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THE MAINTENANCE OF NATURAL ECOSYSTEMS: SMOKE AS A FACTOR

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Introduction

Recent symposia, including the present one, have focused on the emerging interest in the role of wildland fires in a variety of environments (12,26,27). White (31) noted that in moving into this environmental period the forest manager joins with all who seek harmonious use of land and water and plants in achieving a more subtle and more nearly permanent mode of stewardship. He enumerated some of the consequences of embarking into this new era in which technology ceases to be the principal reliance:

> A modified system of social assessment is required in sorting out the possible adjustments in managing fires. The aim then becomes maximum net social benefits rather than minimum monetary costs. A new set of consequences including changes in ecosystem diversity and esthetic enjoyment, must be identified but do not lend themselves readily to quantitative measurement. This effort places fresh demands upon investigation of natural processes, collection of basic data, methods of determining consumer preferences, and the distribution of benefits and costs among different sectors of society. Smoke must be weighed against visual landscapes and national wood products supply.

At the same symposium, Rappaport (21) argued that the problem of how we may live in harmony with our forests is the problem of controlling men's narrow and *linear* purposes so that they will not destroy the *circular* ecosystems to which they are bound. He indicated that if we are to live in harmony with our forests and other ecosystems, we must restore and maintain their circular ecological structure. We must understand the interrelationships among factors that contribute to ecosystem stability if we are to effectively maintain the circular structure of such systems (19,20,9). Such understanding is important to the successful management of the diverse systems found in national parks and wildernesses. Usage of "national park and wilderness" in the text refers to wilderness lands under the jurisdiction of both the National Park Service and the Forest Service.

White (31) called for a state of deepened knowledge and of genuine freedom from conventional modes of thought to achieve the wise management of fire. Jackson (13) admitted that in our conventional approach to ecology we have, perhaps, overemphasized the direct determination of vegetation by climate. He reported that general surveys of the distribution of major plant communities in Tasmania indicate that the many apparent anomalies to such a conventional view result from the failure to understand the interactions between such deflecting influences as fire and soil fertility on vegetation types. Not only does the vegetation, as determined by soil fertility and climate, affect the fire frequency but fire frequency affects the vegetation directly and indirectly (through changes it produces in soil fertility). Thus, Jackson described an elemental ecology of Tasmania based on fire, air, water, and earth. Similar fire-dependent relationships have been established for many biotic communities in the United States (7,1,30,11,8,15).

What does an elemental ecology that includes fire, air, water, and earth as basic processes mean to the management of national parks and wilderness ecosystems? The Congressional Act of 1916 which created the National Park Service stated one of the purposes of parks was "to conserve the scenery and the natural and historic objects and the wildlife 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." At that point in history, protection was an obvious management goal and the variety of park habitats was protected from wildfire. But, by 1963 the Leopold Committee posed some interesting questions to the Park Service:

> Today much of the west slope (of the Sierra Nevadas) 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 concern to the National Park Service.

One year later, in 1964, Congress passed the Wilderness Act which defined wilderness as an area of undeveloped Federal land retaining its primeval character and influence without permanent improvements or human habitation and managed so as to preserve its natural conditions. Wilderness was further defined as an area generally appearing to have been affected primarily by the forces of nature with the imprint of man's work substantially unnoticeable. In meeting these purposes, National Forest Wilderness resources are to be managed to promote, perpetuate, and where necessary, restore the wilderness character of the land and its specific values of solitude, physical and mental challenge, scientific study, inspiration, and primitive recreation. Thus, one of the objectives of wilderness management is to allow natural ecological succession to operate freely to the extent feasible (25).

How have the management directions posed by the Leopold Report and the Wilderness Act been achieved in national parks and wildernesses? The purpose of this paper is to describe specific fire management programs in Sequoia and Kings Canyon National Parks and the Selway-Bitterroot Wilderness that have the common objective of perpetuating natural ecosystems.

Fire Management Program in the Selway-Bitterroot Wilderness

Background

The White Cap Study in the Selway-Bitterroot Wilderness of northern Idaho was designed in 1970 to provide valid methods for the development of fire management prescriptions (2,3). This study was the outgrowth of a Wilderness Workshop that had, in effect, recommended a new policy that "fire be allowed to more nearly play its natural role" in the wildernesses of Idaho and Montana. The key to implementing this new role for fire in wilderness today is based on the preparation and approval of preplanned prescriptions.

At this workshop strict fire control was recognized as an unnatural action in wilderness. This recognition was based on the passages from the Wilderness Act cited earlier. However, Special Provisions of the Act state that "such measures may be taken as may be necessary in the control of fire, insects, and diseases, subject to such conditions as the Secretary deems desirable." Necessary has been defined as "needed for meeting the wilderness definition and for protecting life and property in the wilderness or resources outside."

The White Cap Study

The 100-square-mile area selected for intensive study was in the southern end of the Selway-Bitterroot Wilderness on the West Fork District of the Bitterroot National Forest. The Bad Luck and White Cap Drainages were chosen for this study because they represent a diversity of plant communities and landforms. The fire suppression history of these drainages provided an excellent outdoor laboratory for studying effects of suppression on fuels and plant communities. There have been 212 fires over a 45-year period. Fire suppression efforts have been effective; 154 fires were suppressed at 1/4 acre or less in size. Fifty-eight fires over 1/4 acre in size burned 1,247 acres, for an average of 21 acres per fire.

Objectives of the study were to:

1. Develop inventory methods that relate fire management to the wilderness resource.

2. Determine relationships between fire and wilderness ecosystems.

3. Determine strategies for a more natural incidence of fire in wilderness.

Specific components of the study included fire history, fuel inventory and appraisal, plant community dynamics, landforms, soils, and fisheries.

The Fire Management Plan

Based on study results, 18 land types and 15 habitat types were identified and combined into five ecological land units (or fire management zones): (1) shrubfield, (2) ponderosa pine savanna, (3) ponderosa pine/Douglas-fir, (4) north slope communities, and (5) subalpine. These zones are recognizable subdivisions of the landscape that are ecologically equivalent in terms of topography, vegetation, fuels, and fire potential. Ecological land units have been defined as linkages between vegetation and land systems, providing the opportunity for interdisciplinary communication about ecosystems and their management (6). These perceivable units of the landscape permit the prediction of function and response to management activities.

The ecological land unit description is a labeling process that permits us to subdivide landscapes into different potentials for vegetation, fuels, and fire and also serves as a frame of reference for extending knowledge and prescriptions to other planning units. The final prescriptions reflect the differences observed in the data base for each of the land units (Table 1). As prescriptions were completed, the units were termed fire management zones. The Fire Management Plan was approved by the Chief of the Forest Service in August 1972.

Wilderness Management Fires

A lightning-caused fire on August 18, 1972, in the shrubfield zone was the first fire to be handled under the new prescriptions. The fire occurred on a 65% south slope at an elevation of 4,100 feet. Four days later the aerial patrol reported that the fire had gone out naturally; final size was approximately 24 by 24 feet.

The 1973 fire season in the Pacific Northwest was another story. Extremely dry conditions contributed to accelerated burning rates in many areas. Extended summer droughts were the rule at most locations, but June-July precipitation in the southern portion of the Selway-Bitterroot Wilderness maintained the White Cap Fire Management Area at a lower fire danger level (Table 2). The total number of fires occurring in the White Cap Fire Management Area in 1973 and the action taken are presented in Table 3.

A thunderstorm on the morning of August 10 ignited fuels in the ponderosa pine savanna fire management zone. Prescriptions called for this fire, the Fitz Creek Fire, to be observed; and to prevent the spread of the fire into the ponderosa pine/Douglas-fir zone below an elevation of 4,500 feet. Suppression action was taken, starting on August 13, to contain the east flank of the fire within the pine savanna on this side. The remainder of the fire was permitted to burn naturally. The Fitz Creek Fire burned for 43 days in the ponderosa pine savanna, shrubfield, and a small portion of the ponderosa pine/Douglas-fir zone. The final size of the fire on September 21 was 1,200 acres.

On the afternoon of August 15, the Fitz Creek Fire apparently spread south of White Cap Creek. This fire was called the Snake Creek Fire to distinguish it from the Fitz Creek Fire and to avoid confusion in radio communications and fiscal accounting. The Snake Creek Fire burned 1,600 acres and was controlled on August 21. It was suppressed because it was outside the approved area for the fire management plan.

Wilderness Fire Management and Smoke

There are no easy solutions to wilderness management. Stankey (23) has indicated that the very term *wilderness management* "is in many ways a paradoxical term, for wilderness connotes an image of a landscape untouched and an opportunity for free and unconfined use, while management suggests control and planned direction. It is perhaps because of the inherently contradictory nature of the term that wilderness management is one of the more challenging and difficult tasks facing resource managers today."

Some argue that a fire should be permitted to burn in a completely unconfined manner in wilderness. Then, when fires escape outside wilderness, the public would support a return to the policy of complete suppression. This seems to be a negative approach with ill-conceived consequences. Stankey (23) again makes the pertinent observation that "although the wilderness experience is typified as free and spontaneous and the physical environment in which it takes place as wild and natural, there is considerable evidence that opportunities for such experiences might gradually disappear without some managerial controls. The issue is not whether management action is needed, but what the specific nature of the management goal should be."

The specific management goal for fire in wilderness is that fire should play a more nearly natural role in the perpetuation of ecosystems. The term "more nearly" indicates that management constraints are considered for a variety of reasons (*e.g.*, human safety, property, or undesired fire effects outside wilderness). The White Cap Fire Management Plan (3) recognized three major outside factors that might be influenced by wilderness fires:

1. the anadromous fishery of the Selway River,

2. air quality, and

3. adjacent non-wilderness management units.

Wilderness fires will obviously result in smoke plumes within wilderness and beyond wilderness boundaries. This production of smoke is just as inevitable as the occurrence of fires in the environment of the Northern Rocky Mountains and elsewhere. The success of wilderness fire management programs will depend largely on the public's understanding of wildland smoke, as well as fire, as a part of natural systems. Much time was spent during the course of the White Cap Study with other Government agencies, conservation groups, schools, and individuals regarding the role of fire (and presence of smoke) in wildland ecosystems.

What were the specific smoke factors related to the fire management program in the Selway-Bitterroot Wilderness during the summer of 1973--a summer characterized by dry weather, numerous fires, and considerable smoke in the Pacific Northwest? The two fires in the subalpine zone (Table 3) were self-extinguishing in a short time span due to sparse ground fuels and they produced little smoke. The Fitz Creek Fire, however, burned over a period of 43 days with smoke production controlled largely by changes in fire weather (Fig. 1). Smoke containment was controlled primarily by the frequent occurrence of an inversion condition in the drainage (Fig. 2). Down-canyon air drainage, combined with the inversion, accounted for observation of the smoke plume during morning hours at least 10 miles down the Selway River from the mouth of White Cap Creek. On the morning of August 15, the slope south of White Cap Creek was not visible from the vicinity of Bad Luck Lookout, a distance of one airmile. This condition was repeated on several other mornings. Surface heating dissipated the inversion between noon and 2:00 p.m. The onset of this afternoon instability (and prevailing southwesterly winds) produced a smoke plume that on several occasions was visible over the Bitterroot Valley, about 28 airmiles east of the fire.

Precipitation that occurred during the 43 days that the Fitz Creek Fire burned slowed the burning rate and cleansed the atmosphere of particulate matter. For example, on Labor Day only one small smoke was observed from the entire Fitz Creek Fire (this followed 0.69 inch of precipitation on August 31). But a few days later, as a dry airmass again dominated the area, the fire picked up and burned another 50 acres. It is important to recognize that there was not a constant rate of smoke production during the 43 days that the Fitz Creek Fire burned. The rate of smoke production was as variable as the behavior of the fire, with the smoke and fire imprinting the atmosphere and the plant communities with a mosaic of treatment patterns.

Effects of Smoke on the Living Community

Little is known about the effects of wildland smoke on the life processes of organisms, although the personal communication from Dr. John Parmeter cited by Biswell (5) raises a host of questions.

Parmeter demonstrated that the germination of spores of several rusts and fungi is inhibited on substrates exposed to smoke from burning pine needles. One of the questions early in this paper emphasized the need to experimentally determine the biological significance of smoke on plants and animals. Perhaps naturally occurring fires in wilderness will provide one basis for studying such interactions.

Deer, elk, and black bears were observed within the perimeter of the fire while the fire was still burning. Large numbers of grouse were also seen within the burned area almost daily, sometimes under quite smoky conditions (Fig. 3). Some of the grouse apparently were feeding on seed heads of grass in the ashes.

During the 43-day history of the Fitz Creek Fire, human encounters with smoke were numerous, including backpackers, trail riders on an American Forestry Association trip, resident landowners in the Selway-Bitterroot, campers, big game hunters, guests at a wilderness ranch, and residents of the Bitterroot Valley. Two backpackers from Louisville, Kentucky, were met one evening as fire burned on both sides of the White Cap Trail. They had been hiking for 15 miles that day in smoke, returning from a trip to the upper portion of the White Cap Drainage. They indicated that when they reached the fire area, they were on the lookout for falling rocks and trees but were not unduly concerned about fire. The two hikers responded favorably to an explanation of the wilderness fire management program. One of the landowners in the Selway-Bitterroot Wilderness expressed concern over the obscuration "of a favorite view" by smoke for several days but was supportive of the overall program. When concern arises over the role of fire in wilderness, as it did on two occasions, this concern does provide a focal point for further interchange of ideas on the wilderness resource and the alternatives available for its management.

A large majority of the letters received from groups and individuals during and following the fires in the Selway-Bitterroot Wilderness favored the concept of wilderness fire management. A typical letter to the Regional Forester in Missoula stated that:

> Efforts by the Forest Service and others in this tinder-dry year to extinguish the innumerable forest fires in the Northwest have been valiant, and certainly all persons involved in this effort should be commended.
>
> However, fire in the forest is not unequivocally evil. Forests got along quite well during the millions of years when there were fires and no firefighters to put them out. Fire is obviously part of the ecology of the forest.
>
> I understand that in some wilderness and *de facto* wilderness areas the Forest Service has allowed some fires to burn out naturally. This would seem to me to be an especially wise policy as far as encouraging the regeneration of elk browse in designated wilderness areas.

Fire Management Programs in Sequoia and Kings Canyon National Parks

Sequoia and Kings Canyon National Parks have two fire management programs: (1) Prescribed burning in the generally lower elevation forests between approximately 4,500 feet and 7,000 feet elevation, and (2) a zone generally above 8,000 or 9,000 feet elevation through timberline where naturally occurring fires (*i.e.*, lightning-caused) are allowed to run their course without suppression. A strict monitoring of these fires and a plan to suppress them if required are part of the latter program. All man-caused fires in the Parks are suppressed. A summary of conditions, research and policy behind the establishment of the above programs, with their results through the 1971 fire season, was published by Kilgore and Briggs (16).

In 1963, the Leopold Report (17) recommended restoring park forests to pre-European-man conditions with emphasis on more openness. The report indicated, "Much of the west slope (of the Sierra) is a dog-hair thicket of young pines, white fir, incense cedar, and mature brush--a direct function of overprotection from natural ground fires...A reasonable illusion of primitive America could be recreated, using the utmost in skill, judgment, and ecologic sensitivity." In effect, the Leopold Report summarized what had long been apparent to many, including professionals in fire control with extensive experience in fire behavior; scientists involved with research on wildfire and its effects on forest vegetation; and many others who, though not involved professionally in the management of natural resources, were nevertheless astute observers of nature's ways. The galvanic effect of the Leopold Report was evidenced by a change in National Park Service Policy (29) relating to fire which states:

> The presence or absence of natural fire within a given habitat is recognized as one of the ecological factors contributing to the perpetuation of plants and animals native to that habitat. "Natural fires" are recognized as natural phenomena and may be allowed to run their course when such burning can be contained within predetermined fire management units and when such burning will contribute to the accomplishment of approved vegetation and/or wildlife management objectives.
>
> Prescribed burning to achieve approved vegetation and/or wildlife management objectives may be employed as a substitute for natural fire.

As early as 1965, experimental prescribed burning was undertaken in the Redwood Mountain Grove of giant sequoias in Kings Canyon National Park. Objectives included abating the fire hazard through removal of accumulated fuels and, through this process, returning the area to the pristine condition required for natural regeneration and perpetuation of sequoia groves. Prescribed burning, of course, is not a new idea; it has long been used as a tool in forest management in many areas. However, using it to restore pristine conditions was new.

During the same year (1965) a "Report of Backcountry Conditions and Resources with Management Recommendations for Yosemite National Park"* recommended "departure from the policy of suppressing all fires when reconnaissance and evaluation show a fire is contained by natural fire-breaks, where there is little fuel, and where no damage will result." Although this recommendation did not become policy until 1972, one such fire was permitted to burn naturally in 1965 with only minor control action.

Allowing naturally occurring lightning fires to run their course was a new concept in land management. Undoubtedly small isolated lightning fires occasionally had been allowed to burn out without suppression, but the manager was taking considerable chances in the event such a fire burned beyond his expectations, because past fire policy had required complete and immediate suppression of all fires without exception.

In 1968, Sequoia and Kings Canyon National Parks experimented with allowing lightning fires to burn naturally in the Middle Fork Drainage of the Kings River within Kings Canyon National Park. In 1970, a Naturally Occurring High Elevation Fire Management Zone was established, which included the Middle Fork Drainage (16). Expanded in 1971 and 1972, this zone currently includes nearly 71% of the area within these two parks. Generally, the zone boundary has been set between the 8,000 and 9,000 foot elevation; however, fuel types, exposure, zone configuration, and other factors are also considered.

The ultimate objective of the fire management programs within Sequoia and Kings Canyon National Parks is to allow naturally occurring fire to play its primeval role as a determinator of ecosystems. If all natural fires could be allowed to burn, nature would indeed be playing its natural role. This process has already begun in the high elevation fire management zone.

At lower elevations, strict fire suppression policies over many years have contributed to an immense buildup of fuels on the forest floor and a thick, rank growth of understory trees.**The first fire management action in these areas was prescribed burning to eliminate the fire hazard posed by such accumulated fuels. The program has been limited in scale; however, we have had good success (14,15). Satisfactory burning prescriptions, adapted from those developed by Harry Schimke of the USDA Forest Service, have been worked out. Recently, some funds to carry out this important work have been allocated on an emergency basis out of Park Service reserves. Currently, a project request for continuing funds is number one on the Parks' priority list for new funding.

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* Unpublished report by G. S. Briggs, National Park Service.

** J. L. Vankat. Vegetation change in Sequoia National Park, California. Unpublished Ph.D. dissertation, University of California, Davis. 1970.

The Parks have found that prescribed burn units can be established and burned to eliminate the majority of the smaller understory and to remove accumulated dead and down forest litter of all types. The cost is approximately $25 per acre in a mixed conifer forest. The procedure is to allow fire to do the whole job. Except for some snag falling and, of course, line construction, no other manipulation of the vegetation cover is required prior to burning. Most of the prescribed burning effort has been confined to the Redwood Mountain Grove of giant sequoias in Kings Canyon National Park (Fig. 4). Since 1969, some 400 to 500 acres have been burned under carefully controlled prescriptive conditions. Much of what has been done so far is on or near the exterior boundaries of the Grove on defensible ridge lines. Within the next two years, as the exterior boundaries are secured, larger blocks can be burned which will reduce cost per acre and increase the acreage burned.

In the high elevation fire zone since 1968, 80 naturally occurring fires have been allowed to burn (Fig. 5). Generally, the fires remain small. Three have required some action to keep them within the zone or to protect visitors. Of the 80 fires occurring since 1968, 80% have been smaller than 1/4 acre. There have only been four fires larger than 300 acres, 5% of all fires--one occurred in 1970 and three in 1973. Considerably more acreage burned in 1973 than in all previous years together--4,770 acres. Table 4 summarizes fires occurring in the high elevation fire zone.

Naturally occurring fires allowed to run their course are continually monitored. Such fires are usually detected by Park reconnaissance aircraft. From the time of detection, a daily report is made through aerial, and if feasible, ground surveillance, for any day fire size increases more than two acres. The fire situation is continuously evaluated by members of the Park Wildfire Committee composed of wildland fire experts and Park administrators. The committee, or a quorum thereof, may order a fire suppressed or limit its size, or may recommend other appropriate activity to keep the fire within the zone boundaries.

Crowning or hot-burning has never characterized any of the naturally occurring fires in these parks, although some localized crowning may occur in the larger fires where draws, winds, weather, and fuels all favor that condition.

The average rate of spread on the largest naturally occurring fire was roughly one chain (66 feet) an hour. That rate of spread was fairly consistent throughout the day and night and was not very much affected by slope unless winds and burning conditions contributed to move a front at a greater rate. The fire was characterized by slow, steady state burning, as were other natural fires, remaining predominantly on the ground but consuming small trees up to six to eight feet in height and burning lower limbs on other trees up to six to eight feet above the ground.

Trees over 10 to 12 inches in diameter are seldom killed in natural fires. Larger green trees that are killed usually exhibit scars and pitch, which allow the fire to be led into the crown or to burn the interior of the tree, weakening it, causing it to fall and be consumed by the fire on the ground. Most snags are burned down and then consumed. The shrub layer may or may not be consumed, depending upon the intensity of the fire in a given microsite. For the most part, such close-grown shrubs as manzanita (*Arctostaphylos* spp.), mountain whitethorn (*Ceanothus cordulatus*), and bush chinquapin (*Castanopsis sempervirens*) are either consumed completely by the fire or are scorched enough to kill them. However, we generally find rapid regeneration and regrowth of shrubs and a higher diversity in herbs present after the fires.

This year a few plots were set out in which the vegetation and gross amounts of down material were qualitatively recorded before and after the fire burned the plot (Fig. 6). The plots were filmed before, during, and after burning. This coming spring, vegetation on the plot will again be recorded to determine successional changes. The film captures the effect of a natural fire on the environment and we hope to make it available to interested professional natural resource managers, wildland administrators, and conservation groups.

Public acceptance of the fire management programs in Sequoia and Kings Canyon National Parks has been most encouraging. We use press releases; feature newspaper articles; presentations to civic groups, schools, and colleges; handout material at visitor contact points within the Parks; and interpretive park programs to keep the public informed. Procedures vary with conditions. For example, in 1972 a fire crossed a major trail in one area and burned along its length for a considerable distance in another. A small bulletin board was placed at either end of the fire along the trail, explaining the Park program, with a map showing the approximate extent of the fire. The Park Ranger stationed in the area explained the program to hikers and also insured no safety hazards existed.

Another reason for public support and acceptance may be that the evidence of past fires is everywhere. There is no place within these Parks where there is forest vegetation where one cannot see bits of charcoal on the surface or in the ground, remnants of burned stumps, standing burned snags, or live trees with burned "catfaces." Such signs are strong evidence of the fact that fire has been a major factor in determining the vegetative patterns and associated fauna of the Parks. This is so obvious that most visitors are aware of the relationship; others quickly grasp the idea when it is pointed out to them.

The Parks are charged to perpetuate naturally operating ecosystems and it follows that naturally occurring fires, in other words lightning fires, be allowed to play their ancestral roles as ecosystem determinators. Although smoke from the larger fires may temporarily obscure a view, the visitor can be more than compensated by being able to observe a process of nature functioning unmodified. The chance to observe such activity is an experience of the highest order.

Smoke produced by the fire management program at times affects areas outside Park boundaries. Prescribed fires at the lower elevations and naturally occurring fires at the higher elevations are observed daily from Park reconnaissance aircraft. Observations include direction of smoke drift and density and elevation of the column.

Smoke generated by the fires in the high elevation fire management zone mostly remains within Park boundaries. The terrain in these areas, valleys and deep canyons surrounded by ridges and 11,000-foot and higher peaks, tends to contain smoke. Seasonal winds normally do not drift smoke toward the populated San Joaquin Valley. Winds and terrain cause smoke to dissipate over these Parks. Smoke production patterns also favor local dissipation.

High elevation fires develop slowly over relatively long periods--larger fires may burn for periods up to two months. Only portions of the perimeters are active at any one time though patches of heavier fuels may burn in the interior for several days. A 2,000-acre fire can be expected to have 200 acres or less actually burning at any one time. Smoke emissions from a 2,000-acre fire in the high elevation fire management zone are therefore many times less, in a given period, than from a similar size fire in more highly flammable fuels at lower elevations. The latter type of fire usually develops in a brief period of a few hours or as long as a few days. Much smoke is produced in a shorter period of time.

Most prescribed burning is done at the lower elevations on the west slope of the Sierras and not within the higher mountainous areas of the Parks. For this reason, there is a greater chance for the smoke to be carried in the direction of populated areas, but smoke generated in our prescribed fires can be controlled. Burns are planned to correspond to times when winds and other conditions favor dispersal of smoke over the Parks.

Our prescribed fires are designed, with the limited manpower we have to utilize in this program, to burn a maximum of about 50 acres a day. Fifty acres is the maximum of multistoried mixed conifer forest with large accumulations of dead fuels that approximately 12 men can burn and control in a day even when firelines have been preconstructed. Most current burning is done at elevations of 6,000 feet. Prescribed fires are designed to be ignited as early in the morning as the prescription will permit so the burn can be completed as early in the day as possible. However, ignition usually continues well into the afternoon. By the end of each day plots have been burned and smoke generation has reached a maximum. Usually, fire temperatures are high enough to carry the smoke column well up before it begins to be dispersed. Commonly, smoke columns climb to about 9,500 feet and then dissipate in a northerly or easterly direction over the Parks. By late afternoon most fuels have been consumed; however, smoke continues to be generated as large fuels are consumed. In the evening, smoke settles to the ground as increased humidities, poor burning conditions, and quiet air contribute to smoke buildup in the fire area. Smoke is found near burn sites on the mornings following burn days but is usually cleared out as upslope winds pick up and dissipate smoke to the east over the Parks. Practically no smoke is produced the day following a burn.

Although smoke is generated in both fire management programs, it is also generated by wildfires, and there have been many of them over the years in Sequoia and Kings Canyon. Some wildfires in the Parks have been much larger than any fire occurring under the fire management programs.

Because wildfires are inevitable and will always be uncontrollable some of the time they are burning, quality, volume, and timing of smoke emissions will also be uncontrollable. These disadvantages are avoided in prescription burning. In the higher elevation forests, a more severe climate has not produced the quantities of fuels found at lower elevations, so prescribed burning to remove dangerous fuel accumulation is not necessary. In a few high elevation areas, however, where fuel accumulations are considerable, prescribed burning may be necessary before any naturally occurring fires are allowed to burn without control. If the Parks continued to suppress all wildfires in these high elevation areas, they too eventually might build up dangerous fuel accumulations like those now found at the lesser elevations. This can be avoided by allowing natural processes to prevail (Fig. 7).

Withal, the Parks are quite concerned about smoke no matter how generated--wildfire, high elevation naturally occurring, or prescribed. Research on the various facets of the smoke problem is very high on the Parks' priority list. The research biologist there is designing a project to be pursued by qualified scientists. Nevertheless, fire managed under existing programs should result in fewer problems with smoke production than if the Parks had continued to suppress all fires and not use prescribed burning. Further, the fire management programs are seen as practical and logical means of reducing hazardous or potentially hazardous fuel accumulations, and for perpetuating the structure of the Parks' vegetative communities.

Summary

The fire management programs in Sequoia and Kings Canyon National Parks and the Selway-Bitterroot Wilderness generally have been well received by a variety of publics. Even the observation of smoke and the burned area immediately after a fire has not been a problem. In fact, the opposite reaction has often occurred. One individual, who had spent several seasons fighting forest fires, admitted that he had never been on a fire long enough to see the after effects. He was amazed at the rapidity that ponderosa pine needles covered the forest floor on the Fitz Creek Fire, and his opinions underwent an equally rapid change. Another person who viewed the Fitz Creek Fire in mid-September remarked that, "weren't forest fires supposed to be black?" She, too, was amazed at the rate of change within the burned area as pine needles covered the soil and plants sprouted almost before the ashes were cold.

Why should the role of fire in wildland ecosystems be widely understood and appreciated today? Most people are able to accept fire as a natural and renewing force in many ecosystems. Estella Leopold recognized this function of fire and called on agencies to direct their efforts toward meeting the ecological requirements of the Wilderness Act (1969). People today are beginning to appreciate the role fire plays in giant sequoia groves, high elevation forests, ponderosa pine stands, and food chains. Perhaps as White (31) and Rappaport (21) suggested, we are developing the capacity to think in terms of circular systems.

What are the warning signals we have been reading concerning wildland fires? Beaufait (4) reported that man can never completely prevent wildfires. Man merely postpones the inevitable release of energy stored through photosynthesis when he extinguishes wildfires (22). It is true that fuel accumulation is not the same on every acre, but is regulated by environmental factors; and that some fires result in an increase of fuels for a period of time. But of paramount concern should be the need to understand the function, structure, and requirements of fire-adapted biological systems in the conduct of management programs. National parks and wildernesses provide opportunities for not only challenging recreational experiences but also for naturally evolving baseline communities from which we can derive measures of water quality, air quality, species diversity, and habitat mosaics.

The inevitability of fire in parks and wildernesses is followed by the inevitability of smoke. Hall's (10) summary of the literature indicated that the importance of smoke from woody fuels is limited almost entirely to the obstruction of visibility. A forest is a factory in the sense that it manufactures its own food and releases dead organic matter as a by-product (and the living and dead organic matter burns, periodically, producing smoke as a by-product). But the forest is not a factory in the sense that emission control devices can be installed to control or eliminate the particulates in smoke. So our options are complex and will not be solved by simple linear solutions.

Changing public attitudes and the National Environmental Policy Act require that man's impact on his environment be carefully assessed. But what kind of assessment is made as we remove man's high profile from national parts and wildernesses, and move toward the perpetuation of *natural* systems with all environmental processes operating within certain constraints? The real solution may not be conformity with particular statutory requirements, but thoroughly presenting the various alternatives for informed public choice.

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TABLE 1.--WILDERNESS FIRE MANAGEMENT PRESCRIPTIONS FOR WHITE CAP CREEK AND BAD LUCK CREEK DRAINAGES

Management Zone	Suppression	Observation	Observation & Suppression
1. Shrubfield	a. Hunting season: BUI[1/] >170 b. Along study boundaries	a. Prehunting season b. Hunting season: BUI <170	a. Fires approaching Wapiti Creek Ridge
2. Ponderosa pine savanna		a. BUI <170	a. BUI >170
3. Ponderosa pine/ Douglas-fir	a. <4,500 feet elevation	a. >4,500 feet elevation, BUI <170	a. >4,500 feet, BUI >170
4. North slope	a. Along study boundaries b. BUI >170: Peach Creek Drainage	a. West of Peach Creek Drainage b. Upper White Cap unit	a. BUI >170: fires approaching Peach Creek buffer
5. Subalpine	a. Along study boundaries b. BUI >170: Bitterroot Crest passes	a. Season-long	a. BUI >170: fires approaching Bitterroot Crest passes

[1/] BUI = Buildup Index from the 1972 National Fire-Danger Rating System. BUI is being used as an interim fire management index only until a similar index is incorporated into the new danger-rating system.

TABLE 2.--JANUARY-AUGUST PRECIPITATION, 1973, AT NORTH STAR RANCH (SELWAY RIVER); DARBY, MONTANA; AND MISSOULA, MONTANA

Month	North Star Ranch[1/]	Darby, Montana	Missoula, Montana
	- - - - - - -	-Inches-	- - - - - - -
January	1.75	0.52	0.44
February	1.14	0.47	0.17
March	1.17	1.28	0.23
April	0.96	0.25	0.33
May	1.15	0.57	0.54
June	2.74	1.59	1.57
July	0.58	0.35	0.09
August	0.31	0.40	0.31
Total:	9.80	5.43	3.68

1/ Weather station 10 miles down Selway River from White Cap Creek.

TABLE 3.--FIRES IN THE WHITE CAP FIRE MANAGEMENT AREA, 1973

Fire name	Date		Cause	Fire size	Fire management zone	Action taken
	Origin	Out				
				Acres		
Peach Creek	8/10	8/14	Lightning	<1/4	North slope	Delayed suppression[1/]
Fitz Creek	8/10	9/21	Lightning	1,200	Ponderosa pine savanna, ponderosa pine/Douglas-fir, and shrubfield	Suppression and observation
Lookout Creek	8/10	8/16	Lightning	<1/4	North slope	Suppression[2/]
Cub Lake	8/11	8/12	Lightning	<1/4	Subalpine	Observation
Mt. Paloma	8/14	8/15	Lightning	<1/4	Subalpine	Observation
Peach Ridge	9/6	9/13	Lightning	<1/4	North slope	Observation

1/ Suppressed because fire near area boundary.

2/ Suppressed because this fire at first assumed to be a spot fire from Snake Creek Fire.

TABLE 4.--NUMBER OF LIGHTNING FIRES IN THE NATURALLY OCCURRING HIGH ELEVATION FIRE MANAGEMENT ZONES, SEQUOIA AND KINGS CANYON NATIONAL PARKS, 1968-1973

Year	Size class by acres					Total No. fires	Total acres burned
	<1/4	>1/4 to 9	10 to 99	100 to 299	300+		
1968	1	1	0	0	0	2	8.0
1969	2	0	0	0	0	2	0.3
1970	20	1	2	0	1	24	494.5
1971	23	1	0	1	0	25	115.0
1972	11	2	2	1	0	16	161.8
1973	7	1	0	0	3[1/]	11	4,772.7
Total:	64	6	4	2	4	80	

[1/] South Sentinel Fire burned 2,486 acres; Moraine Creek Fire burned 1,760 acres; and Chagoopa Fire burned 525 acres.

FIGURE 1. The observer at Bad Luck Lookout measures humidity as the Fitz Creek Fire burns in shrubfield fire management zone.

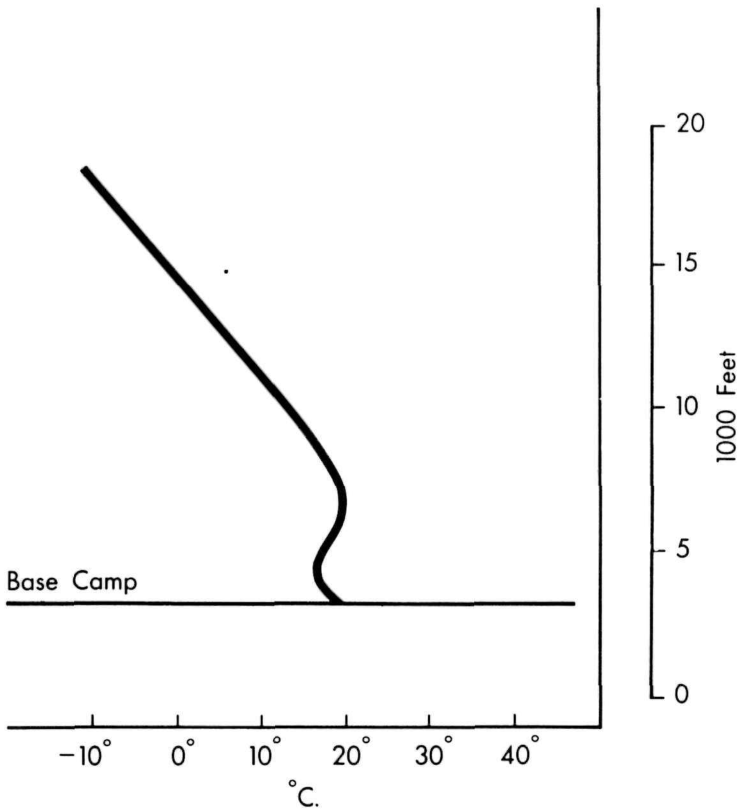

FIGURE 2. Temperature inversion recorded on the morning of August 27, 1973, near the Fitz Creek Fire.

FIGURE 3. Grouse walking up the White Cap Creek trail during early stages of the Fitz Creek Fire.

FIGURE 4. Prescribed burning in Sequoia and Kings Canyon National Parks is returning fire to fire-adapted giant sequoia groves and reducing fuel accumulations.

FIGURE 5. A portion of the 2,486-acre South Sentinel Fire that burned in the High Elevation Fire Management Zone in Sequoia and Kings Canyon National Parks in 1973.

FIGURE 6. An inventory crew records vegetation and fuel data while the South Sentinel Fire burns in pine needle litter.

FIGURE 7. Fire consuming large fuels in the South Sentinel Fire, 1973.

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