all fires; however, even in those early days of fire exclusion, concern was expressed over the increase of combustible fuels in the sequoia forests. To reduce the fuel hazard, an area was burned in General Grant National Park in 1904 (Wells 1906), and this became the first "prescribed burn" in the national park system. After this, a policy of fire prevention and suppression was established and remained in effect for the next 60 years.

Fire suppression resulted in an unnatural accumulation of fuel, particularly in the sequoia and mixed conifer furests; this accumulation reached a point at which the forest was threatened by fires of higher intensity than those to which it was adapted (Kilgore 1971a). The removal of fire also increased the density of fire-tolerant species such as white fir. The fire regime appeared to be changing from low to high intensity and from short to long return.

Severe wildfires in the Sierra Nevada in 1955 and 1960 demonstrated the potential of these dangerous fuels. These fires influenced the Leopold Report (Leopold and others 1963), which describes the importance of fire and other natural processes to the preservation of natural communities. As a result, the National Park Service shifted in 1967 to a policy that allowed natural fires and prescribed burning as well as suppression of wildfires.

EVOLUTION OF THE NATURAL FIRE MANAGEMENT PROGRAM

Early Research

The initial fire research in Sequoia and Kings Canyon focused on the importance of fire to the regeneration of giant sequoias. Beginning in 1964, plots were burned and various fire effects documented (Harvey and others 1980). Although 99 percent of the seedlings died within 2 years, the sequoia seedling survival was highest in the hottest burned areas, where fuels were cut and piled. Because other disturbance factors also tend to create a mosaic of vegetation types or successional states, Harvey and others (1980) concluded:

> *The implication of this pattern for management is that fire as a tool probably should not be applied evenly in a short period of time throughout a large area. Prescription fires should be applied in a patchy manner thus coming closest to re-establishing the primitive mixed conifer forest. The overall long term goal should be the establishment of conditions that would allow natural processes to operate unf.nterrupted in the ecosystem.*

Patchiness is the result of local variations in fire intensity. Based on Muir's (1909) description of a forest fire during early settlement times, Bonnicksen (1975) suggested that fuels were variably distributed and that flame lengths were generally less than 2 feet (0.6 m). In pockets of heavier fuels, however, 100- to 200-year-old sequoias were killed. Such information pravided valuable insight into the fire regime of sequoia-mixed conifer forests.

In the late 1960's reseatch into the natural role of fire grew in scope. Kilgore (197la, 1971h) conducted studies on the use and effects of prescribed burning in giant sequoia and red forests, using prescriptions adapted from Schimke and Green (1970) that produced low-intensity, controllable fires. These burns reduced dead and downed fuel, killed the understory, raised crown height, and initiated seed germination of conifers. They were also thought to approximate the effects of primeval natural fires. The former study developed into the prescribed burning program in the Parks' mixed conifer forests; the latter study paved the way for the creation of a "let burn" or natural fire management zone in the higher elevations (Kilgore and Briggs 1972).

In summary, the information that led to the initiation of both the natural fire management and prescribed burning programs included recognition that fire was important in maintaining many park ecosystems; certain ecosystems were adapted to such long fire cycles (more than 25-year return interval) or were so remote that fire suppression had not been important to them; and in many areas where suppression did result in i.ncreased fuels, fire could be reintroduced without harm under prescribed conditions that at least partially simulated natural fire.

Implementation

In 1968, nearly 75 percent of these Parks (basically the subalpine and alpine zones) was set aside as a "let burn" or natural fire management zone (Kilgore and Briggs 1972) . The only support of this strategy was observations that fires in subalpine forests behaved as primeval fires were believed to have burned: of generally low intensity with occasional torching of individual trees, or groups of trees, and no general crovn fires (Show and Kotok 1924; Kilgore 1971b; Weaver 1974). There appeared not to have been sufficient fuel buildup in the past 60 years to alter the natural fire regime.

Although subalpine stands of red fir and lodgepole pine can often be found growing in extensive stands of similar diameter, no attempt was made to determine if the subalpine forest fire regime of the Sierra Nevada is actually a "variable regime" type (Kilgore 1981), with both frequent, low-intensity fires and long-return, stand-replacing fires. Even if the area had such a regime, however, fire suppression vould not have had a major impact on the yatential role of fire. At vorst, it may have delayed fire’s catastrophic appearance in this century, as well as possibly increasing eventual fire size.

In contrast to the natural fire management program, the prescribed burning of sequoia-mixed conifer forests in the early 1970’s was hampered by a lack of a clearly defined goal. Neither the natural forest structure and dynamics nor the magnitude of change due to fire suppression were fully understood. Moreover, the question remained whether the Leopold Report (Leopold and others 1963) intended that ”natural” be defined as the ecosystem structure that was in place at the moment of arrival on the scene hy Europeans or as the general fire regime under which the comrnunities evolved. Is the goal to recreate the 19th century forest, a ”vignette of primitive America,” frozen in time or to create what ”would have been here” if fire suppression had not interfered? Or is it to restore the general fire regime and let natural processes determine the forest structure, even though the result may differ from the structure at the time of discovery? Is the role of the American Indian in the historic fire regime to be mimicked?

Such questions have appeared (Bonnicksen and Stone 1982a) and should be resolved, at least on the park level, before a natural fire management program is initiated. The program’s managers in the 1970’s focused on objectives rather than the goal and specifically on fuel reduction and white fir understory remaval; Briggs (1976) notes that prescriptions and firing techniques were developed to remove 70-100 percent of the dead and downed fuel. The early documentation of ”patchiness” was averlooked; homogeneity became the standard, White fir saplings and poles, whether occurring as a second tier under the mature canopy or as a yaung, codominant stand in an opening, were to be uniformly removed.

Prescribed burns conducted in the early to mid-1970’s attempted to meet these objectives. Monitoring was restricted to recording mortality and, occasionally, fuel loading. Prescribed burns were conducted in 30- to 50-acre (12 to 20-ha) blocks, using strip head fires and 15- to 20-person crews. Bonnicksen and Stone (1981) reemphasized to park managers that the presettlement mixed conifer forest was a network of small ”aggregations,” even-aged, codominant clumps of trees in an uneven-aged forest. The concept of even-aged ”aggregation” is not new. Cooper (1961) noted for ponderosa pine:

> *The mosaic pattern of the forest has developed under the influence of recurrent light fires. Each even-aged group springs up in an opening left by the death of a predecessor. (After remaining intact for 300 years or more, groups break up quite suddenly--often in less than 20 years.) The first fire that passes through consumes the dead trees, and leaves a good seedbed of ash and mineral soil, into which seed drifts from surrounding trees. Young ponderosa seedlings cannot withstand even a light surface fire, but in the newly seeded opening they are protected by the lack of dry pine needles to fuel such fires. Consequently the young stand escapes burning for the first few years. Eventually the saplings drop enough needles to support a light surface fire, which kills many smaller saplings but leaves most of the larger ones alive. As a group of trees grows taward maturity, new seedlings germinate beneath it.*

> *The volume of dry fuel dropped by the older trees, however, supports fires hot enaugh to eradicate the seedlings entirely. Fire and shade together prevent younger trees from developing; the even-aged character of the group is maintained throughout its life.*

Parsons and DeBenedetti (1979) observed that fire is a process that not only consumes fuel but also creates gaps in the forest, which are colonized by young conifers or shrubs. Thus fire suppression not only resulted in the frequently mentioned thickets of white fir understory but also allowed old, diseased, weak, and dead trees to remain standing, blocking the formation of new gaps and, therefore, of new seedling aggregations.

The work of Bonnicksen and Stone (1982a) is significant because it describes the structure of a sequoia-mixed conifer forest as it now exists and as it probably looked in 1890; the effects of fire suppression can be quantified and forest growth models can be generated to show the impacts of management actions. This work has led Sequoia and Kings Canyon Parks to examine the policy implications of the natural fire management program. Bonnicksen and Stone (1982b) suggest that the goal should be to recanstruct the forest structure as it was in 1890 (a curious choice, as that date follows several decades of settler burning) and only then allow natural fire to burn. They maintain that the present forest is deficient (relative to 1890) in seedling and sapling aggregations; overabundant in pole-sized aggregations, which germinated in unnaturally high numbers at the close of the 19th century due to fire exclusion; and that the poles should be removed with burning or mechanical means to increase the propartion of seedlings and sapling aggregations to 1890 levels.

The origin of the much-maligned pole-sized white fir aggregation is in question. Since pole-sized aggregations are, by definition, top tier, they germinated in openings that appeared about 100 years ago (Bonnicksen and Stone 1982a). If these openings were caused by, for example, cutting or burning by loggers, the Bonnicksen and Stone data document an artifact. If the openings are naturally derived, then there is nathing "unnatural" about them; the seedling aggregations of 1890 have aged to pole-size trees today, although fire would have thinned the stand somewhat. If there is an overabundance of any aggregations, it is of very old or dead trees that fire would have brought down and turned into seedbeds, and the truly unnatural white fir poles are those occurring as a secand tier. These, as Cooper (1961) noted, would have been vulnerable to fire.

Refinement

The early 1980's have seen a significant increase in the appreciation of what ecological information managers need to have and in what they can use as tools in a natural fire management program. Prescribed burning has become more a science than an art as predictive capabilities become more accurate. Rothermel's fire spread model (1972), Albini's nomograms (1976), and Deeming and others' (1977) fire danger rating system are useful tools for natural fire management. In the refinement phase, research enjoyed a new ascendancy; Kilgore and Taylor (1979) developed a fire history for a sequoia-mixed conifer forest, including not only frequency but fire size and intensity. They also expressed the importance of Indian fires in increasing the fire scar frequency. Expanded studies of this type are needed for other sequoia groves and other vegetation types.

Parsons (1978) examined fuel accumulation rates in giant sequoia and started fire research in the chaparral zone (Parsons 198lb; Rundel and Parsons 1979). The effects of natural fires were also documented by Greenlee and others (1979) and DeBenedetti and Parsons (1979). Data on fire characteristics, behavior, and effects began to be routinely collected on all prescribed burns. Firing techniques changed from strip headfires to spot ignitions, allowing fuel characteristics to determine intensity, and recognizing at last the importance of patchiness in Sierra mixed conifer forest dynamics. This information, along vith refined management objectives and strategies and more precisely defined responsibilities, is now part of the Parks' fire management plan (Bancroft and Partin 1979, revised 1984).

The basic reasons for the use of fire, and the ecosystem characteristics it is supposed to recreate or maintain, are only now being clearly defined. The opinions of "naturalness" have ranged from emphasis on ecosystem structure (for example, the suggestion by Bonnicksen and Stone [1982b] to recreate the structure of the 1890 forest and then allowing natural processes to function) to an emphasis on ecosystem dynamics. These Parks selectively use the whole spectrum, allowing natural fire where possible and prescribed burning to restore an approximation of the natural fire regime. In areas where natural fire is incompatible with public safety or some other constraint, prescribed burning in lieu of natural fire will be conducted to mimic the effects of natural fire. In specific "showcase" areas, historic structure will be maintained by artificial means.

Prescribed fire can be used to create any pattern of forest structure and function the manager desires; however, until the goals and objectives are clearly defined, its use must be conservative. The initiation of the natural fire and prescribed burning programs in these Parks was not supported by an adequate definitian of the goal. Since Park Service policy does not clearly define "natural," it is the responsibility of each park to define the goals of its natural fire management program. Thus, the program's refinement phase has involved natural fire management techniques, data collection, and redefinition of the goals and obj ectives of the programs.

THE FUTURE

The future of the natural fire management program in Sequoia and Kings Canyan National Parks will involve at least five important components:

1. Redefinition of the goal of the program and, in particular, definition of what is "natural."

2. Continuation of prescribed burning of hazardous fuels and the gradual inclusion of these burned areas into the natural fire management zone. Prescribed burning will be used in areas in which natural fire and public use are incompatihle and will mimic natural fire as much as possible. Detailed objectives for specific burns will be required.

3. Intensive surveillance of natural fires and accurate predictions of their behavior. As more of the Parks are placed under a natural fire strategy, the chances for accidents to the public by free-burning

fire increase.

4. Monitoring of the effectiveness of. prescribed fires in achieving stated objectives. This will involve an ecological monitoring program of fire behavior and effects on fuels and vegetation.

5. Continuous reevaluation of objectives and methods.

The goal of the natural fire management program is to restore or maintain the natural fire regime; this does not imply that the composition of the forest as first vieved by Europeans or as occurred at any given point in time will be precisely recreated or perpetuated, except in a few ”showcase” situations. The ecosystems are dynamic, ever changing communities. They are adapted to short-term fluctuations in climate and fire regime. A half-century of fire suppression probably has not had any lasting effect that is not within the range of perturbation previausly experienced. The focus is on function, not structure; consequently, much of the data collection will focus on fuels data that can be put into predictive fire behavior models.

Data also need to be collected on fire history and the effects of natural fire in communities included in the natural fire management zone. Such data will be used to write prescribed burning prescriptions in similar vegetation types that have been influenced by fire suppression. Future data collection will emphasize primeval fire behavior, present fire behavior without prescribed burning and, if prescribed burning is needed, the influence of prescribed burning on future fire behavior. Computer simulation of historical fire patterns, intensities, and frequencies will be helpful in these studies. The effects of natural fires must be quantified to act as guides, not only for a prescribed burn designed to mimic natural fire but also to give the park manager an appreciation of the full range of predictable intensities natural fires, some of which may be incompatible with public use. It is the responsibility of park manager to recreate and maintain an ecosystem in which fire can function in as nearly natura1 way as is possible without endangering human lives or property.

CONCLUSION

The most critical step of a natural fire management program is to define clearly the program’s goals Concurrently, an understanding of what is to be considered natural must be developed. This involves resolving the question of managing for ecosystem structure or dynamics, determining the importance of Indian fires, and characterizing the natural fire regime under which the ecosystem evolved. The third point is critical to safe operation of the program. High-intensity fire regimes increase the risk of costly escape fires such as the Ouzel fire in Rocky Mountain National Park and the Mack Lake fire in Michigan (Kilgore 1982). A natural fire management program is never ”let burn.” All fire allowed to burn must be prescribed and controlled, and an understanding of natural fire behavior will guide the formulation of adequate control measures.

Data collection in these Parks, therefore, emphasizes the documentation of fire’s role in ecosystem dynamics. Although investigations into the primeval structure of the ecosystem will shed light on fire’s natural role, the focus should not be on structure, which is the result of myriad ecosystem influences, of which fire is only one. If, however, a natural area is to be managed for the preservation of some natural process and ecosystem dynamics, care must be taken to ensure that the process still exists and can play its former role. Some parks, as Leopold (pers. comm) believes, ”are too small in area to relegate to the forces of nature that shaped a continent.” If the area that is now a park seldom received lightning strikes, having been burned by fires originating some distances away, it may never receive the fire its ecosystems need if management waits for a ”natural” or unscheduled fire.

Although it is apparent that professional natural resaurces management requires the most complete and accurate scientific information available, that information may be available only in imperfect form. Nonetheless, management decisions must be made, for even to do nothing is a course of action. Given our limited and imperfect information about forest structure, fire regimes, the role of Indians, and reasons to believe that long-term climatic variance has induced community structure changes far greater than those induced anthropogenically in the past century, we feel minimum intervention is the wisest and the most conservative management stratagy . Our program of maintaining and restoring the natural fire regime (with a few carefully defined exceptions) is part of a larger view of these Parks – an International Biosphere Reserve and a living laboratory of natural ecological processes.

REFERENCES

Albini, Frank A. Estimating wildfire behavior and effects. Gen. Tech. Rep. INT-30. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 92 p.

Bancroft, William L.; Partin, W. A. Fire management plan, Sequoia and Kings Canyon National Parks. Sequoia and Kings Canyon National Parks, Three Rivers CA: Resources Management Office; 1979. 190 p.

Bonnicksen, Thomas M. Spatial pattern and succession within a mixed conifer-giant sequoia forest ecosystem. Berkeley, CA: University of California; 1975. M.S. thesis.

Bonnicksen, Thomas M.; Stone, E. C. The giant sequoia-mixed conifer forest community characterized through pattern analysis as a mosaic of aggregations. For. Ecol. Manage. 3(4): 307-328; 1981.

Bonnicksen, Thomas M.; Stone, E. C. Reconstruction of a presettlement giant sequoia-mixed conifer forest community using the aggregation approach. Ecology. 63(4): 1134-1148; 1982a.

Bonnicksen, Thomas, M.; Stone, E. C. Managing vegetation within U.S. National Parks: a policy analysis. Environ. Manage. 6(2): 101-102, 109-122; 1982b.

Briggs, George. Resource management objectives, prescriptions, and special conditions relating to fall, 1976 prescribed burning. Sequoia and Kings Canyon National Parks, CA: Resources Management Office; 1976: 5.

Cooper, Charles F. The ecology of fire. Sci. Am. 204: 150-160; 1961.

DeBenedetti, Stephen H.; Parsons, D. J. Natural fire in subalpine meadows: a case description from the Sierra Nevada. J. For. 77(8): 477-479; 1979.

Deeming, John E.; Burgan, R. E.; Cohen, J. D. The National Fire-Danger Rating System--1978. Gen. Tech. Rep. INT-39. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 63 p.

Greenlee, Jason, M.; Villeponteaux, J.; Sheekey, E. A.; Omi, P. N.; Greenberg, R.; Rubel, M. K. Natural fire in the Sierra Nevada, California. Sequoia and Kings Canyon National Parks, CA: Resources Management Office; 1979. 60 p.

Harvey, H. T.; Shellhammer, H. S.; Stecker, R. E. Giant sequoia ecology. Washington, DC: U.S. Department of the Interior, National Park Service; 1980. 182 p.

Heinselman, Miron L. Fire in wilderness ecosystems. In: Hendee, John C.; Stankey, George H.; Lucas, Robert C., eds. Wilderness Management. Misc. Publ. 1365. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978: 248-278.

Kilgore, Bruce M. The role of fire in a giant sequoia-mixed conifer forest. Philadelphia, PA: American Association for the Advancement of Science; 1971a.

Kilgore, Bruce M. The role of fire in a giant sequoia-mixed conif.er forest. J. Quat. Res. 3(3): 496-513; 1971a.

Kilgore, Bruce N. The role of fire in managing red fir forests. Trans. M. Am. Wild. Nat. Conf. 36: 405-416; 1971b.

Kilgore, Bruce M. Fire in ecosystem distribution and structure: western forests and shrublands. In: Mooney, H. A.; Bonnicksen, T. M.; Lotan, J. E.; Chri.stensen, N. L.; Reiners, W. A., eds. Fire regimes and ecosystem properties: Proceedings; 1978 December 11-15; Honolulu, HI. Gen. Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981: 58-89.

Kilgore, Bruce M. Fire management programs in national parks and wilderness. In: Lotan, James F , ed. Fire--its field effects: Proceedings of the symposium; 1982 October 19-21; Jackson, WY. Missoula, MT: The Intermountain Fire Council; Pierre, SD: The Rocky Mountain Fire Council; 1983: 61-91.

Kilgore, Bruce M.; Briggs, G. S. Restoring fire to high elevation forests in California. J. For. 70(5): 266-271; 1972.

Kilgore, Bruce M.; Taylor, D. Fire history of a sequoia-mixed conifer forest. Ecology. 60: 129-142; 1979.

Leopold, A. Starker. Letter to Boyd Evison, Sequoia and Kings Canyon National Parks; 1983 June 9.

Leopold, A. Starker; Cain, S. A.; Cottam, C. M.; Gabrielson, I. N.; Kimball,.T. L. Study of wildlife problems in national parks. Trans North Am. Wildl. Nat. Resour. Conf. 28: 28-45; 1963.

McCool, Stephen F. The national parks in post-industrial America. West Wildl. 9(2): 14-19; 1983.

Muir, John. On the post-glacial history of *Sequoia gigantea.* Proc. Am. Assoc. Advance. Sci. 25; 1877.

Muir, John. Our national parks. Boston; New York: Houghton Mifflin; 1909. 382 p.

Parsons, David J. Fire and fuel accumulation in a giant sequoia forest. J. For. 76(2): 104-105; 1978.

Parsons, David J. The role of fire management in maintaining natural ecosystems. In: Mooney, H. A.; Bonnicksen, T. M.; Lotan, J. E.; Christensen, N. L.; Reiners, W. A., eds. Fire regimes and ecosystem properties: Proceedings; 1978 December 11-15; Honolulu, HI. Gen. Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981a: 469-488.

Parsons, David J. The historical role of fire in the foothill communities of Sequoia National Park. Madrono. 28(3): 111-120; 1981b.

Parsons, David J.; DeBenedetti, S. H. Impact of fire suppression on a mixed-conifer forest. For. Ecol. Manage. 2: 21-33; 1979.

Pyne, Stephen J. Fire in America: a cultural history of wildland and rural fire. Princeton, NJ: Princeton University Press; 1982. 654 p.

Rothermel, Richard C. A mathematical model for fire spread predictions in wildland fuels. Res. Pap. INT-115. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972. 40 p.

Rundel, Phil; Parsans, D. J. Structural changes in chamise *(Adenostoma fasciculatum)* along a fire-induced age gradient. J. Range Manage. 32: 462-466; 1979.

Schimke, Harry F..; Green, L. R. Prescribed fize for maintaining fuel-breaks in the central Sierra Nevada. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest

Forest and Range Experiment Station; 1970. 9 p.

Show, S. B.; Kotok, E. I. The role of fire in the California pine forests. Bull. 1294. Washington, DC: U. S. Department of Agriculture; 1924.

Vankat, John L. Fire and man in Sequoia National Park. Ann. Assoc. Am. Georg. 76: 17-27; 1977.

Vankat, John L. A gradient perspective on the vegetation of Sequoia National Park, California. Madrono. 29(3): 200-214; 1982.

Weaver, Harold. Effects of fire on temperate forests: western United States. In: Kozlowski, T. T.; Ahlgren, C. E., eds. Fire and ecosystems. San Francisco: Academic Press; 1974: 279-319.

Wells, A. J. Helping the Sierra Sequoias. Sunset Magazine. 16: 280-283; 1906.