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The Use of Geographic Information for Fire Management Planning in Yosemite National Park

Fire has played a critical role in the ecosystems of Yosemite National Park for millennia. Before the advent of Euro-Americans, lightning fires and fires set by Native Americans burned freely across the landscape. These fires burned periodically, with the interval between fires dependent on the availability of ignition sources, adequate fuels, and weather conducive to burning. As a result, different vegetation types burned at different intervals.

Designation of Yosemite Valley and the Mariposa Grove as a state reserve in 1864, and of the remaining area surrounding the valley as a national park in 1890, led to an era of fire suppression. Landscape-scale changes resulted from decades of a management philosophy that excluded naturally occurring fires. These landscape-scale changes are characterized by departures from the natural fire-return interval—the number of years between successive naturally occurring fires for a given vegetation type. Prior to the exclusion of fire, intervals between fires ranged from a few years in the lower montane forests to centuries in the subalpine forests.

Interruption of the natural regime, reflected in the fire return-interval departure, is a major thrust in the development and analysis of the Yosemite fire management plan and environmental impact analysis. Areas that have missed multiple return intervals are more susceptible to stand-replacing wildland fires, which are uncommon in natural surface-burning fire regimes. The plan strives to restore and maintain the natural range of variability by focusing treatment of areas based on the fire return-interval departures.

Geographic Information

Geographic information systems (GIS) have been used in Yosemite National Park for fire research and management applications since the early 1980s (van Wagtendonk 1991). A GIS model was used for the fire return-interval departure analysis in the new fire management plan for the park. The analysis was originally developed in Sequoia and Kings Canyon National Parks (Caprio et al. 1997). It combines information on fire history and fire ecology to assess the ecological condition of all vegetation communities, using departures from the natural fire return intervals as an indicator of change. The analysis consists of four steps: (1) vegetation types are defined based on similar fuels and fire behavior, (2) fire return intervals are assigned to each type, (3) the number of years since an area last burned is determined from fire history maps, and (4) departures from the natural fire interval are calculated using the return interval. The results from this analysis are then applied to the fire management planning process.

Although the park is currently developing a new vegetation map, the most recent map dates from the 1930s and was compiled from field surveys and sample plots (van Wagtendonk 1986). This map was digitized and entered into a GIS in 1981. Over 6,500 polygons were assigned species names from over 1,200 unique combinations of species. These polygons were reclassified into 33 types as part of the park's vegetation management plan. Fire history maps and data have been collected in the park since 1930 and were also entered into a GIS in 1981. This GIS coverage has been updated after each fire season and includes the name, year, management type, and ignition source of each fire. Both the vegetation map and the fire history map were converted into ArcInfo raster data sets. The ArcInfo GRID module and the Spatial Analyst extension of ArcView were used to perform the fire return-interval departure analyses (ESRI 1996). These modules allowed multiple raster data sets to be analyzed simultaneously.

Vegetation Communities

The vegetation zones across the park follow general elevation bands across the Sierra Nevada from chaparral oak woodlands, through lower montane forests, upper montane forests, and subalpine forests, to alpine meadows. At the lowest elevations in the park (about 2,000 feet above mean sea level), the vegetation is chaparral and oak woodland. Lower montane mixed-conifer forests occur from about 3,000 to 6,700 feet. Upper montane conifer forests occur from about 6,000 to 10,000 feet. Subalpine conifer forests occur from 8,000 to 11,000 feet. Alpine communities dominate above 10,000 feet.

Fire professionals examined each of the 33 vegetation management plan types and reclassified them based on similar vegetation, fire behavior, and fuel loads. In most cases, the reclassification was a simple reassignment, but in a few cases vegetation types were lumped based on the characteristics of neighboring types.

For example, if a subalpine meadow adjoins a lodgepole pine forest, it would be lumped with the forest since the meadow would be likely to burn if the forest was ignited. If, however, the meadow was surrounded by barren rock, it would be lumped with the rock since it would be unlikely to be ignited. These neighborhood analyses were performed for meadows, riparian vegetation types, and western juniper.

The resulting 15 vegetation groups and the barren and water categories are shown in Figure 1 and listed in Table 1 for the 747,955 acres in Yosemite National Park and the 1,137 acres in the El Portal Administrative Site. The types are listed by zone, generally from higher to lower elevation. Table 2 includes information on fuel loads, fireline intensities, and typical fire behavior in each of the vegetation types. A description of each of the vegetation zones follows.

Subalpine forests. The subalpine zone includes whitebark pine and

Table 1. Vegetation zone, types, and acreage for Yosemite National Park and the El Portal administrative site.

Vegetation zone	*Vegetation type*	*Acres*
Subalpine forests	Whitebark pine–mountain hemlock forest	87,582
	Lodgepole pine forest	175,516
Upper-montane forests	Red fir forest	68,125
	Western white pine–Jeffrey pine forest	132,708
	Montane chaparral	15,137
Lower-montane forests	Giant sequoia–mixed conifer forest	218
	White fir–mixed-conifer forest	46,871
	Ponderosa pine–mixed-conifer forest	34,370
	Ponderosa pine–bear clover forest	33,846
	California black oak woodland	3,156
	Canyon live oak forest	21,473
	Dry montane meadow	1,530
Foothill woodlands	Foothill pine–live oak–chaparral woodland	7,130
	Foothill chaparral	1,785
	Blue oak woodland	473
Subtotal, Vegetation		629,920
Barren	Bare rock	112,022
	Water	7,150
Total		749,092

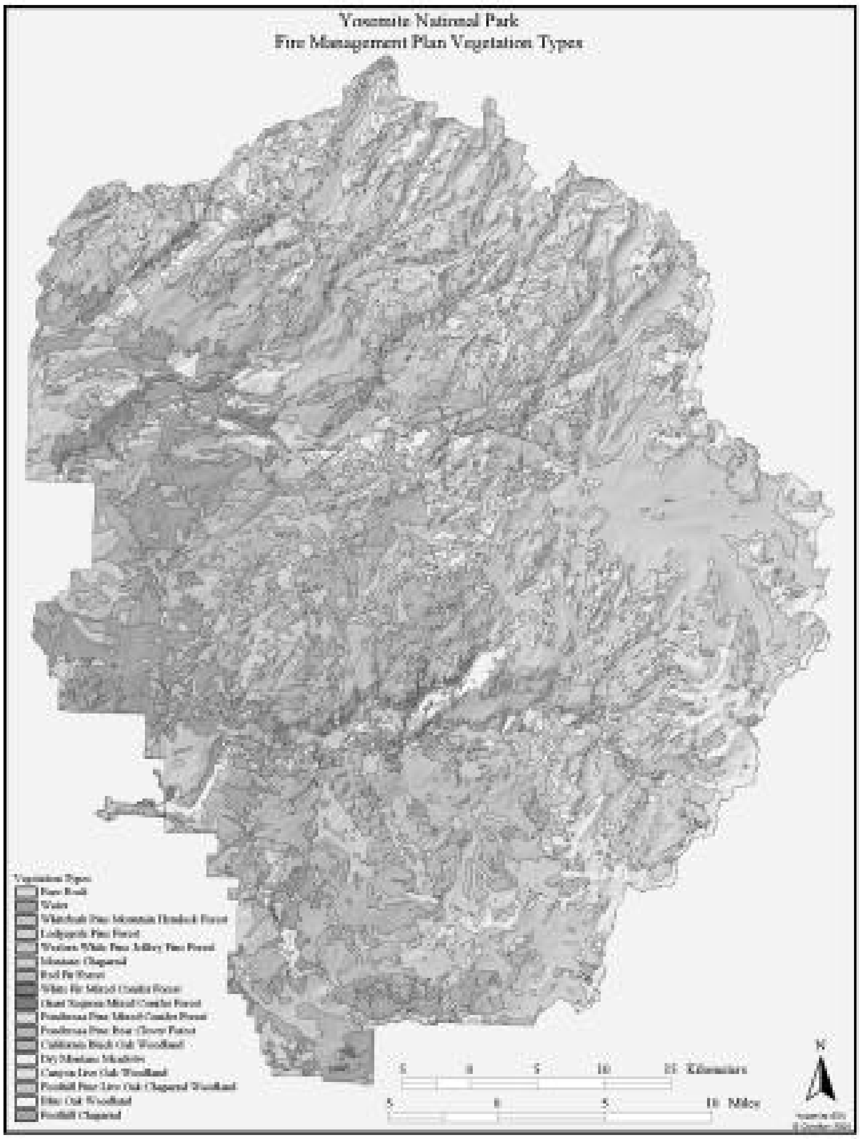

Figure 1. Vegetation types, Yosemite National Park and El Portal administrative site.

Mountain hemlock forests and lodgepole pine forests, which together occupy about 35% of the park. Characteristic trees include lodge-pole pine *(Pinus contorta),* mountain hemlock *(Tsuga mertensiana),* and whitebark pine *(Pinus albicaulis),* with smaller amounts of red fir *(Abies magnifica),* western white pine *(Pinus monticola)* and western juniper *(Juniperus occidentalis).* Although this zone receives approximately 35% of the lightning strikes in the park, fires are infrequent and do not become large (van Wagtendonk 1994). These fires usually smolder or spread as low-intensity surface fires.

Upper montane forests. The upper montane zone includes red fir forest, western white pine/Jeffrey pine forest, and montane chaparral, and makes up about 30% of park vegetation. Characteristic trees include red fir, western white pine, Jeffrey pine *(Pinus jeffreyi),* western juniper, and aspen *(Populus tremuloides).* Dominant shrub species in- clude greenleaf manzanita *(Arctostphylos patula),* pinemat manzanita *(Arctostaphylos nevadensis),* mountain white thorn *(Ceanothus cordulatus),* huckleberry oak *(Quercus vacinifolia)* and, at lower elevations, bitter cherry *(Prunus emarginatus)* and chinquapin *(Castanopsis sempervirens).* This zone receives 23% of the lightning strikes in the park, and fires are numerous, generally remain small, and are of low intensity (van Wagtendonk 1994). However, under extremely dry and windy conditions, large stand-replacing fires can occur.

Lower montane forests. The lower montane zone, which includes giant sequoia, white fir, and ponderosa pine mixed-conifer forests and ponderosa pine–bear clover forest, covers about 15% of the park. This zone also contains California black oak woodlands, canyon live oak forests, and dry montane meadows. Dominant tree species include ponderosa pine *(Pinus ponderosa),* sugar pine *(Pinus lambertiana),* incense-cedar *(Calocedrus decurrens),* white fir *(Abies concolor),* giant sequoia *(Sequoiadendron giganteum),* California black oak *(Quercus kelloggii),* and canyon live oak *(Quercus chrysolepsis).* The most common understory shrubs are bear clover *(Chamaebatia foliolosa),* whiteleaf manzanita *(Arctostaphylos viscida),* and deerbrush *(Ceanothus intergerimus).* Although the lower montane forests receive only 17% of the lightning strikes in the park, the mixed-conifer community experiences frequent, low-intensity fires (van Wagtendonk 1994). Many of these fire were suppressed, however, resulting in a change from open forest to dense thickets of shade-tolerant tree species, particularly incense-cedar and white fir in the upper part of the zone, and an increase in shrubs in the lower part. Under natural conditions, the median fire return interval is estimated at 8 to 12 years. Existing conditions,

Table 2. Fuel load, fireline intensity, and typical fire behavior for vegetation types in Yosemite National Park and the El Portal administrative site. Loads are from van Wagtendonk et al. (1998), intensities from Caprio and Lineback (1997), and typical fire behavior from Botti (1990).

Vegetation Type	*Fuel Load*		*Fireline Intensity*	*Typical Fire Behavior*
	Duff	*Woody*		
	-----Tons/ac-----		--Btu/ft/s--	
Whitebark pine–mountain hemlock forest	50.2	3.7	1-40 mean=10	Smoldering or low intensity, surface fire
Lodgepole pine forest	27.7	2.0	1-40 mean=10	Smoldering or low intensity, surface fire
Red fir forest	39.8	8.9	1-120 mean=25	Surface fire, flames <1 ft, flare-ups in heavy fuel
Western white pine– Jeffrey pine forest	41.7	1.5	1-60 mean=30	Moderate intensity fire, flames 1-4 ft, torching may occur
Montane chaparral	—	3.5	50-6,330 mean=3,000	Fast spread involving entire biomass, flames 20-30 ft
Giant sequoia–mixed-conifer forest	68.6	10.4	20-1,000 mean=100	Erratic spread, flames <2 ft, intense burning in heavy fuels
White fir–mixed-conifer forest	36.1	4.6	20-1,000 mean=100	Slow spread, flames <2 ft, intense burning in heavy fuels
Ponderosa pine–mixed-conifer forest	55.5	4.4	20-1,000 mean=100	Low intensity, surface fire, flames 2 ft
Ponderosa pine–bear clover forest	48.0	4.4	20-1,000 mean=100	Surface fire in shrub layer, flames 2 ft

California Black oak forest	10.0	2.0	1-120 mean=25	Low intensity, surface fire, flames <1 ft
Canyon live oak forest	—	25.0	50-6,330 mean=3,000	Torching of large trees, frequent crown fire
Dry montane meadow	3.0 (grass)		4-125 mean=100	Fast spread with wind, flames 2-10 ft
Foothill pine–live oak–chaparral	20.7	21.7	50-6,330 mean=3,000	Fast spread, torching and crowning in trees and shrubs
Foothill chaparral	—	14.0	50-6,330 mean=3,000	Fast spread involving entire biomass, flames 20-30 ft
Blue oak woodland	0.75 (grass)		4-125 mean=100	Fast spread in grass with wind, flames 2-10 ft

however, often generate fires of much greater intensity than would occur under a natural fire regime.

Foothill woodland. The foothill woodland zone includes foothill pine–live oak–chaparral woodland, blue oak woodland, and foothill chaparral. This zone covers about 5% of the park ranging from 1,700 to 6,000 feet. Dominant tree species include California black oak, foothill pine *(Pinus sabiniana)*, canyon live oak, interior live oak *(Quercus wislizenii)*, and blue oak *(Quercus douglasii)*. Many of the types are better recognized by the dominant shrubs, including mountain mahogany *(Cercocarpus betuloides)*, poison oak *(Toxicodendron diversiloba)*, whiteleaf manzanita, deerbrush, and buckbrush *(Ceanothus cuneatus)*. Lightning is not frequent in the foothill zone, receiving only 2% of the recorded strikes in the park (van Wagtendonk 1994). Even when made proportional to the size of the zone, only 8% of the strikes occur there. Consequently, lightning fires are not very frequent, but when they do occur, they spread quickly and are very intense.

Fire Return Interval

Fire plays a varying role in the vegetation types, characterized by the fire return interval. A fire return interval for a given vegetation type is defined as the number of years between fires at a specific location that is representative of that type. For example, a fire scar analysis of a sample of trees in a stand of ponderosa pines might show that fire has occurred in that stand from as frequently as every two years (minimum value) or as infrequently as every six years (maximum value). The average fire return interval is the arithmetic mean of all the intervals (mean interval); due to sampling techniques, it is usually closer to the minimum interval than the maximum. If fire return intervals for all trees are arranged from shortest to longest, the tree in the middle would have the median interval, which might be every four years (median value).

Table 3 lists the minimum, median, and maximum fire return intervals for each of the vegetation types and the sources for that information. In some cases, only the mean value was available; it is listed in table 3 in the median column. Skinner and Chang (1996) give a thorough discussion on return intervals and were the primary or secondary source for most of the entries. Caprio and Lineback (1997) provided additional sources. In cases where no specific studies existed for a species, the closest ecologically similar species was selected. The information from Table 3 was used to reclassify the park vegetation map into maximum and median fire return-interval maps. Maximum fire return intervals ranged from five years for dry montane meadows to 508 years for whitebark pine and western hemlock forests. These same types had the shortest (1 year) and longest (187 years) median intervals.

Fire History

Fire history maps dating back to 1930 for the park proper and to 1958 for the El Portal administrative site were used to develop information on ignition source, fire size, number of times a particular area has burned, the decade in which each burn occurred, and the last year in which a burn occurred within a particular area. The fire history data are as complete as possible, but there are a few historic fires that are incompletely documented, and it is suspected that there are a few historic fires that are totally undocumented. Table 4 shows the variation in the area burned over the decades. Reburns within a decade are not recounted, but reburns occurring in multiple decades are. During the 1930s, fuel accumulations had not become critical and most fires did not become large before they were suppressed. A single human-caused fire in 1948 accounted for most of the acres burned during that decade. Increased suppression efforts in the 1950s and 1960s, combined with new equipment and technology, resulted in a reduction in the acreage burned.

Table 3. Minimum, median, and maximum fire return intervals for the vegetation types in Yosemite National Park and the El Portal administrative site.

Vegetation type	*Return Interval*			*Source*
	Min.	*Med.*	*Max.*	
	---------Years---------			
Whitebark pine–mountain hemlock forest	4	187	508	Caprio and Lineback 1997
Lodgepole pine forest	4	102	163	Kiefer 1991
Red fir forest	9	30	92	Caprio and Lineback 1997
Western white pine–Jeffrey pine forest	4	12	96	Skinner and Chang 1996
Montane chaparral	10	30	75	Caprio and Lineback 1997
Giant sequoia–mixed-conifer forest	1	10	15	Swetnam et al.1991
White fir–mixed-conifer forest	3	8	35	Skinner and Chang 1996
Ponderosa pine–mixed-conifer forest	3	9	14	Kilgore and Taylor 1979
Ponderosa pine–bear clover forest	2	4	6	Caprio and Swetnam 1993
California black oak woodland	2	8	18	Stephens 1997
Canyon live oak forest	7	13	39	Skinner and Chang 1996
Dry montane meadow	1	2	5	Anderson 1993
Foothill pine–live oak–chaparral woodland	2	8	49	McClaran and Bartolome 1989
Foothill chaparral	10	30	60	Caprio and Lineback 1997
Blue oak woodland	2	8	49	McClaran and Bartolome 1989

The prescribed burning and wildland fire use programs began in 1970 and 1972, respectively, ushering in the era of fire management. The acreage burned increased dramatically as these programs began to allow fire to play its natural role in the ecosystem. This growth continued during the 1980s in spite of the moratorium on management fires in 1989 as a result of the Yellowstone fires. During the 1990s, three large lightning fires that were suppressed burned nearly 60,000 acres in the park and the administrative site. Only 47 acres were burned in 2000, the year of another moratorium, this one resulting from the Los Alamos fires.

Figure 2 shows the year of last burn by vegetation type for all ignition sources combined. This map is used in the calculation of fire return-interval departure as an indicator of the most recent fire to burn an area. Ecologically, it makes no difference whether the fire was ignited by lightning or by humans, on purpose or by accident. The large burns on the western edge of the park were suppressed lightning fires that occurred in 1990 and 1996. The area in the

Table 4. Acres burned of each vegetation type by decade, Yosemite National Park and the El Portal administrative site, 1930 through 2000. The acreages include overlap between decades.

Vegetation Type	*Decade*							
	1930s	***1940s***	***1950s***	***1960s***	***1970s***	***1980s***	***1990s***	***2000***
	----------------------------------Acres-------------------------							
Whitebark pine–mtn. hemlock	16	0	0	2	23	31	3	0
Lodgepole pine forest	20	175	13	233	897	4,536	3,059	39
Red fir forest	6	744	48	576	1,435	7,706	7,466	4
W. white pine–Jeffrey pine	66	4,962	249	390	6,720	18,928	20,296	6
Montane chaparral	6	910	11	262	277	1,832	1,368	0
Giant sequoia–mixed-conifer	0	0	0	0	81	31	88	0
White fir–mixed-conifer	41	390	61	300	2,439	7,541	17,144	1
Ponderosa pine–mixed-conifer	6	381	468	817	4,796	4,641	14,956	3
Ponderosa pine–bear clover	11	481	832	794	4,604	4,602	18,055	0
California black oak forest	0	56	4	0	241	622	354	0
Canyon live oak forest	331	3,514	83	638	1,517	129	9,258	0
Dry montane meadow	0	36	5	30	197	125	434	0
Foothill pine–oak–chaparral	5	440	2,163	962	269	126	6,216	0
Foothill chaparral	0	0	0	32	0	63	363	0
Blue oak woodland	0	0	0	0	116	4	301	0
Total	508	12,089	3,937	5,036	23,612	50,917	99,361	53

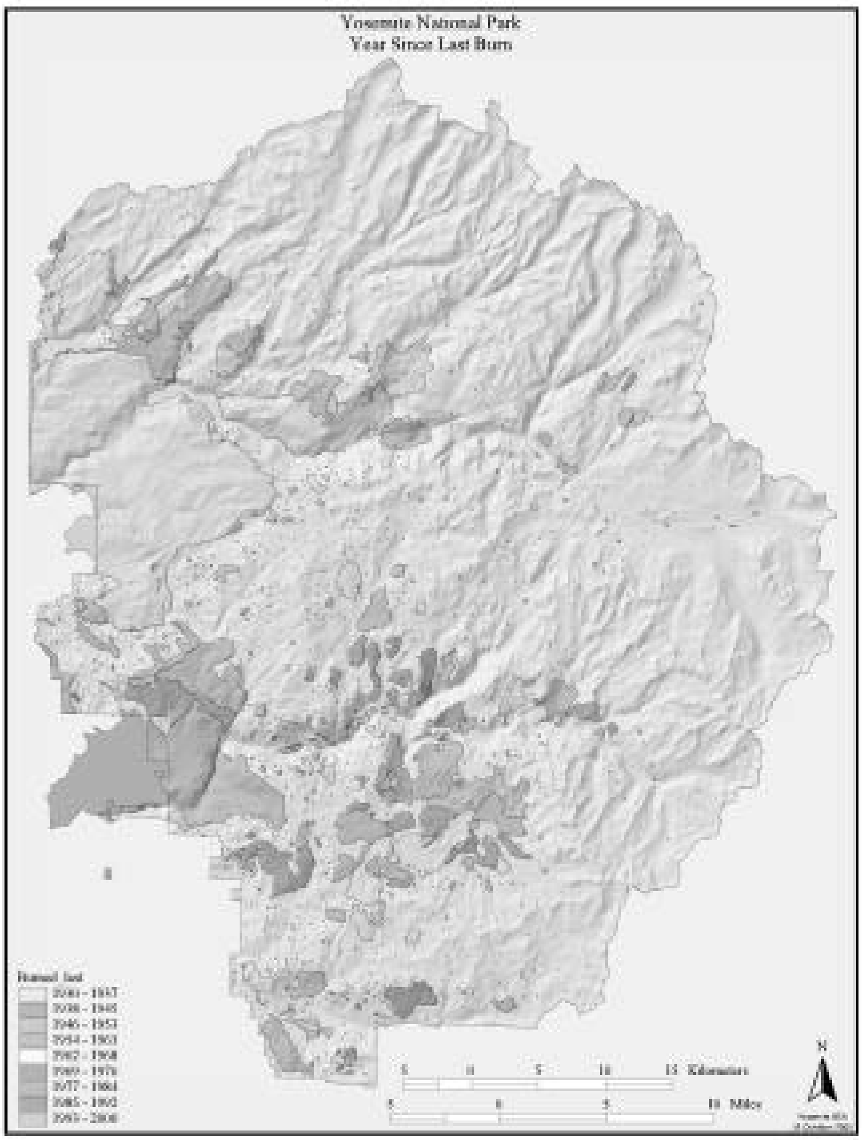

Figure 2. Area burned by vegetation type and decade, Yosemite National Park and El Portal administrative site, 1930 through 2000.

south-central portion of the park includes the Illilouette Creek basin where large lightning fires have been allowed to run their course since 1972 as part of the wildland fire -se program (van Wagtendonk 1994). Similar areas of large lightning fires occur in the Frog Creek drainage north of Hetch Hetchy Reservoir.

The ignition source data are shown in Table 5. Acreage numbers do not include areas that were reburned by fires of the same ignition source; however, areas burned by fires from more than one ignition source are counted two or three times. Lightning accounts for over 93% of the unplanned ignitions. The resulting fires have burned over 145,400 acres. Two hundred forty-five human-caused fires have burned nearly 18,600 acres; 12,000 acres burned in a single fire in 1948. Managers have ignited 399 prescribed fires between 1970 and 2000, and those fires have burned over 41,000 acres. Most of the prescribed burning has been conducted in the white fir and ponderosa pine types where fuel conditions have been affected by fire exclusion in the past.

When reburned areas are not recounted, a total of 160,511 acres (25%) of the vegetated areas of the park and the administrative site have burned during the past 71 years (Table 6). Over 469,400 acres have not burned; most of these are in the whitebark pine–mountain hemlock and lodgepole pine forest types in the subalpine zone. Only 877 acres have burned four or more times, while 6,880 acres have burned three times; 36,100 acres burned two times, and 116,653 acres burned only once. Reburns have been most common in the mixed-conifer types where prescribed burns have been set and in the Illilouette Creek and Frog Creek basins.

The largest number of acres burned by a single lightning fire in each vegetation type and the year of that fire are shown in Table 7; however, these data do not include the 1990 A-Rock and Steamboat fires or the 1996 Ackerson fire. Data collected in the field on the 1990 fires indicate that, in addition to unnaturally high fuel loads, atmospheric conditions combined with steep slope topography and local winds contributed to catastrophic fire behavior. Fire suppression activities, particularly back-firing on the Ackerson fire, have also increased the area burned beyond what might have done so naturally for all three fires omitted from Table 7. The 1953 fire was the only one that did not occur under the wildland fire-use program and indicates the maximum size that might be expected to burn in each vegetation type under natural conditions. Landscape-scale changes in the fire regime are characterized by an analysis of departures from the fire return interval that would have prevailed had fires been allowed to burn naturally.

Table 5. Number of fires and acres burned by vegetation type and ignition source, Yosemite National Park and El Portal administrative site, 1930-2000. The acreages include overlap between ignition sources.

Vegetation Type	*Ignition Source*					
	Lightning		*Human*		*Prescribed*	
	No.	*Acres*	*No.*	*Acres*	*No.*	*Acres*
Whitebark pine–mountain hemlock forest	56	121	0	0	0	0
Lodgepole pine forest	427	8,358	25	399	13	354
Red fir forest	591	16,767	18	1,004	5	307
Western white pine–Jeffrey pine forest	893	41,982	47	6,385	24	5,584
Montane chaparral	126	2,651	11	1,175	22	755
Giant sequoia–mixed-conifer forest	0	0	0	0	17	241
White fir–mixed-conifer forest	427	20,436	25	625	13	7,387
Ponderosa pine–mixed-conifer forest	341	15,545	19	809	88	10,976
Ponderosa pine–bear clover forest	247	19,160	59	1,494	121	11,619
California black oak woodland	24	353	3	81	22	868
Canyon live oak forest	108	10,510	21	5,001	22	2,025
Dry montane meadow	16	421	3	54	36	433
Foothill pine–live oak–chaparral woodland	34	8,555	8	1,424	3	302
Foothill chaparral	17	336	3	25	6	110
Blue oak woodland	2	315	3	120	7	62
Total	3,309	145,462	245	18,596	399	41,023

Table 6. Number of times burned in acres by vegetation type, Yosemite National Park and El Portal administrative site, 1930-2000. The total does not include bare rock and water areas.

Vegetation type	***Times Burned***					***Total***
	0	***1***	***2***	***3***	***4+***	
	----------Acres----------					
Whitebark pine– mtn hemlock	87,461	121	0	0	0	87,582
Lodgepole pine forest	166,903	7,467	989	157	0	175,516
Red fir forest	50,483	16,084	1,476	81	1	68,125
Western white– Jeffrey pine	88,668	34,477	6,884	2,423	256	132,708
Montane chaparral	11,285	2,787	874	185	6	15,137
Giant sequoia– mixed-conifer	36	88	81	9	4	218
White fir–mixed-conifer forest	22,426	20,000	3,979	448	18	46,871
Ponderosa pine– mixed conifer	14,744	12,609	6,178	792	47	34,370
Ponderosa pine– bear clover	12,168	12,411	7,201	1,731	335	33,846
California black oak forest	2,012	959	158	27	0	3,156
Canyon live oak forest	10,250	4,871	5,596	661	95	21,473
Dry montane meadow	911	402	154	38	25	1,530
Foothill pine–oak–chaparral	705	3,666	2,357	312	90	7,130
Foothill chaparral	1,243	503	39	0	0	1,785
Blue oak woodland	114	208	135	16	0	473
Total	469,409	116,653	36,101	6,880	877	629,920

Fire Return-Interval Departure

In general, the further that vegetation communities depart from their natural fire regimes, the more that unnatural conditions will prevail and the higher the risk of the occurrence of a stand-replacing wildland fire that is not natural to surface-burning fire regimes. Maximum fire return-interval departure represents the most conservative estimate of how severe the deviation from natural conditions might be in terms of fuels and vegetation. Median fire return-interval departure gives a more moderate view, while the minimum presents the most extreme situation of how far the stand is from its natural condition. For example, if fire suppression has been successful in excluding fire from the stand for sixty years, it would have missed thirty fires based on the minimum fire return interval of two years, fifteen fires based on the median interval of four years, and ten fires based on the maximum interval of six years. These departures from the normal fire regime are expressed in terms of fire return-interval departures of 30, 15, and 10 missed intervals, respectively.

The number of interval departures for both the median and maximum fire return interval departures is calculated using the following map algebra:

Fire return-interval departure = [fire return interval – (current year – year last burned)] ÷ fire return interval

The fire return-interval departure map is the absolute value of the fire return-interval map minus the value of the current year less the year-last-burned map all divided by the fire return-interval map. The return interval can be calculated for both the maximum and median interval. For areas that have not burned since 1930 in Yosemite National Park or 1985 for the El Portal administrative site, the year last burned was considered to be 1930 and 1958, respectively.

Maximum and median fire return-interval departures were grouped into three categories: 0-2 intervals missed, 3-4 intervals missed, and five or more intervals missed. These groupings are based on the assumption that fire exclusion increases surface and ladder fuels, greatly increasing the potential for catastrophic fire.

Table 7. Size and year of largest lightning fires by vegetation type, Yosemite National Park and the El Portal administrative site, 1930 through 2000.

Vegetation type	*Acres*	*Year*
Whitebark pine–mountain hemlock forest	20	1988
Lodgepole pine forest	773	1987
Red fir forest	1,265	1999
Western white pine–Jeffrey pine forest	3,274	1974
Montane chaparral	641	1999
Giant sequoia–mixed-conifer forest	0	1976
White fir–mixed-conifer forest	1,092	1988
Ponderosa pine–mixed-conifer forest	960	1999
Ponderosa pine–bear clover forest	1,247	1987
California black oak woodland	91	1999
Canyon live oak forest	3,517	1999
Dry montane meadow	35	1988
Foothill pine–live oak–chaparral woodland	1,909	1953
Foothill chaparral	43	1987
Blue oak woodland	5	1987

These high-intensity and severe fires are outside the natural range of variability. The rationale for the 0-2 departures-missed group is that, for most vegetation types, two median intervals lie between the minimum and maximum return intervals. For example, California black oak woodland has a median interval of eight years, and twice that interval (16years) falls between the minimum (two years) and maximum (18 years) fire return intervals. Areas that have missed two or fewer median fire return intervals are considered to be within their natural range of variability. For most vegetation types, a departure of three or more median return intervals was outside of the maximum fire return interval for the type. For example, the median fire return interval for lodgepole pine forest is 102 years. If a lodgepole pine stand has a departure value of three, it means that the area has not burned for at least 306 years. This length of time is much greater than 163 years, the recorded maximum return interval for the type. But in a few vegetation types, a return interval departure of three is still within the maximum fire return interval for the type. The red fir forest median return interval is 30 years, and 90 years will have passed before areas have missed three fire cycles. This value is less than the maximum return interval of 92 years.

Results of the analysis using the maximum fire return-interval departure indicate that 95% of the park and the administrative site had missed no more than two return intervals (Table 8). The remaining 5% was all in short fire return-interval types containing ponderosa pine or dry montane meadows. The median fire return-interval departure analysis is depicted in Figure 3. The analysis shows that 74% of the vegetation has missed no more than two return intervals and is considered to be in an acceptable ecological condition (that is, exhibiting little to no deviation from a natural fire regime) as of 2000 (Table 9). These areas are expected to remain in an acceptable ecological condition as long as the natural fire regime is maintained. Another 1% of the vegetation shows significant deviation from natural conditions, and 25% is considered highly compromised by past fire suppression. Most of the deviation from natural conditions occurs in the lower-to-mid-elevation conifer forests, including the giant sequoia groves. Despite ongoing reintroduction of fire to the groves over the past 30 years, progress has been slow—17% of the groves still contain unnaturally high levels of fuel. The analysis does show positive effects from fire management activities because many areas are in an acceptable condition, but also underscores the fact that large areas require attention.

Table 8. Acres of each vegetation type by number of maximum fire return intervals missed, Yosemite National Park and El Portal administrative site, 1930 through 2000. The total does not include bare rock and water areas.

Vegetation type	*Number of Maximum Return Intervals Missed*			*Total*
	0-2	*3-4*	*5+*	
	----------Acres----------			
Whitebark pine–mtn. hemlock forest	87,582	0	0	87,582
Lodgepole pine forest	175,516	0	0	175,516
Red fir forest	68,125	0	0	68,125
Western white pine–Jeffrey pine forest	132,708	0	0	132,708
Montane chaparral	15,137	0	0	15,137
Giant sequoia–mixed-conifer forest	182	36	0	218
White fir–mixed-conifer forest	46,871	0	0	46,871
Ponderosa pine–mixed-conifer forest	19,414	557	14,399	34,370
Ponderosa pine–bear clover forest	20,013	1,174	12,659	33,846
California black oak woodland	1,143	2,013	0	3,156
Canyon live oak forest	21,473	0	0	21,473
Dry montane meadow	545	27	958	1,530
Foothill pine–live oak–chaparral	7,130	0	0	7,130
Foothill chaparral	1,785	0	0	1,785
Blue oak woodland	473	0	0	473
Total	598,097	3,807	28,016	629,920

Fire Management Planning Applications

The fire return-interval departure analysis was used extensively in the development of a new fire management plan. Although the nature and extent of the unnatural build-up of fuels had long been recognized, the maps depicting the results of the analysis reinforced this recognition and communicated the extent and severity of the problem. The results of the analysis were an important tool in the development of the alternatives, because they identified the areas in greatest need of treatment. Areas that had missed numerous return intervals, and thus were in greatest danger of an undesired fire, were a focal point for analysis of environmental consequences.

Fire return-interval departures were used extensively to compare environmental consequences of different alternatives in the plan. The analysis of potential impacts on vegetation, wildlife habitat, watersheds, soils, and water quality used return-interval departures as a basis for determining if areas were within the natural range of variability.

The impacts on the ecosystem

Table 9. Acres of each vegetation type by number of median fire return intervals missed, Yosemite National Park and El Portal administrative site, 1930 through 2000.

Vegetation type	*Number of Median Return Intervals Missed*			*Total*
	0-2	*3-4*	*5+*	
	----------------------Acres----------------------			
Whitebark pine–mtn. hemlock forest	87,582	0	0	87,582
Lodgepole pine forest	175,516	0	0	175,516
Red fir forest	68,125	0	0	68,125
Western white pine–Jeffrey pine forest	40,970	3,035	88,703	132,708
Montane chaparral	15,137	0	0	15,137
Giant sequoia–mixed-conifer forest	182	0	36	218
White fir–mixed-conifer forest	23,871	374	22,626	46,871
Ponderosa pine–mixed-conifer forest	18,414	1,354	14,602	34,370
Ponderosa pine–bear clover forest	18,311	1,766	13,769	33,846
California black oak woodland	921	210	2,025	3,156
Canyon live oak forest	10,729	623	10,121	21,473
Dry montane meadow	251	101	1,178	1,530
Foothill pine–live oak–chaparral	6,272	1	857	7,130
Foothill chaparral	1,785	0	0	1,785
Blue oak woodland	338	21	114	473
Total	468,404	7,485	154,031	629,920

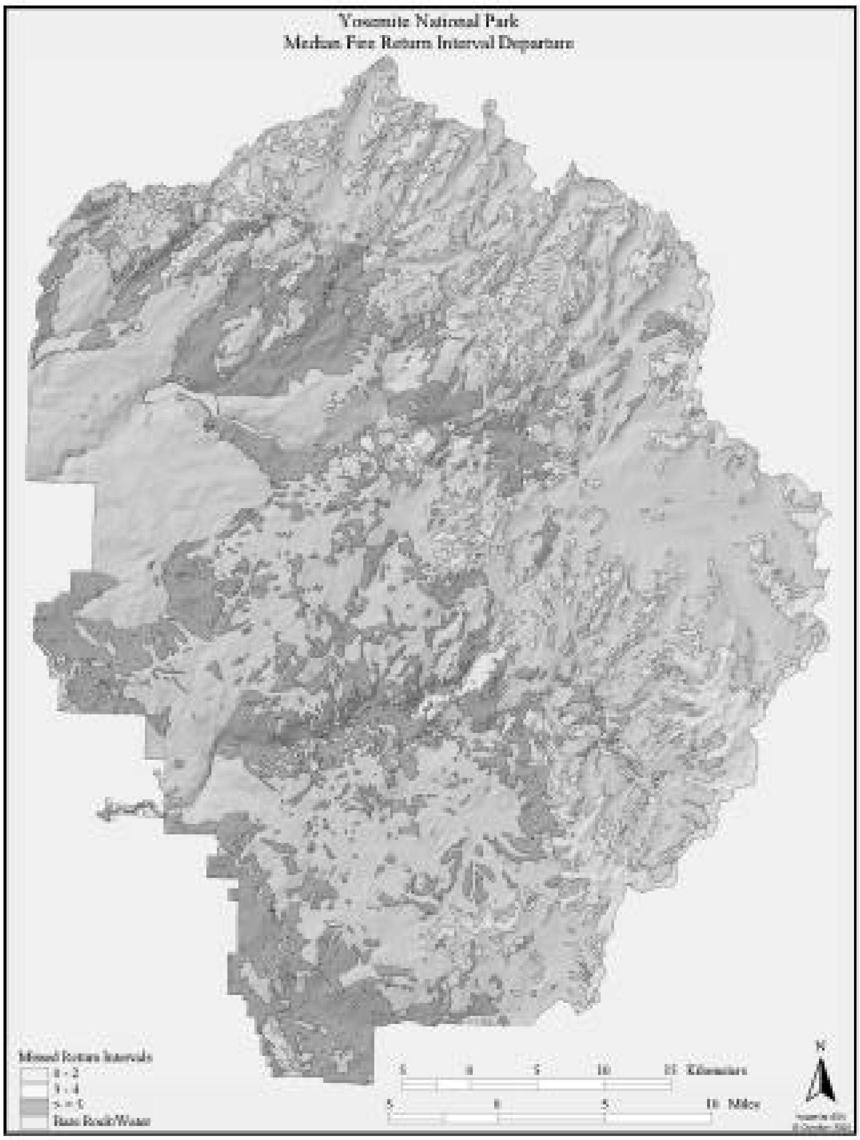

Figure 3. Number of median fire return intervals missed by vegetation type, Yosemite National Park and El Portal administrative site, 1930 through 2000.

were examined by looking at the number of departures. Similarly, analysis of cultural concerns used departures to determine the potential for damage by fire based on changes in fuel loading.

For prescribed burning operations, the fire return-interval departure analysis will be used to prioritize areas for treatment; i.e., those with the highest departure values would be burned first. In the wildland fire-use unit, the analysis would highlight areas where intensive monitoring might be necessary because of unnaturally high fuel accumulations or dense stands. Similarly, the analysis would aid fire suppression operations by indicating where wildland fires might be expected to be more intense than under natural conditions, and would help set priorities for fuel treatments in the wildland–urban interface.

Conclusion

An effective fire management program requires spatial and non-spatial scientific data. Therefore, an analysis of these data is essential for long-range fire management planning. The fire return-interval analysis is an excellent example of how scientific data and analyses were used in the fire management plan, resulting in a science-based plan. The analysis will continue to improve and evolve as other factors, such as slope, aspect, and elevation, are incorporated into the model. Additionally, the completion of a modern vegetation map for the park will better reflect current vegetative conditions, and the analysis will be updated annually based on future fires.

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