Fires in Previously Burned Areas: Fire Severity and Vegetation Interactions in Yosemite National Park

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Abstract

In 2009, four fires occurred in Yosemite National Park in extensive areas that had burned in the 1990s. In some high severity areas resulting from these fires, a vegetation type conversion from lower and upper montane pine and fir forests to montane chaparral communities occurred. Questions arose from resource managers and the public regarding whether the park should reintroduce fire into those areas. This analysis evaluates the effect that the 1990s fires had on vegetation and the severity of the 2009 fires. In particular, areas that resulted in high severity in the first fires shaped vegetation and, therefore, the severity distribution of the subsequent fires. With external factors such as climate change, population growth, and air quality concerns affecting how Yosemite implements federal fire policy, the park can use this information to evaluate and manage fires in a more effective manner.

Introduction

Yosemite National Park covers 747,955 ac of the central Sierra Nevada in California, and varies from 2,000 ft in the west to 13,000 ft along the crest of the range. The elevation profile from west to east produces distinct vegetation communities. Lower montane forests occur between 2,000 and 6,000 ft, upper montane forests from 6,000 to 8,000 ft, and subalpine forests from 8,000 ft to tree line at 11,000 ft.

The Mediterranean climate of Yosemite is characterized by warm, dry summers and cool, wet winters with precipitation primarily occurring between November and April. However, a monsoonal flow from the southeast, south, and southwest creates numerous thunderstorms, and is responsible for lightning and rain in the summer. At the lower elevations, where burnable vegetation is abundant, lightning is less frequent. The converse is true for the higher elevations: abundant lightning, sparse vegetation. In Yosemite and the Sierra Nevada, lightning ignited fires will burn fire-adapted and dependant vegetation every year (van Wagtendonk et al. 2002, van Wagtendonk and Fites-Kaufman 2006, van Wagtendonk and Cayan 2008).

Fires that have not burned since the start of park's fire history dataset, dating back to 1930, or burn areas that have missed more than three return intervals, are considered first entry. Subsequent, or second entry, fires that burn within the initial fire footprints interact based on fire

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severity and vegetation. The first entry burns can influence the vegetation and subsequent severity of future fires. Severity is defined by the amount of environmental changed caused by fire, or how the vegetation responds to fire.

Methods

Severity data. Satellite imagery compiled by Thode (2005) and Miller and Thode (2007) was used to determine fire severity for all fires between 1974 and 2003. They used Landsat Multitemporal Spectral Scanner (Landsat MSS) imagery to map the severity of all fires greater than 100 ac in the Sierra Nevada between 1974 and 1983, using the normalized difference vegetation index (NDVI). They used Landsat Thematic Mapper (Landsat TM) imagery to map fires from 1984 through 2003, using the differenced normalized burn ratio (dNBR). To account for heterogeneity of pre-fire vegetation among fires, relative measures of fire severity were used: the Relative differenced NBR (RdNBR) for fires mapped with Landsat TM, and the Relative NDVI (RNDVI) for fires mapped with Landsat MSS (Thode 2005, Miller and Thode 2007). Since 2004, for fires greater than 100 ac, the park used the USGS Monitoring Trends in Burn Severity (MTBS) program (Eidenshink et al. 2007). The severity thresholds determined by Thode (2005) between severity levels in the RdNBR data were used to distinguish unchanged, low, moderate, and high severity areas.

Vegetation data. The vegetation in Yosemite was mapped in the 1930s and 1990s. Field surveys for the first map were conducted between 1932 and 1936, as part of an effort to map areas of continuous forest cover throughout California (Wieslander 1935). The second map was completed in 1997, using plot data and aerial photography (Keeler-Wolf et al. 2011). Both maps indicated dominant overstory and understory species, and were entered into a geographic information system (GIS) by the park (van Wagtendonk et al. 2002).

Data analysis. The severities of first entry burns were initially clipped, using ArcGIS (Environmental Systems Research Institute, Redlands, CA), to the extent of the second entry fire, to provide an analysis with the reburned areas for each subsequent fire. The severity of the first fire was compared to the severity of the second fire to determine how the initial fire influenced the subsequent fire. The vegetation that burned in the second fire was also compared to that fire's severity to determine which vegetation types resulted in any given severity category.

Results

The A-Rock and Steamboat fires of 1990, and the 1996 Ackerson fire were three of the largest fires in park history (Figure 1). August thunderstorms ignited these unprecedented fires in the western part of Yosemite. Large areas of ponderosa pine, white fir, and red fir were burned in crown- or canopy-fires, which converted the habitat to chaparral, dominated by species of ceanothus and manzanita.

In 2009, fires reburned parts of all three of these large burned areas (Figure 1). The Cottonwood and Harden fires reburned entirely within the footprint of the Ackerson fire, the Grouse fire reburned a portion of the Steamboat fire extent, and the Big Meadow fire reburned part of the area the A-Rock fire burned. The Big Meadow fire also burned part of the 1988 Walker fire burned area, and a prescribed burn completed the reburn of the Walker fire extent in 1980. A 1979 prescribed burn was almost completely reburned by the A-Rock fire, except for a small area that was then reburned by the Big Meadow fire. Additionally, there were areas that the Big Meadow fire burned that had not burned in over 100 years.

All acres reported here were generated from the GIS analysis. Figure 2 breaks down each fire in terms of severity, by the initial fire and the subsequent fire. The "total" row for each analysis is the number of acres in each severity category for the first fire, each "total" column relates to the acres in each severity class for the 2009 fire year. The "unburned" column lists the acres that

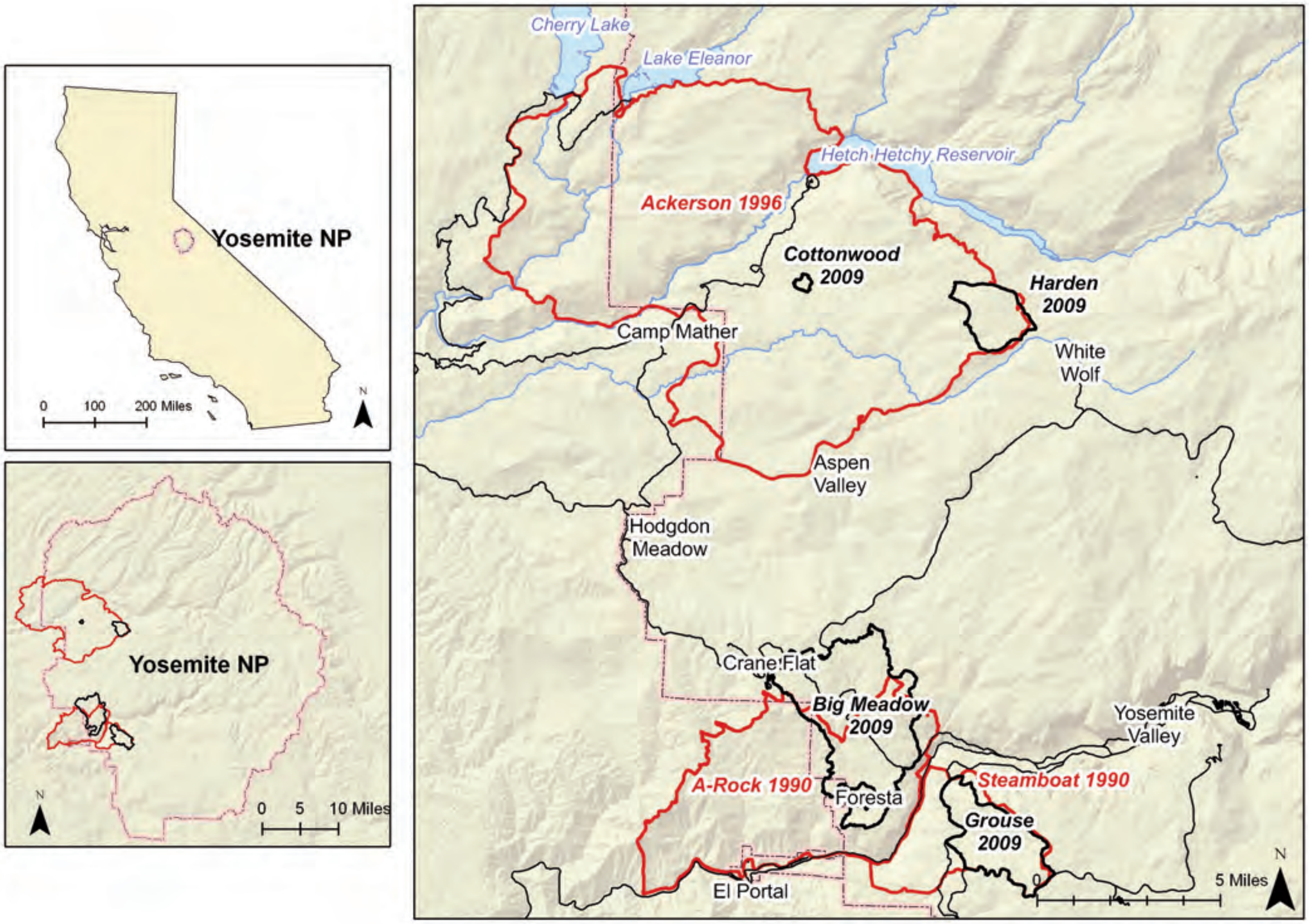

Figure 1. Vicinity map showing California, Yosemite, and fires. A-Rock and Steamboat fires burned over 13,000 ac of the park in 1990 and Ackerson burned nearly 47,000 park ac in 1996. The fires of 2009 burned a total of 12,200 ac.

burned in the subsequent fire, but not in the initial fire. The rest of the data report how many acres of each category in the first fire relate to how many acres resulted in each class of the second fire. For example, in the Cottonwood fire, 2 ac that resulted in low in the Ackerson fire resulted in unchanged in Cottonwood fire. Figures 3 and 4 show the severity of the initial Ackerson fire and the severity of the subsequent Harden fire.

Cottonwood, Grouse, and Harden fires. The 2009 Cottonwood fire reburned 94 ac of the Ackerson fire from May 18th to 25th. While the Ackerson fire had 44 ac that resulted in high severity, the Cottonwood fire only had 3 ac. The majority of Cottonwood resulted in low severity (Figure 2). The majority of the vegetation burned was ponderosa pine (45 ac) and chaparral (39 ac). Ponderosa pine resulted in the 3 ac of high severity.

The 2009 Grouse fire was ignited on May 30th, but did not grow in size until the last week of June when weather conditions were conducive to fire growth. By July 11th, the Grouse fire had grown to 3,067 ac, reburning 3,026 ac of the 1990 Steamboat fire. Even though the severity distribution was similar between the two fires, there was a shift in severity from unchanged to low and from low to moderate from the Steamboat fire to the Grouse fire. It is worth noting, though, that the majority of high for the Grouse fire came from the high from the Steamboat fire (Figure 2). The two widely burned vegetation types in the Grouse fire were red fir (908 ac) and white fir (820 ac). However, the chaparral resulted in the largest amount of high severity: 184 out of 396 ac (46%). This represented 62.5% of all high severity acres.

2009 fire	2009 severity	1980 - 1996 severity (acres)					
		Unch	Low	Mod	High	Unbrnd	**Total**
Cottonwood/Ackerson	Unchanged	0	2	1	3	0	**6**
	Low	0	20	12	29	0	**61**
	Moderate	0	3	10	11	0	**24**
	High	0	1	1	1	0	**3**
	Total	**0**	**26**	**24**	**44**	**0**	**94**
Grouse/Steamboat	Unchanged	159	157	54	5	13	**388**
	Low	390	704	152	15	18	**1,279**
	Moderate	164	510	304	119	9	**1,106**
	High	10	48	58	177	1	**294**
	Total	**723**	**1,419**	**568**	**316**	**41**	**3,067**
Harden/Ackerson	Unchanged	43	159	54	9	9	**274**
	Low	23	304	117	16	17	**477**
	Moderate	3	129	200	77	10	**419**
	High	1	14	146	251	0	**412**
	Total	**70**	**606**	**517**	**353**	**36**	**1,582**
Big Meadow/ A-Rock and Walker	Unchanged	18	31	71	114	0	**234**
	Low	59	217	168	236	0	**680**
	Moderate	95	318	514	906	0	**1,833**
	High	28	70	282	1,195	0	**1,575**
	Total	**200**	**636**	**1,035**	**2,451**	**0**	**4,322**
Big Meadow/1979 & 1980 Rx	Unchanged	9	28	16	0	14	**67**
	Low	110	358	281	0	13	**762**
	Moderate	127	483	621	0	0	**1,231**
	High	29	77	220	0	0	**326**
	Total	**275**	**946**	**1,138**	**0**	**27**	**2,386**
Big Meadow/previously unburned	Unchanged					11	**11**
	Low					211	**211**
	Moderate					350	**350**
	High					268	**268**
	Total					**840**	**840**
Big Meadow total	Unchanged	27	59	87	114	25	**312**
	Low	169	575	449	236	224	**1,653**
	Moderate	222	801	1,135	906	350	**3,414**
	High	57	147	502	1,195	268	**2,169**
	Total	**475**	**1,582**	**2,173**	**2,451**	**867**	**7,548**

Figure 2. Number of acres resulting in severity classes. The columns report the resultant acres of severity for the initial fires, and the rows report the resultant acres of severity for the subsequent fires. The unburned column shows acres that burned in the subsequent fire but not in the initial fire. The total column reports the total acres the severity for the initial fires, and the column row reports the total acres for severity of the subsequent fires.

The 2009 Harden fire, ignited on June 8th, remained small until the end of June, and was declared out on July 11th. Both the Grouse and the Harden fires were managed with fire personnel herding the fire to predetermined and established boundaries. The Harden fire reburned of 1,546 ac of the Ackerson fire, as well as 36 previously unburned acres. There was much less unchanged vegetation in the Ackerson fire than in the Harden fire. The severity distribution of

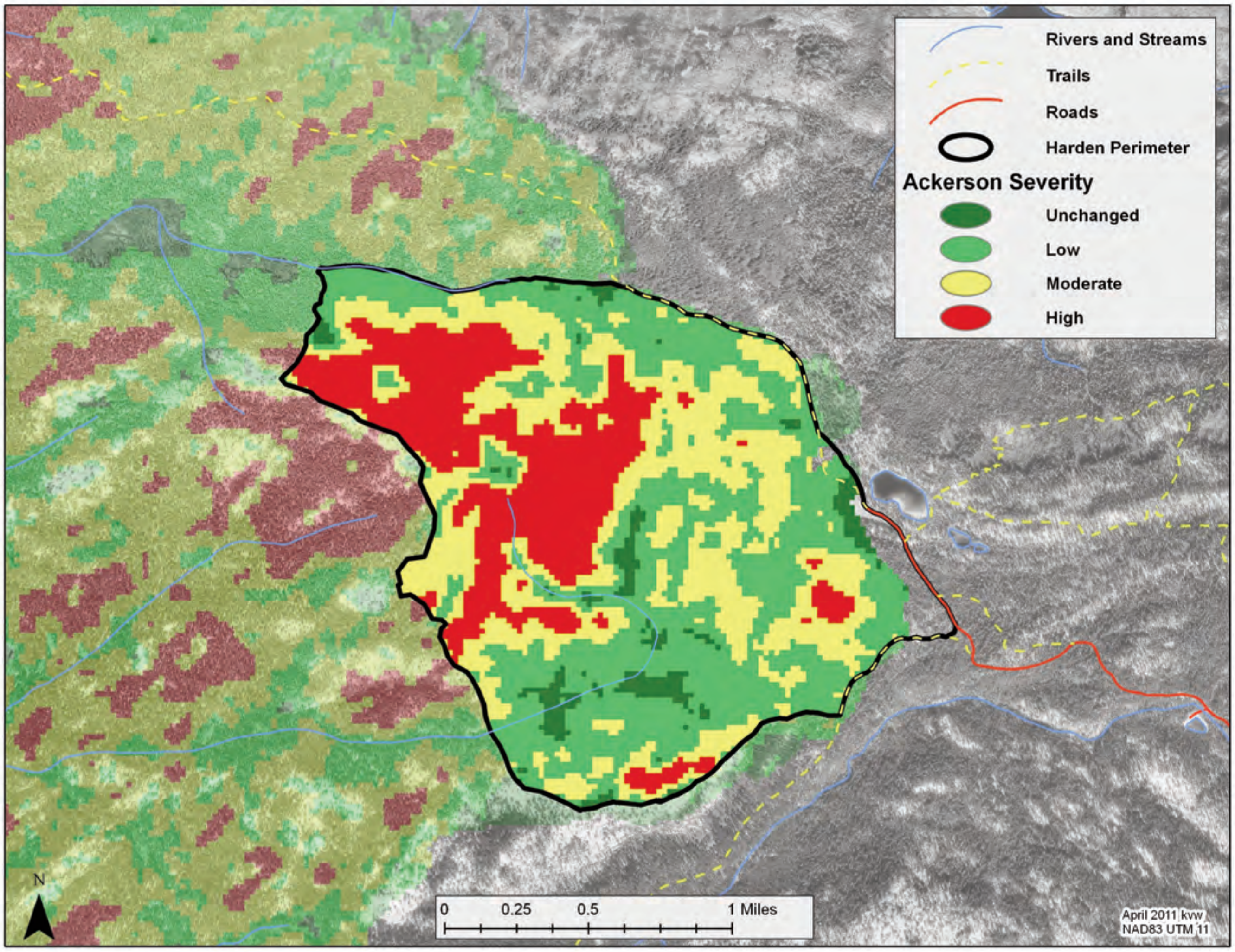

Figure 3. Map of the 1996 Ackerson fire severity. The dark green areas represent unchanged severity, light green low severity, yellow moderate severity, and the red symbolizes areas that resulted in high severity. The 2009 Harden fire perimeter is shown for reference.

the other classes is similar. However, it is interesting to note that the majority of high severity in the Harden fire came from areas of moderate and high severity from the Ackerson fire (Figure 2). Red fir (1,035 ac) and chaparral (434 ac) are the dominate vegetation types within the Harden footprint. The resulting high severities were 105 ac and 300 ac respectively. For red fir, this was 10% and for chaparral 69% of the area of each of those vegetation types. In terms of percentage of high severity acres, red fir accounted for 25% with chaparral making up 73%.

Big Meadow fire. The 2009 Big Meadow was a management-ignited prescribed burn conducted on August 26th. The intent of the burn was to treat 91 ac of Big Meadow. However, the fire escaped control lines, and by September 4th, it had burned 7,548 ac (Figure 2). Of those acres, 2,386 had burned in a 1980 prescribed burn, 361 in the 1988 Walker fire, and 3,961 in the 1990 A-Rock fire. Eight hundred forty acres burned in the Big Meadow had not previously burned. There was an additional prescribed burn completed in 1979; the A-Rock fire reburned all but 27 ac of that earlier burn. The reburn analyses of A-Rock fire and this prescribed burn were completed, but not included because it did not influence the behavior, intensity or resultant severity of A-Rock fire. Most of the area of the 1979 prescribed burn, regardless of initial severity (mostly unchanged and low), resulted in high severity when reburned by the A-Rock. The

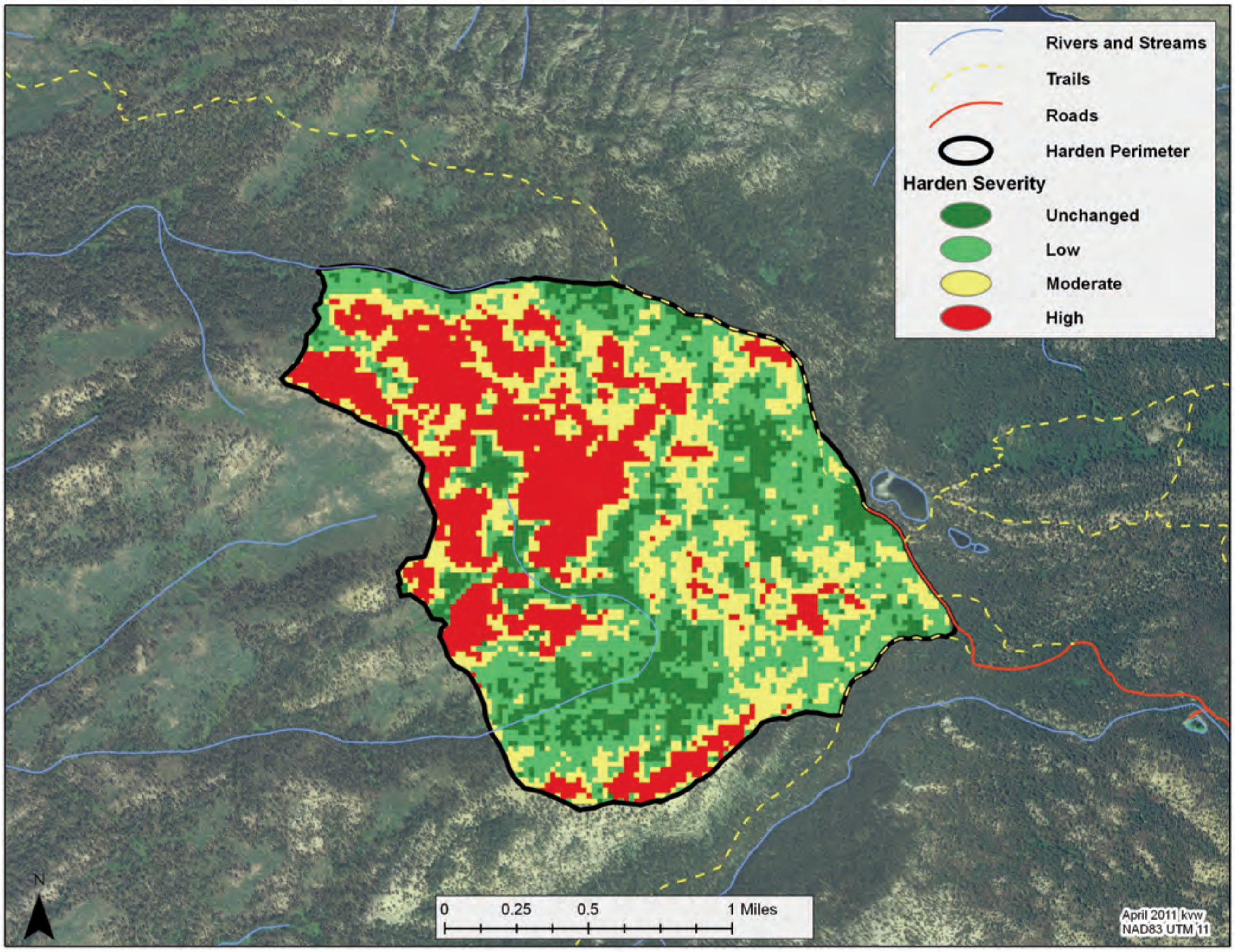

Figure 4. Map of the 2009 Harden fire severity. The dark green areas represent unchanged severity, light green low severity, yellow moderate severity, and the red symbolizes areas that resulted in high severity.

severity of the Big Meadow fire was skewed toward moderate and high severity. This was true in the areas that were burned by the Walker and A-Rock fires, as well as in the previously unburned areas, and to some extent in the area previously burned by the prescribed fire (Figure 2).

The two dominate vegetation types that burned in the Big Meadow were white fir and chaparral with 1,891 and 1,760 ac respectively. Other species of note are ponderosa pine, red fir, and live and black oak. Chaparral had the most acres resulting in a high severity burn, with 967 ac, or 55% of that vegetation type. This accounted for 44.5% of all high severity acres. White fir had the second largest amount of acres resulting in high severity with 376, or 20% of that vegetation type. This represented 17% of all high severity acres. Live oak had the second largest percentage resulting in high severity within its vegetation type with 177 out of 454 ac (39%), making up 8% of all high severity acres.

Discussion

In areas of high severity that are now chaparral, early season burns could be used to reduce the large amount of coarse woody debris that remain, either standing or fallen, from the first entry fire. The Cottonwood fire is a good example of how areas of high severity in the initial fire converted ponderosa pine to chaparral, but then when reburned; it did not result in high severity.

The in-season burns, however, show that areas of high severity in the first entry burn subsequently reburned with high severity. For example, a patch of forest that had burned with high severity might be replaced with shrubs that will subsequently burn with a high severity stand replacing crown fire (Collins and Stephens 2010). As a result, the high severity patch is perpetuated by the change in vegetation.

In the footprint of the Big Meadow fire, the previous wildfires of 1988 and 1990 also converted extensive areas of pine and fir to chaparral in those areas that resulted in high severity. These areas resulted in high severity when reburned by the Big Meadow fire. Additionally, in the areas that had not previously burned, resulting moderate and high severity acres made up the majority of area burned by the Big Meadow fire. Conversely, subsequent high severity was lower in areas that had previously been prescribe burned, because and the fire did not burn into the canopy. Therefore, prescribed burn areas were, in subsequent burns, had only a small acreage of high severity burn.

Frequent resultant high severity in these type converted landscapes could lead to a permanent shift from pine and fir to chaparral. This is especially true if the climate changes allowing fires to start earlier, last longer, and grow large (Westerling et al. 2006). However, early season burns can allow for the large coarse woody debris to be consumed and, in Yosemite, typically burn with unchanged or low severity. Wildfires, which usually do not burn under prescribed conditions, burn with moderate and high severity (van Wagtendonk and Lutz 2007). Using prescribed fire or natural lightning ignitions to burn under prescribed conditions can effectively reduce fuels and the probability of large, unprecedented fires that may lead to a change in vegetation types.

A transitory fire fuel type was created after the large fires of the 1990s, as a result of high severity. The type conversion from lower and upper mixed conifer that has occurred over the past 15 to 20 years has resulted in homogeneous patches of tall and compact ceanothus and manzanita, growing among the standing snags and fallen logs created by the initial fire. Yosemite has thousands of acres of this fuel type as a result of the high severity of fires in the past 40 years. Since 1972, the park has attempted to restore fire as a landscape level ecosystem process that was excluded for decades (van Wagtendonk 2007). The goal had been, and continues to be, to avoid the large, unprecedented fires that lead to type conversions from timber to chaparral, as seen by the A-Rock, Steamboat, and Ackerson fires. The park now has severity data for first entry burns, vegetation data from 1997, and severity data for second entry burns. New lightning ignited fires that occur in areas that resulted in high severity in previous years can be assessed by park managers when deciding a course of action for fire management.

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