Research Article

Factors Associated with the Severity of Intersecting Fires in Yosemite National Park, California, USA

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ABSTRACT

In 1972, Yosemite National Park established a wilderness fire zone in which lightning fires were allowed to run their courses under prescribed conditions. This zone was expanded in 1973 to include the 16 209 ha Illilouette Creek basin, just to the southeast of Yosemite Valley. From 1973 through 2011, there have been 157 fires in the basin. Fire severity data were collected on all 28 of those fires that were larger than 40 ha. The proportion burned in each fire severity class was not significantly associated with fire return interval departure class. When areas were reburned, the proportion of unchanged severity fire decreased while the proportion of high severity fire increased. The proportion of fire severity of the subsequent fires was associated with the number of years since last burned, the burning index, and the severity of the previous fires. The main effects were significant for unchanged severity and low severity, and the interaction between return interval class and burning index class was significant for high severity. Most vegetation types remained the same when burned with unchanged, low, or moderate severity, while high severity often resulted in conversion to montane chaparral. The factors that were associated with reburn severity worked in combination with each factor influencing some aspect of severity. Managers and scientists can use this information to better understand the role fire plays in these ecosystems and how to best manage this dynamic ecological process.

Keywords: climate change, fire severity, Sierra Nevada, vegetation change, Yosemite National Park

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INTRODUCTION

Fire has been an ecological factor in the Sierra Nevada of California, USA, for millennia (Swetnam 1993). The establishment of Yosemite National Park in 1890 brought efforts to suppress all fires, regardless of cause (van Wagtendonk and Lutz 2007). As a result, there was a dramatic decline in fires recorded by scarred trees and an increase in the return interval between fires (Wagener 1961, Kilgore and Taylor 1979, Swetnam 1993, Scholl and Taylor 2010). The cessation of burning led to the accumulation of fuel on the forest floor and to an increase in shade tolerant trees in the understory (Biswell *et al*. 1968, Dodge 1972, van Wagtendonk 1974, Scholl and Taylor 2010). These effects were most pronounced in the lower montane forests where growing conditions were best and fire return intervals (FRI, the number of years between fires) were historically short. Fires that did escape suppression action were large, burned intensely, and resulted in high severity (van Wagtendonk 2007). In addition, recent changes in climate may have made these fires more intense and severe than they would have been historically (Westerling *et al*. 2006, Lutz *et al*. 2009, Miller *et al*. 2009)

In an effort to manage fires from an ecological perspective, Yosemite finalized a fire management plan in 2004 based on historic fire return intervals and the magnitude of departures from the historic intervals for each vegetation type (van Wagtendonk *et al.* 2002). Fire return interval departure (FRID) is defined as the number of historic fire return intervals since a vegetation type has burned. Fire return interval departure is a quantification of the difference between historic and current fire frequencies at the biophysical or stratum scale, as used in the analysis of fire regime condition classes (Hann and Bunnell 2001, Schmidt *et al*. 2002, NIFTT 2010). The rationale for using FRID in the plan is that the greater the departure from historic conditions, the more fuel would have accumulated and the more severe fires would become. Generally, all fires had been suppressed in areas in the lower montane and foothill zone where, as a result of fire exclusion, return interval departures often became three departures or higher. Prescribed fires have been used in these vegetation zones since 1970 to reduce fuels and to restore historic conditions. Beginning in 1972, lightning caused wilderness fires have been allowed to burn with little or no management intervention in most of the upper montane, subalpine, and alpine zones, where departures have generally been two or fewer times the historic return intervals.

Concern about the effect of climate change on wildland fires has prompted several regional and local studies. McKenzie *et al*. (2004) felt that, at the regional scale, extreme fire weather was still the dominant influence on area burned and fire severity. Westerling *et al*. (2006) concluded that, after the mid 1980s, wildland fire activity in the western US had increased, with more prevalent large fires, longer fire durations, and longer fire seasons. Across Forest Service lands in the Sierra Nevada and the southern Cascade Mountains in California and Nevada, Miller *et al*. (2009) found that the area burned annually, the size of the fires, and the extent of high severity stand-replacing fires had increased noticeably since the 1980s. They attributed these trends to a regional rise in temperature and a long-term increase in precipitation, and suggested that forest fuels no longer limit fire occurrence and behavior. Similarly, in Yosemite National Park, Lutz *et al*. (2009) found that the average annual area burned by lightning-ignited fires from 1984 to 2005 was more than two times that that burned from 1972 to 1983. Fire severity increased with annual area burned and was related to years of lower snowpack. However, in an area of the park where lightning fires had been allowed to burn, Collins *et al*. (2009) found a relative stability in the proportion of area burned among fire severity classes.

To further complicate matters, fires can cause vegetation changes that can influence the severity of subsequent fires. For example, a patch of forest that had burned with high severity might be replaced with shrubs that subsequently reburn 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. Similarly, van Wagtendonk (2012) found that some high severity areas reburned with high severity when vegetation was converted from lower montane forests to montane chaparral.

Questions remain about the relative roles of fuel, vegetation, and climate in determining fire severity. The first fires to burn in areas where fire has been excluded for decades are likely to encounter fuels that have accumulated during that time and could be more severe because of the added fuel. Alternatively, that increase in severity might be a result of interactions between climate, vegetation, and fire in spite of accumulated fuels. To answer these questions, more info is needed about reburned areas in which surface fuels have been reduced by previous fires.

Only a few studies of reburn severity are available for the US. Thompson (*et al*. 2007) studied an area in southern Oregon that reburned after 15 yr. They showed that areas that burned severely tended to reburn severely, and that these areas were largely montane chaparral (Thompson and Spies 2010). Areas with large conifer canopies that burned at lower severities tended to reburn at lower severities 15 yr later. Holden *et al*. (2010) investigated 13 fires that reburned areas of the Gila Aldo Leopold Wilderness Complex in New Mexico, USA, between 1984 and 2004. They found that the severity of reburned areas was sensitive to the severity of the original fire. and varied by vegetation type and the time elapsed between fires. Additionally, Godwin and Kobziar (2011) investigated two overlapping wildfires in Florida and found that higher severity fire led to lower severity or unburned conditions of subsequent fires, while low severity fire had a less pronounced impact in either preventing or reducing the severity of subsequent fires.

The Illilouette Creek basin just southeast of Yosemite Valley is an area where multiple fires have been studied since 1974 (van Wagtendonk 1978). Collins and Stephens (2007) cross dated 420 trees in the basin and calculated a mean point fire return interval of 6.3 yr for the period between 1700 and 1900. Based on scars recorded between 1973 and 2000, they concluded that the number and extent of fires during that period approached historical levels. Collins *et al*. (2009) looked at the thresholds for reburns for 19 fires that occurred in the Illilouette Creek basin of Yosemite National Park in 2001 and 2004, and at the reburn severities in the portions of those fires that had burned twice. They examined the effects of the interval between fires and the burning index (BI), a component of the National Fire Danger Rating System (NFDRS) that measures energy release and rate of spread and is linearly related to flame length (Deeming *et al*. 1977). They concluded that the spread of fires in the basin was limited when the burning index was less than 34.9 or when the interval between fires was less than nine years. Reburns were more likely when those values were exceeded. Although they found no trend in the proportion of high severity when comparing 10 yr periods since 1974, they did find that the proportion of high severity was greater when the burning index was 34.9 or higher. Collins *et al*. (2009), however, did not look at the numerous other fires in the basin that had reburned.

Multiple fires have burned within the Illilouette Creek basin since 1973, when it was placed in the wilderness fire zone—a period long enough to investigate the effects of fuel, climate, and vegetation on fire severity (Figure 1). These fires have burned together into a jigsaw pattern and either went out when they encountered a previous burn or reburned with re-

Figure 1. The 2001 Hoover Fire burned over several previous burns in the Illilouette Creek basin. The gray smoke in the center middle ground is coming from an area that had not burned for 27 years. The area in the left foreground burned in the 1991 Ill Fire, and the light green area near the lower right edge is montane chaparral that burned in the 1974 Starr King Fire.

duced intensity (van Wagtendonk 2007). Fire severity data are available beginning in 1974, as are fire return interval departure (FRID) maps. Weather and climate data are available for a station comparable in elevation to the basin, and two vegetation maps compiled in 1937 and 1997 allow before- and after-burning comparisons to be made.

Our objective was to determine what factors were associated with the fire severity of reburns in the Illilouette Creek basin as detected by satellite imagery. Specifically, we hypothesized: 1) that increases in fire return interval departure would result in increases in fire severity; 2) that increases in the number of times an area burned over the past 39 years would result in decreases in fire severity; 3) that the more severe the fire weather at the time of burning, the greater the increase in fire severity; 4) that increases in the interval between fires would result in increases in fire severity; and 5) that the vegetation type at the time of reburning would have a variable effect on fire severity.

METHODS

Study Area

The Illilouette Creek basin comprises 16 209 ha in Yosemite National Park, California, USA (Figure 2). Elevations range from 1768 m at the brink of Illilouette Fall above Yosemite Valley to 3574 m at Merced Peak along the crest of the Clark Range. The basin has a moderate climate with hot, dry summers and cold, moist winters. Temperature ranges from a July maximum temperature normal (1971 to 2000) of 28 °C at the lowest elevations to a January minimum temperature normal of −11 °C at the Clark Range crest. Annual precipitation averages 1193 mm, with most precipitation falling as snow (Daly *et al*. 2002, Daly 2006).

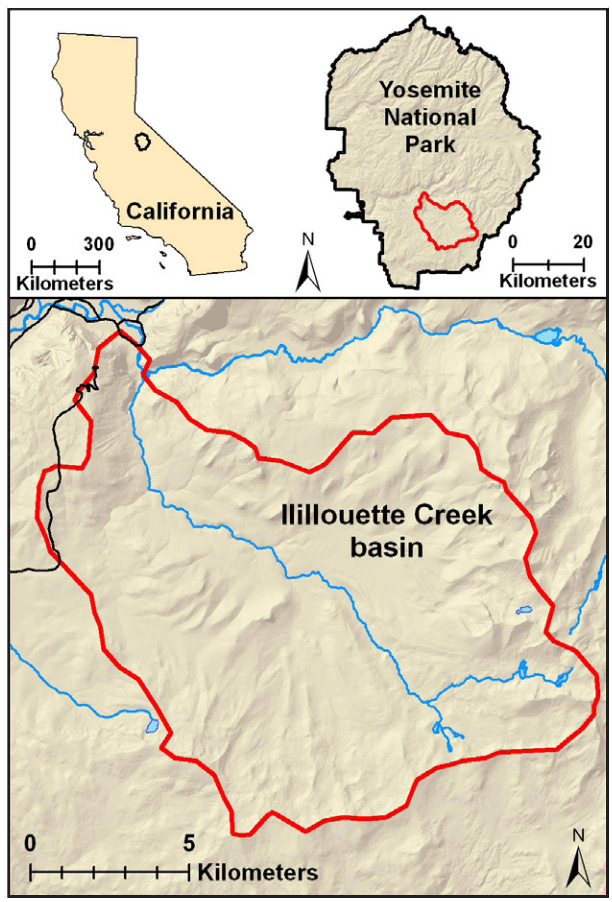

Figure 2. The Illilouette Creek basin is located in the south central part of Yosemite National Park, California, USA.

Fire regime attributes have been described for the vegetations types that occur in the Sierra Nevada (van Wagtendonk and Fites-Kaufman 2006). At the lowest elevations, the lower montane zone (7.7% of the basin) consists of a mix of ponderosa pine (*Pinus ponderosa* C. Lawson) and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), and white fir (*Abies concolor* [Gord. and Glend.] Lindl. ex Hildebr.). Low to moderate severity surface fires are relatively frequent in the lower montane zone. The majority of the basin is in the upper montane zone (52.3%) with white fir, Jeffrey pine (*P. jeffreyi* Balf.), red fir (*A. magnifica* A. Murray), and western white pine (*P. monticola* Douglas ex D. Don) as the dominant species, with quaking aspen (*Populus tremuloides* Michx.) and western juniper (*Juniperus occidentalis* Hook.) in scattered stands. Montane chaparral species include chinquapin (*Chrysolepis sempervirens* [Kellogg] Hjelmqvist), greenleaf manzanita (*Arctostaphylos patula* Greene), whitethorn (*Ceanothus cordulatus* Kellogg), snowbrush (*C. velutinus* Douglas ex Hook.), and huckleberry oak (*Quercus vaccinifolia* Kellogg). In the upper montane zone, fires vary in frequency and severity. Just above the upper montane zone, the subalpine zone (26.7%) contains lodgepole pine (*P. contorta* Douglas ex Louden), whitebark pine (*P. albicaulis* Engelm.), and mountain hemlock (*Tsuga mertensiana* [Bong.] Carrière). Fires are infrequent in the subalpine zone and, when they do occur, burn only small areas with low severity. The alpine zone (13.3%) includes meadows, willow (*Salix* sp. L.) patches, and extensive barren areas with sparse vegetation. No fires have occurred in the alpine zone.

Thode *et al.* (2011) created fire-regime types by grouping mapped vegetation types with similar fire regime characteristics. In areas that burned within the Illilouette Creek basin, they assigned white fir, red fir, and lodgepole pine to the low fire severity type; Jeffrey pine-western white pine to the moderate-low type; Jeffrey pine-shrub to the moderate type; and upper montane chaparral to the high type.

Data Sources

Fire perimeters for all fires that occurred in Yosemite since the 1930s have been mapped and digitized by the Park Service. From 1930 through 1972, 99 lightning fires were suppressed in the Illilouette Creek basin, burning only 27 ha. Since 1973, 157 fires have burned over 8000 ha in the basin, including 137 lightning fires, one management-ignited prescribed fire, and 19 human-caused fires.

The vegetation in Yosemite, including the Illilouette Creek basin, has been 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). Vegetation polygons were recorded on 30 minute US Geological Survey topographic maps (scale = 1:125 000) and rectified to current maps (scale = 1:24 000) by Walker (2000). The second map was completed in 1997 using plot data and aerial photography (scale = 1:15 860) (Keeler-Wolf *et al*. 2012). 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).

For the fire return interval departure analysis, we refined the method developed in Sequoia and Kings Canyon national parks by Caprio *et al.* (1997). Our analysis consisted of four steps: 1) vegetation polygons from both maps were combined into the four fire regime types found in the basin based on similar fuels and fire behavior (Thode *et al*. 2011); 2) historical median fire return intervals were assigned to each type (van Wagtendonk *et al*. 2002); 3) the number of years since an area last burned was determined from the fire perimeter maps; and 4) departures from the natural fire interval were calculated using the return interval (van Wagtendonk *et al*. 2002)

(Table 1). The fire return interval departure (FRID) is the absolute value of the fire return interval (FRI) minus the value of the current year (Y_c) less the year last burned (Y_b), all divided by the fire return interval (FRI):

$$FRID = \left|\left[FRI - \left(Y_c - Y_b\right)\right] \div FRI\right| \qquad (1)$$

Table 1. Vegetation types, fire severity regime types, and median fire return intervals used to define fire return interval departures for each type in the Illilouette Creek basin. Fire severity regimes are from Sugihara *et al.* (2006), vegetation type assignments are from Thode *et al.* (2011), and fire return intervals are from van Wagtendonk *et al.* (2002).

Vegetation type	Fire severity regime type	Median fire return interval (yr)
White fir	Low	8
Red fir	Low	30
Jeffrey pine-western white pine	Moderate-low	12
Jeffrey pine-shrub	Moderate	30
Upper montane chaparral	High	30
Lodgepole pine	Low	102

For areas that have not burned since 1930 in Yosemite, we used 1930 as the year last burned. Fire return interval departures were grouped into classes: from 0 to 1 fire return intervals were placed in Class 1 (low departure from the natural fire regime); departures 2 and 3 in Class 2 (moderate departure); and departures 4 and greater in Class 3 (high departure).

For our weather data, we used records from the Crane Flat weather station over the time each fire burned. Crane Flat is located 25 km WNW of the Illilouette Creek basin at a similar elevation (2022 m) and has a comparable climate (maximum temperature = 25 °C, minimum temperature = −2 °C, annual precipitation = 1053 mm). The weather variable most likely to affect future fire behavior and fire severity is temperature. Fireline intensity is the result of fuel moisture, topography, fuels, and wind; and fuel moisture is directly affected by temperature (Rothermel 1972). Fireline intensity is the rate of energy release per unit of fire flaming front and can be visualized through its relationship with flame length (Byram 1959) and the burning index (Deeming *et al*. 1977). The burning index combines the components of fire spread and energy release. We calculated daily ninety-fifth percentile burning index values for NFDRS fuel model H (short-needled conifers) for the period of time that the fire burned rather than the average daily burning index because peak weather has the greatest influence on fire behavior and effects. By averaging daily values over the duration of a fire (which was often two months or more), we would have diluted the influence of peak weather periods.

We obtained fire severity data for all 28 fires >40 ha that occurred in the Illilouette Creek basin from two sources. Thode (2005) compiled severity data from satellite imagery for all fires >40 ha in Yosemite National Park between 1973 and 1983 from the Normalized Difference Vegetation Index (NDVI). For fires between 1984 and 2003, she used the differenced Normalized Burn Ratio (dNBR). For fires >40 ha occurring after 2003, we requested data from the Monitoring Trends in Burn Severity program (MTBS) (Eidenshink *et al*. 2007). The MTBS provides severity data for all fires >405 ha in the western US and >202 ha in the eastern US going back to 1984; special requests can be made for smaller fires. Differences in NDVI and dNBR depend on the pre-fire vegetation, which varies by forest type and successional stage (Miller and Thode 2007). Therefore, we used the Miller and Thode (2007) relative Normalized Difference Vegetation Index (RNDVI) and relative dNBR (RdNBR). Thode (2005) concluded that there was minimal difference between severity maps derived from the RNDVI and RdNBR; thus, we felt that we could extend our analysis back to 1974. For both RNDVI and RdNBR, we used the thresholds determined by Thode (2005) to distinguish unchanged, low, moderate, and high severity areas. She classified areas within the fire history perimeters as unchanged if the severity was so low that she could not detect a change in the imagery one year post fire. Where remote sensing detected areas outside previously mapped perimeters that had burned, she added them to the burned area.

The 28 fires >40 ha burned a total of 16 722 ha and ranged in size from 46 ha to 3172 ha (Table 2). One of the fires was a planned prescribed fire, one was accidentally human-caused, and 26 were ignited by lightning. Sixteen fires that burned only once prior to 1997 were reburned between 1997 and 2011. Excluding the portions outside of the basin, the fires covered an area of 8187 ha, of which 4463 ha burned two times, 767 ha three times, 72 ha four times, and 4 ha five times (Figure 3a). Fire severity varied across the basin from unchanged to high (Figure 3b).

Data Analysis

We used a geographic information system and statistical linear models to analyze the various effects on fire severity. For the 28 fires used in the fire return interval departure analysis, we calculated the FRID for the year immediately prior to being burned the first time using the 1930s vegetation map for fires before 1997, and the 1997 vegetation map for fires from 1997 to 2011. We first aggregated the severity data by computing the total proportions of area burned among different severity classes for each fire by FRID class. Based on work by van Mantgem and Schwilk (2009), we felt that spatial autocorrelation would have a negligible effect. We then compared the proportions within each severity class using separate one-way ANOVAs with FRID class as the independent variable. We normalized all proportions using the arcsine square root transformation and applied $\alpha = 0.05$ to all significance tests.

Table 2. Fire severity data were collected from the 28 fires >40 ha in the Illilouette Creek basin in Yosemite National Park that burned between 1973 and 2011. One of the fires was a planned prescribed fire (Rx.), one was accidentally human-caused (Hum.), and 26 were ignited by lightning (Ltg.). The total area burned by those fires was 16 722 ha, of which 13 502 ha were in the basin. The maximum number of times reburned indicates how many times any portion of a fire was reburned. The 16 fires that burned only once prior to 1997 and were reburned a second time after 1996 are indicated by a "Yes" in the last column.

Name	Year	Cause	Area (ha)	Maximum times reburned	Reburned post 1996
Starr King	1974	Ltg.	1660	4	Yes
Surprise	1975	Ltg.	122	2	Yes
J. L.	1978	Ltg.	123	1	Yes
Hoover	1978	Ltg.	282	3	Yes
Twin Snake	1978	Ltg.	155	1	No
Fat Head	1980	Ltg.	608	3	Yes
Fat Chance	1980	Ltg.	259	2	Yes
Gordo	1980	Ltg.	119	1	No
Buena Vista	1981	Ltg.	946	3	Yes
The Rocks	1983	Ltg.	67	0	No
Sucker	1984	Ltg.	58	0	No
Glacier Point	1986	Hum.	291	1	No
Lost Bear	1987	Ltg.	827	2	Yes
Horizon	1988	Ltg.	286	1	Yes
Edson	1988	Ltg.	101	1	Yes
Alaska	1988	Ltg.	790	2	Yes
Panorama	1990	Ltg.	86	2	Yes
Ill	1991	Ltg.	1469	1	Yes
Ostrander	1992	Ltg.	175	1	No
Horizon	1994	Ltg.	1375	1	Yes
Adam	1996	Ltg.	108	1	Yes
Ill	1996	Ltg.	245	1	Yes
Lost Bear	1999	Ltg.	897	1	No
Lost Burnout	1999	Rx.	54	0	No
Hoover	2001	Ltg.	3147	0	No
Meadow	2004	Ltg.	2318	0	No
Buena Vista	2005	Ltg.	48	0	No
King	2006	Ltg.	106	0	No

For the reburn analysis, we compared the severity data for fires that reburned both once and twice. Portions of fires that reburned three and four times were not analyzed because there was insufficient area involved. We aggregated

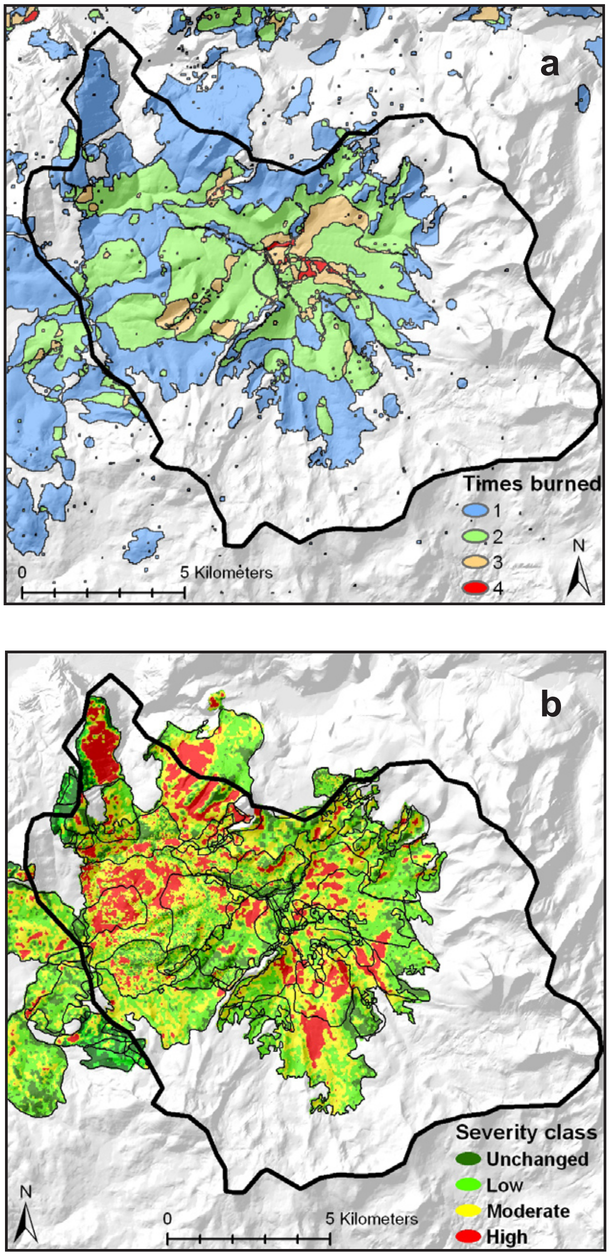

Figure 3. Fires in the Illilouette Creek basin burned to form a jigsaw pattern where some fires were limited by previous fires while others reburned extensive areas (a). The number of times burned is indicated for 28 fires greater than 40 ha from 1973 through 2011. Composite fire severity for the 28 fires greater than 40 ha in the Illilouette Creek basin from 1973 through 2011 (b). The severity of the last fire to burn an area is shown in colors, and perimeters for all 28 fires are shown in black.

the areas corresponding to different reburn severities (second and third fires) by each severity class of each previous fire (first and second fires, respectively). We used two-way ANCOVAs with the proportion in each severity class of the second or third fires as the dependent variables, the number of reburns as the independent categorical variable, and the severity of the first or second fire as the covariates. Severity levels were quantified by assigning 1 to unchanged, 2 to low, 3 to moderate, and 4 to high severity.

To discern the effects of weather at the time of burning, of interval between fires, and of severity of the initial fire on the severity of the second fire, we divided the fires into four groups based on Collins *et al*. (2009). Fires that reburned within nine years were separated from those that reburned after longer intervals, and fires that burned with burning indices less than 34.9 were separated from those with higher indices. For each second fire, we aggregated the fire severity by burning index class, return interval class, and severity class of the first fire. We then compared the transformed proportion burned within each severity class of the second fire using three-way ANCOVAs with burning index class and return interval class as categorical variables and fire severity of the first fire as the covariate.

In order to determine the effect of vegetation on fire severity, we first used the 1930s vegetation map to delineate vegetation types in the 16 fires that burned between 1973 and 1996. We then compared those vegetation types to the types in the same areas that were reburned by four fires between 1997 and 2011 using the 1997 vegetation map. Polygons of vegetation types that reburned less than a total of 10 ha were merged with adjacent vegetation types. If the types differed strongly, we attributed those changes to the fires. Because many of the combinations of fires and vegetation types resulted in very small or null areas, the data were not subjected to statistical analysis.

RESULTS

Fire Return Interval Departure

Out of the 13 493 ha that were analyzed, 6111 ha were in fire return interval departure Class 1, 3150 ha in departure Class 2, and 3002 ha in departure Class 3. An additional 1231 ha were classified as unburnable and were not included in the analysis. The proportion burned in each fire severity class was not significantly associated with fire return interval departure class. However, low severity made up the greatest proportion within all three departure classes, while high severity was the least in each departure class (Figure 4). Unchanged severity decreased and high severity increased slightly with increasing departure class.

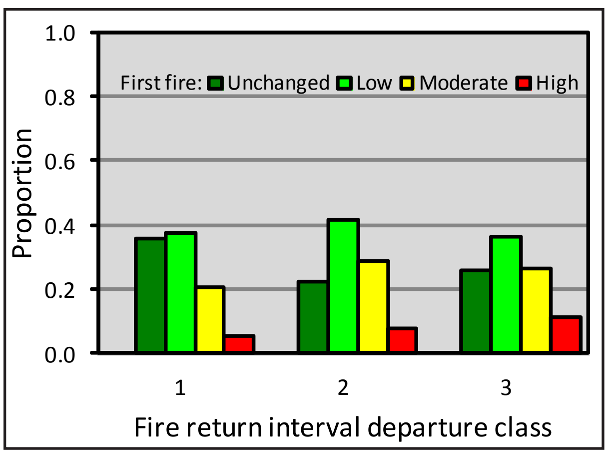

Figure 4. Proportion of area burned by first fires in each of three fire return interval departure classes. Fire Return Interval Departures from 0 to 1 were placed in Class 1 (low departure), departures 2 and 3 in Class 2 (moderate departure), and departures 4 and greater in Class 3 (high departure).

Reburn Fire Severity

When the proportions between the second and third fires were compared, there was a significant effect for unchanged and high severity ($F_{3,\ 73}$ = 4.41, P = 0.039; $F_{3,\ 73}$ = 7.57, P = 0.008). The proportion of unchanged severity was highest when the first fires were reburned by the second fires while the proportion of high severity was highest when the second fires were burned by the third fires (Figure 5a, b). There was no significant difference between the proportions of low and moderate severity when first and second fires were reburned by the second and third fires, respectively.

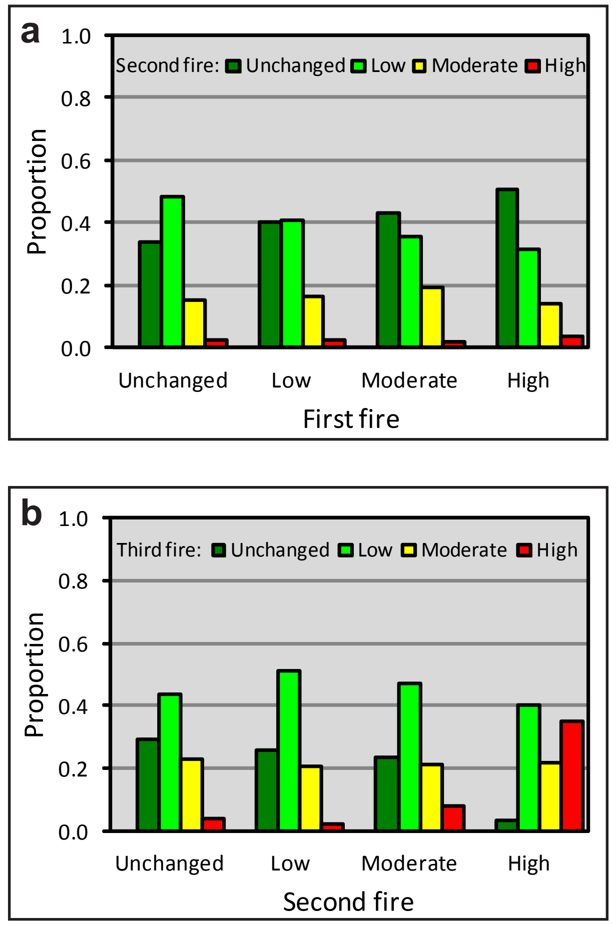

Figure 5. Proportion of area in severity classes for the first reburn (a) and the second reburn (b). The proportion of high severity for the subsequent fire increased when the severity of the initial fire was high.

The proportion of fire severity of the subsequent fires was associated with the number of years since last burned, the burning index, and the severity of the previous fires (Figure 6a, b, c, d). The main effects were significant for unchanged severity (FRI: $F_{1,\ 81}$ = 7.03, P = 0.010; BI: $F_{1,\ 81}$ = 4.49, P = 0.037; previous severity: $F_{1,\ 81}$ = 5.97, P = 0.017) and low severi-

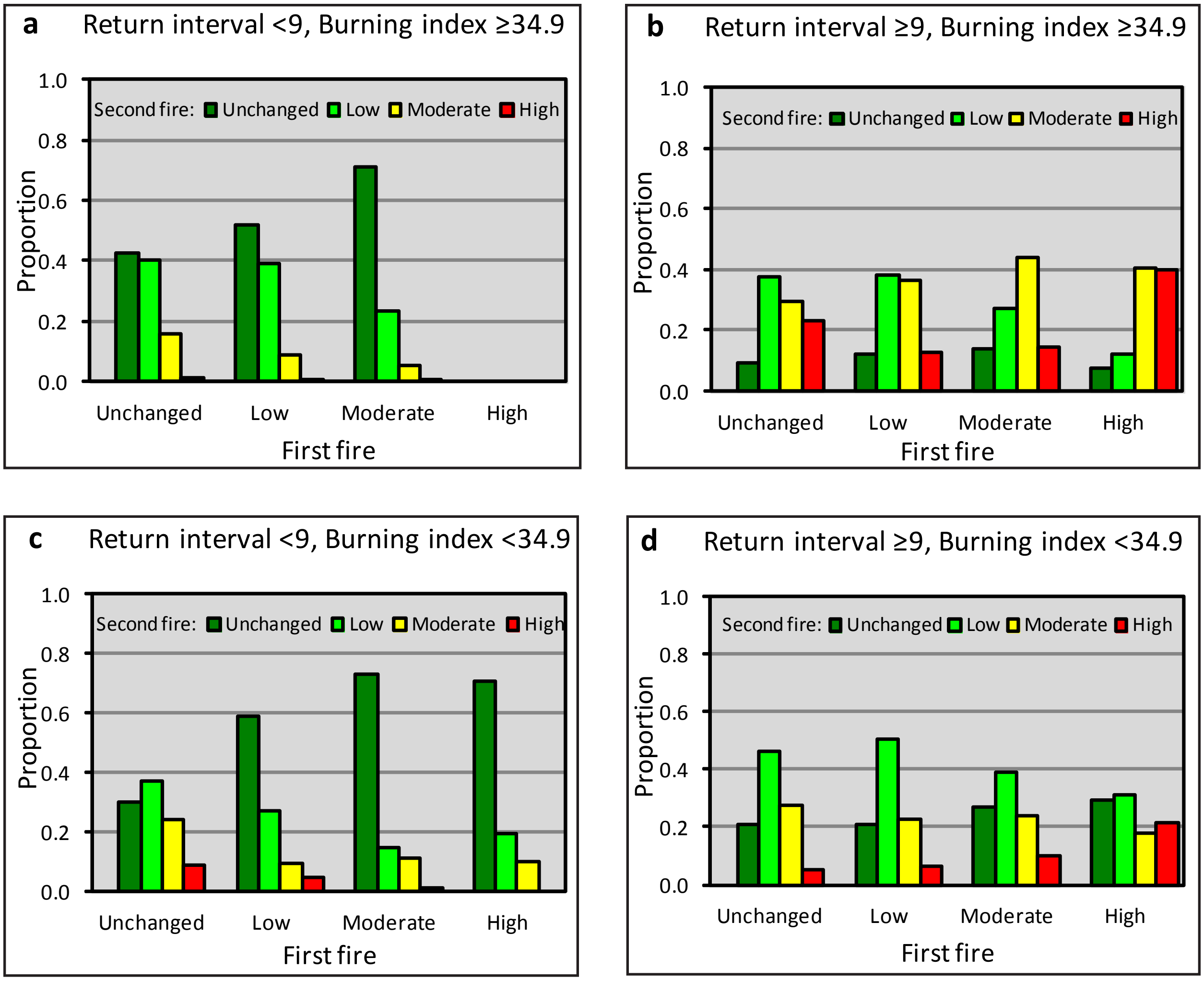

Figure 6. Proportion of area in severity classes of the first fires reburned by the second fires when (a) the fire return interval <9 and the burning index ≥34.9, (b) the fire return interval ≥9 and the burning index ≥34.9, (c) the fire return interval <9 and the burning index <34, and (d) the fire return interval ≥9 and the burning index <34.9.

ty (FRI: $F_{1, 81}$ = 5.48, P = 0.022; BI: $F_{1, 81}$ = 5.61, P = 0.020; previous severity: $F_{1, 81}$ = 3.97, P = 0.049). Only the interaction effect between return interval class and burning index class was significant for the proportion of high severity (FRI*BI: $F_{1, 81}$ = 8.49, P = 0.005). The combination of the two (high FRI and high BI) had a higher effect than the sum of the two main effects. This effect was most evident for the first fires that were reburned by the second fires with a return interval of nine years or greater, and a burning index of 34.9 or greater (Figure 6a). Those fires burned over five to ten times as much area as fires burning with shorter return intervals and lower burning indices (Table 3). When the second fires were reburned by the third fires, there was a similar pattern, although the differences in area burned were not as great (Table 3).

Pre-Fire Vegetation

Over 3000 ha of the 16 fires that burned between 1973 and 1996 were reburned once between 1997 and 2011. The fire regime types in those fires included white fir (117 ha), red fir (278 ha), Jeffrey pine-western white pine (1134 ha), Jeffrey pine-shrub (463 ha), upper

Table 3. Area in hectares of the first fires reburned by the second fires and second fires burned by third fires. Areas are categorized by Burning Index (BI <34.9 and BI ≥34.9) and Fire Return Interval (FRI <9 and FRI ≥9). Dashes mean that no area burned in the category and 0 indicates that the area in the category was less than 0.5 ha.

			Return interval <9					Return interval ≥9				
			Unchanged	Low	Moderate	High	Total	Unchanged	Low	Moderate	High	Total
			ha					ha				
			First fire									
Second fire	BI ≥34.9	Unchanged	36	55	20	-	111	70	137	159	18	384
		Low	34	41	7	-	82	280	434	317	29	1060
		Moderate	13	10	1	-	24	219	416	508	96	1239
		High	1	0	0	-	1	173	147	171	94	585
		Total	84	106	28	-	218	742	1134	1155	237	3268
	BI <34.9	Unchanged	9	44	34	3	90	22	53	112	14	201
		Low	11	20	7	1	39	50	130	161	15	356
		Moderate	7	7	5	0	19	29	59	99	8	195
		High	3	3	1	-	7	6	16	41	10	73
		Total	30	74	47	4	155	107	257	412	47	823
			ha					ha				
			Second fire									
Third fire	BI ≥34.9	Unchanged	5	4	1	0	10	22	32	13	2	69
		Low	17	11	3	0	31	73	78	23	3	177
		Moderate	15	9	2	-	26	55	72	51	9	187
		High	4	2	0	-	6	14	18	26	14	72
		Total	41	26	6	0	73	164	200	113	28	505
	BI <34.9	Unchanged	10	20	3	-	33	3	7	2	-	12
		Low	42	29	3	-	74	11	13	4	0	28
		Moderate	16	6	1	-	23	6	7	3	-	16
		High	0	-	-	-	0	1	2	1	-	4
		Total	68	55	7	-	130	21	29	10	0	60

montane chaparral (159 ha), and lodgepole pine (457 ha).

Most of the original white fir areas that burned with unchanged, low, and moderate severity areas remained white fir (Table 4). High severity usually resulted in upper montane chaparral, while some remained white fir. The severity of the second fire that reburned white fir areas after 1996 was primarily low or moderate, while the upper montane chaparral reburned with high severity.

The majority of red fir remained red fir after the first fire burned with unchanged, low, or moderate severity, although there was some Jeffrey pine-western white pine in the unchanged, low, and moderate areas (Table 5). Upper montane chaparral was the primary vegetation type to become established in high severity areas. When areas that were originally red fir were reburned by the second fire, it was primarily with low or moderate severity. Areas that had converted to the other types, primarily Jeffrey pine-western white pine, reburned with unchanged, low, or moderate severity.

Although a portion of the Jeffrey pine-western white pine type remained that type when initially burned with unchanged, low, or moderate severity, some converted to red fir (Table 6). In addition, those severities resulted in small amounts of white fir, Jeffrey pine-shrub, and upper montane chaparral. The area

Table 4. Reburned area in hectares of the white fir type based on the 1930s vegetation map by the initial fire severity level, resultant vegetation type, and subsequent fire severity level. Dashes mean that no area burned in the category and 0 indicates that the area in the category was less than 0.5 ha. Unch. = unchanged, and Mod. = moderate.

Resultant 1997 fire regime type	Subsequent (1997 to 2011) severity level	Initial severity level (1974 to 1996)				
		Unch.	Low	Mod.	High	Total
		ha				
White fir	Unch.	7	14	7	0	28
	Low	58	106	60	1	225
	Mod.	32	83	89	5	208
	High	55	24	9	1	90
	Total	152	227	165	7	551
Red fir	Unch.	1	1	1	–	3
	Low	15	0	1	–	16
	Mod.	6	1	2	0	9
	High	12	0	0	–	12
	Total	34	2	4	0	40
Jeffrey pine-western white pine	Unch.	0	0	1	0	1
	Low	0	1	1	0	2
	Mod.	–	0	2	0	2
	High	–	–	–	–	–
	Total	0	1	4	0	5
Jeffrey pine-shrub	Unch.	0	1	1	0	2
	Low	0	2	2	0	4
	Mod.	0	1	3	–	4
	High	1	0	0	–	1
	Total	1	4	6	0	11
Upper montane chaparral	Unch.	–	–	0	0	0
	Low	–	0	0	0	0
	Mod.	–	0	2	2	4
	High	–	0	2	10	12
	Total	–	0	4	12	16
Lodgepole pine	Unch.	–	–	–	–	–
	Low	–	–	–	–	–
	Mod.	0	–	–	–	0
	High	0	–	–	–	0
	Total	0	–	–	–	0
Grand total		187	234	183	19	623

Table 5. Reburned area in hectares of the original red fir type based on the 1930s vegetation map by the initial fire severity level, resultant vegetation type, and subsequent fire severity level. Dashes mean that no area burned in the category and 0 indicates that the area in the category was less than 0.5 ha. Unch. = unchanged, and Mod. = moderate.

Resultant 1997 fire regime type	Subsequent (1997 to 2011) severity level	Initial severity level (1974 to 1996)				
		Unch.	Low	Mod.	High	Total
		ha				
White fir	Unch.	–	–	–	–	–
	Low	–	0	1	–	1
	Mod.	0	0	2	–	2
	High	–	–	–	–	–
	Total	0	0	3	–	3
Red fir	Unch.	7	11	2	0	20
	Low	31	35	6	0	72
	Mod.	25	15	7	1	48
	High	11	5	4	1	21
	Total	74	66	19	2	161
Jeffrey pine-western white pine	Unch.	4	12	10	–	26
	Low	8	16	9	–	33
	Mod.	13	9	5	–	27
	High	1	0	0	–	1
	Total	26	37	24	–	86
Jeffrey pine-shrub	Unch.	1	0	0	–	1
	Low	2	2	1	–	5
	Mod.	3	3	2	–	8
	High	1	3	1	–	5
	Total	7	8	4	–	19
Upper montane chaparral	Unch.	0	–	0	0	0
	Low	0	0	1	0	1
	Mod.	1	0	1	1	2
	High	0	0	0	1	1
	Total	1	0	2	2	5
Lodgepole pine	Unch.	1	0	–	–	1
	Low	3	0	0	–	3
	Mod.	1	0	0	–	1
	High	–	–	–	–	–
	Total	5	0	0	–	5
Grand total		113	111	52	4	280

of high severity converted primarily to upper montane chaparral. Most of the post-1996 fire regime types reburned with low or moderate severity. However, some high severity fires did occur in each type.

Jeffrey pine-shrub remained the dominant fire regime type in areas originally burned with unchanged, low, and moderate severities (Table 7). Moderate severity also resulted in conversions to each of the other types except to

Table 6. Reburned area in hectares of the original Jeffrey pine-western white pine type based on the 1930s vegetation map by the initial fire severity level, resultant vegetation type, and subsequent fire severity level. Dashes mean that no area burned in the category and 0 indicates that the area in the category was less than 0.5 ha. Unch. = unchanged, and Mod. = moderate.

Resultant 1997 fire regime type	Subsequent (1997 to 2011) severity level	Initial severity level (1974 to 1996)				
		Unch.	Low	Mod.	High	Total
		ha				
White fir	Unch.	2	9	14	1	26
	Low	5	19	29	1	54
	Mod.	12	38	58	6	114
	High	6	12	17	3	38
	Total	25	78	118	11	232
Red fir	Unch.	12	16	7	0	35
	Low	66	77	34	0	177
	Mod.	17	31	29	1	78
	High	7	11	3	0	21
	Total	102	135	73	1	311
Jeffrey pine-western white pine	Unch.	10	20	21	1	52
	Low	28	30	23	3	84
	Mod.	20	24	29	3	76
	High	13	11	8	1	33
	Total	71	85	81	8	245
Jeffrey pine-shrub	Unch.	2	4	8	0	14
	Low	7	9	23	3	42
	Mod.	8	24	66	10	108
	High	3	8	11	3	25
	Total	20	45	108	16	189
Upper montane chaparral	Unch.	0	0	1	1	2
	Low	0	2	5	2	9
	Mod.	0	4	24	17	45
	High	0	0	21	32	53
	Total	0	6	51	52	109
Lodgepole pine	Unch.	1	2	0	–	3
	Low	3	5	2	–	10
	Mod.	2	14	4	–	20
	High	4	8	5	–	17
	Total	10	29	11	–	50
Grand total		228	378	442	88	1136

Table 7. Reburned area in hectares of the original Jeffrey pine-shrub type based on the 1930s vegetation map by the initial fire severity level, resultant vegetation type, and subsequent fire severity level. Dashes mean that no area burned in the category and 0 indicates that the area in the category was less than 0.5 ha. Unch. = unchanged, and Mod. = moderate.

Resultant 1997 fire regime type	Subsequent (1997 to 2011) severity level	Initial severity level (1974 to 1996)				
		Unch.	Low	Mod.	High	Total
		ha				
White fir	Unch.	0	2	5	0	7
	Low	1	4	6	0	11
	Mod.	3	5	13	2	23
	High	1	1	3	0	5
	Total	5	12	27	2	46
Red fir	Unch.	1	2	1	0	4
	Low	6	4	5	0	15
	Mod.	7	9	12	3	31
	High	5	4	8	1	18
	Total	19	19	26	4	68
Jeffrey pine-western white pine	Unch.	6	11	15	1	33
	Low	6	10	16	1	33
	Mod.	4	8	16	2	30
	High	0	0	2	0	2
	Total	16	29	49	4	98
Jeffrey pine-shrub	Unch.	5	10	17	2	34
	Low	5	11	18	2	36
	Mod.	14	20	33	2	69
	High	3	8	10	1	22
	Total	27	49	78	7	160
Upper montane chaparral	Unch.	0	0	5	8	13
	Low	1	1	5	7	14
	Mod.	1	1	13	16	31
	High	1	1	14	9	26
	Total	3	3	37	40	84
Lodgepole pine	Unch.	0	0	–	–	0
	Low	1	1	–	–	2
	Mod.	1	3	1	–	5
	High	1	0	1	–	2
	Total	3	4	2	–	9
Grand total		73	116	219	57	465

lodgepole pine. Areas of high severity were primarily converted to upper montane chaparral. Reburns after 1996 were primarily moderate in severity, with all severity levels occurring in each fire regime type.

In the upper montane chaparral fire regime type, Jeffrey pine-shrub dominated the areas burned with unchanged severity (Table 8). White fir came into areas burned with low and moderate severities, while high severity areas

Moderate and high were the most common fire severity levels for the second fire reburns, especially in the shrub and chaparral types.

The majority of lodgepole pine that burned with unchanged, low, and moderate severities was converted to red fir, although some remained as lodgepole pine (Table 9). Of the high severity areas, most were converted to upper montane chaparral. Areas of lodgepole pine that were converted after the original fire

Table 8. Reburned area in hectares of the original upper montane chaparral type based on the 1930s vegetation map by the initial fire severity level, resultant vegetation type, and subsequent fire severity level. Dashes mean that no area burned in the category and 0 indicates that the area in the category was less than 0.5 ha. Unch. = unchanged, and Mod. = moderate.

Resultant 1997 fire regime type	Subsequent (1997 to 2011) severity level	Initial severity level (1974 to 1996)				
		Unch.	Low	Mod.	High	Total
		ha				
White fir	Unch.	0	2	5	0	7
	Low	1	4	7	0	12
	Mod.	3	5	18	5	31
	High	2	1	4	1	8
	Total	6	12	34	6	58
Red fir	Unch.	0	0	0	–	0
	Low	0	1	1	0	2
	Mod.	3	1	4	1	9
	High	3	2	1	0	6
	Total	6	4	6	1	17
Jeffrey pine-western white pine	Unch.	–	0	0	0	0
	Low	–	0	1	0	1
	Mod.	1	3	1	0	5
	High	0	0	0	0	0
	Total	1	3	2	0	6
Jeffrey pine-shrub	Unch.	0	1	1	0	2
	Low	0	1	2	0	3
	Mod.	2	1	7	2	12
	High	11	3	3	6	23
	Total	13	6	13	8	40
Upper montane chaparral	Unch.	0	0	1	0	1
	Low	0	0	2	1	3
	Mod.	0	1	5	5	11
	High	4	3	6	9	22
	Total	4	4	14	15	37
Lodgepole pine	Unch.	–	–	–	–	–
	Low	–	–	–	–	–
	Mod.	–	–	–	–	–
	High	–	–	–	–	–
	Total	–	–	–	–	–
Grand total		30	29	69	30	158

Table 9. Reburned area in hectares of the original lodgepole pine type based on the 1930s vegetation map by the initial fire severity level, resultant vegetation type, and subsequent fire severity level. Dashes mean that no area burned in the category and 0 indicates that the area in the category was less than 0.5 ha. Unch. = unchanged, and Mod. = moderate.

Resultant 1997 fire regime type	Subsequent (1997 to 2011) severity level	Initial severity level (1974 to 1996)				
		Unch.	Low	Mod.	High	Total
		ha				
White fir	Unch.	0	0	0	–	0
	Low	1	2	1	0	4
	Mod.	0	3	2	0	5
	High	–	0	2	0	2
	Total	1	5	5	0	11
Red fir	Unch.	4	8	6	0	18
	Low	18	41	12	0	71
	Mod.	23	59	26	1	109
	High	14	15	10	1	40
	Total	59	123	54	2	238
Jeffrey pine-western white pine	Unch.	1	1	0	–	2
	Low	3	4	2	0	9
	Mod.	5	4	3	0	12
	High	4	3	2	1	10
	Total	13	12	7	1	33
Jeffrey pine-shrub	Unch.	–	–	–	–	–
	Low	0	0	–	–	0
	Mod.	1	0	0	–	1
	High	–	0	1	–	1
	Total	1	0	1	–	2
Upper montane chaparral	Unch.	–	0	0	1	1
	Low	0	1	1	1	3
	Mod.	0	2	9	3	14
	High	0	2	12	9	23
	Total	0	5	22	14	41
Lodgepole pine	Unch.	5	3	1	0	9
	Low	8	20	4	0	32
	Mod.	15	33	12	1	61
	High	9	18	3	0	30
	Total	37	74	20	1	132
Grand total		111	219	109	18	457

to red fir reburned with low and moderate severities, while upper montane chaparral reburned with moderate and high severities. Areas that remained lodgepole pine reburned with moderate severity.

DISCUSSION

Fire Return Interval Departure

The severity of fires that burned in areas in fire return interval Class 1 (FRID 0 and 1) was predominantly unchanged or low. The high severity that did occur in Class 1 was the result of reburns in areas that had been previously converted to chaparral. Fires in Class 2 (FRID 2 and 3) burned with similar severities. This is consistent with the concept of the fire regime condition class in which areas that have not been altered substantially from their historic condition would burn within the range of variability (Hann and Bunnell 2001). Most of these fires were ignited by lightning and were allowed to run their courses. As van Wagtendonk and Lutz (2007) pointed out, these fires were thought to most closely mimic the historic fire regime. In fact, the wilderness fire management unit of the park was designed to include mostly areas with a FRID less than 4 (van Wagtendonk *et al*. 2002). In areas in Class 3 (FRID 4 and above), the proportion of high severity did increase but was still exceeded by the areas in low and moderate severities. This increase in high severity occurred on large fires and can be attributed to fuel accumulations combined with weather conditions.

Reburn Fire Severity

The severity of the first fire tended to influence the severity of subsequent fires. For example, areas that initially burned with unchanged, low, or moderate severity resulted in predominately the same severities in the second fire. Areas that first burned at high severity reburned with a higher proportion of high severity, primarily due to a conversion to chaparral (van Wagtendonk 2012). This pattern held for areas that reburned two and three times, although there was very little high severity in the reburned areas. The reduction in the proportion of high severity is likely caused by a reduction of fuels by the previous fires. An increase in severity could be attributed to a change in vegetation type to a more flammable type such as montane chaparral. This was the case in southern Oregon where Thompson *et al*. (2007) found that areas that reburned with high severity tended to be montane chaparral. Holden *et al*. (2010) found a similar result in the Gila Aldo Leopold Wilderness in New Mexico where low severity fires tended to reburn at low severity, while reburned areas where initial fire severity was high showed a higher probability of reburning at high severity. They also found that the severity of the reburned areas varied by vegetation type and the time elapsed between fires.

When reburn severities are evaluated by the burning conditions as represented by the burning index, the differences become more obvious. Collins *et al*. (2009) determined that a burning index of less than 34.9 constrained the spatial extent of 19 fires that burned in the Illilouette Creek basin. Above that threshold, we found that second and third fires burned considerably more area, especially when the return interval was nine years or greater. Because the burning index combines several factors that contribute to fire behavior, it is difficult to determine which factor might have the most influence. For the 2001 Hoover Fire, Collins *et al*. (2007) attributed the amount of low severity to high relative humidity. Relative humidity directly affects fine fuel moisture, which contributes to the burning index (Deeming *et al*. 1977). Fuel moisture was also implicated by Lutz *et al*. (2009) when they looked at the number and size of 1870 lightning fires throughout Yosemite in relation to spring snowpack. When the snowpack was decreased, the number of lightning fires increased exponentially, and larger fires burned with higher severity.

The time between fires was also important, but the effect was not as great as that for the burning index. Both the second and third fires reburned larger areas at high severity when the time between fires was nine years or greater, and nearly half of the original high severity areas reburned at high severity. The third and fourth fires did not burn at high severity when the return interval was less than nine years. These changes indicate that the effect of fuel reduction is offset by fuel accumulation over a nine-year period. Fuel accumulations and deposition rates determined by van Wagtendonk and Sydoriak (1987) and van Wagtendonk and Moore (2010) substantiate that nine years is sufficient time for fuels to recover to their preburn levels. Although nine years is considered low for historic fire regimes in the vegetation types, other factors such as lightning probability and weather conditions combine with fuels to determine return intervals.

Pre-Fire Vegetation

In general, low to moderate severity fires led to perpetuation of existing cover types or allowed succession to shade-tolerant species. High severity led to chaparral in almost all types. These changes are viewed as fire-induced changes to different points along normal successional pathways within a given system. If the interval between fires remains short enough, the change to chaparral could be considered a permanent type conversion.

When the initial fire severity in white fir or red fir was unchanged, low, or moderate, the original vegetation type was perpetuated. At these severities, both fir species are not susceptible to fire and would be expected to remain dominant. Collins *et al.* (2007) found the same result for red fir in the 2001 Hoover reburn. These results indicate that the severities are within the historic range for those types (Thode *et al*. 2011). High severity patches, however, either came back as fir or were replaced by upper montane chaparral. Seed banks of chaparral species, especially whitethorn and snowbrush, have been found to remain viable for decades (Quick and Quick 1961, Gratkowski 1962). Intense fires help crack the seed coats and allow germination to occur (Moreno and Oechel 1991). Reburns in white fir and red fir followed the same general pattern of severity as the initial fires. However, once chaparral replaced the firs, subsequent fires were predominantly of high severity. Collins and Stephens (2010) examined stand-replacing patches in the 2001 Hoover Fire and the 2004 Meadow Fire and found that high severity patches of white or red fir were large and included other vegetation types. However, high severity patches in montane chaparral appeared to be limited by the size of the chaparral patch. Although Collins and Stephens (2010) did not analyze the 1930s vegetation map, their findings based on the 1997 vegetation map are consistent with ours.

The Jeffrey pine-western white pine type presents a more complex response to reburning. After initially burning with unchanged, low, or moderate severity fires, this type either remained the same type or converted to nearly equal areas of white fir or red fir. In some cases, these stands had become ingrown with the more shade tolerant firs, and the fires were not severe enough to eliminate those trees. High severity fires resulted primarily in a type conversion to upper montane chaparral as a result of mortality in the overstory pines. Severity of the reburns was low to moderate in the new fir and pine stands and moderate to high in the converted chaparral stands. The severities are consistent with what would be expected for these fire regime types (Thode *et al*. 2011).

Although there was some conversion to white fir, red fir, and Jeffrey pine-western white pine, the primary response of the Jeffrey pine-shrub type to unchanged, low, and moderate severity initial fires was a return to Jeffrey pine-shrub. It is possible that these lower severities were not sufficient to kill understory firs where they had encroached underneath the pines. The response to high severity fire was a conversion to upper montane chaparral. As before, this is the expected response to high severity fires. Reburns in each of the resulting types was primarily moderate; however, there was some high severity in the shrub and chaparral types.

When the upper montane chaparral type was burned by moderate severity fires, the response was conversion to white fir. Again, the possibility exists that firs became established during the period between fires and were not killed by the moderate severity fires. Where white firs had succeeded after the initial fire, reburns were moderate in severity. High severity fires in chaparral resulted in perpetuation of the chaparral stands and relatively high severity reburns. This corresponds with the results from Collins and Stephens (2010) and van Wagtendonk (2012) and confirms the finding by Nagel and Taylor (2005) that fire exclusion caused the average area of montane chaparral to shrink.

Lodgepole pine fire severities after the initial fires were similar to that found by Thode *et al*. (2011), with low severity dominating. Based on the single 2001 Hoover Fire reported by Collins *et al*. (2007), however, we had expected high severity fire to be more prevalent than it was. The most common vegetation response to unchanged, low, and moderate severity fires was a conversion to red fir. At the elevations that were burned in the Illilouette Creek basin, lodgepole pine stands have an understory of red fir. If the interval between fires is long enough and the severity not greater than moderate, the thicker-barked red firs are able to survive while the lodgepole pines are not. Where high severity did occur, upper montane chaparral was the resulting type. Reburns in both red fir and lodgepole were primarily low to moderate, consistent with the Thode *et al*. (2011) severity distributions.

Although some of the changes that we observed between pre-fire and post-fire vegetation might be attributed to different methods and classifications used in 1930s and 1997 maps, we feel that collapsing the vegetation types into the Thode *et al*. (2011) fire regime types minimizes those differences. However, the finer classification and smaller minimum mapping unit of the 1997 map could have resulted in a larger number of post-fire vegetation types. This is particularly true for the Jeffrey pine-western white pine type in which the post-fire vegetation was distributed across all types.

Conclusion

The severity of fires in the Illilouette Creek basin was associated with the fire return interval departure, the years since last burned, the severity of the previous fire, the number of times an area had burned, the weather conditions at the time of reburning, and the pre-fire vegetation type. The factors that were associated with reburn severity worked in combination with each factor, influencing some aspect of severity. Fire return interval departure affects vegetation density and composition changes. Years since last burned primarily affects surface and understory live fuels as they accumulate over the years. The number of times an area has burned affects fuel reduction. The weather conditions at the time of burning directly affect fire behavior (i.e., fireline intensity), which directly affects fire severity. Fine fuel moisture content and wind speed are the primary weather variables affecting fire behavior and may fluctuate markedly from fire to fire, leading to differing fire behavior and severity across fires even when other factors are more or less similar. The burning index combines all of these variables into a single measure and has been determined to affect fire severity (Collins *et al*. 2009).

The role of pre-fire vegetation was also important. When fire severity was unchanged, low, or moderate, the initial vegetation was usually maintained. However, when fire severity was high, a change to upper montane chaparral often occurred. These high severity patches were perpetuated by subsequent fires. At the landscape scale, this means that there would be an increase in chaparral as high severity patches are converted from their initial vegetation type. Over time, however, the original vegetation would return if conifers encroach during long intervals between fires, and future climate effects do not alter such traditional processes. In areas where fires are allowed to play their natural role as much as possible, such as the Illilouette Creek basin, the proportion of area burned among fire severity levels appears to be stable (Collins 2009). After 39 years of fires interacting with previous burns, it appears that a dynamic balance currently exists between the vegetation and naturally occurring fires.

Future climate change, however, could alter the dynamic balance. Fire severity appears to be increasing in the western US (Westerling *et al*. 2006) and in the Sierra Nevada (Miller *et al*. 2009), and is projected to increase in Yosemite (Lutz *et al*. 2009). At the smaller scale of Yosemite, changes in fire severity are not yet apparent due to high inter-annual variation in fire severity (Lutz *et al.* 2011). An increase in temperature can decrease relative humidity and fuel moisture content. This increases fireline intensity and resultant fire severity. The impact on some species would be exacerbated by the effects of climate change on the climatic water budget. For example, Lutz *et al*. (2010) found that declining water budgets would disproportionally affect western white pine, a species that we found to be impacted by high severity fires. The Illilouette Creek basin in Yosemite is one of the few areas where it is possible to see the effects of the long-term interactions of vegetation, fire, and climate. Managers and scientists can use this information to better understand the role fire plays in these ecosystems and how to best manage this dynamic ecological process.

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