Illilouette Creek Basin Research and Publications

STEPHENS LAB
Research & Education in Wildland Fire Science

Center for Fire Research and Outreach

Berkeley Forests

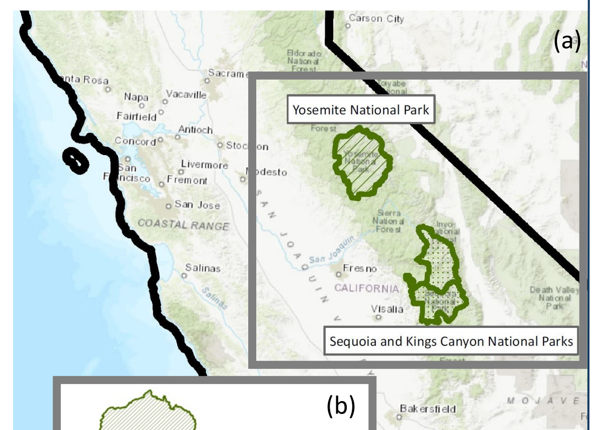
Photo by Scott Stephens

Overview

Authored by Rachelle Hedges and Gabrielle Boisramé

Illilouette Creek basin in Yosemite National Park and Sugarloaf Creek basin in Sequoia and Kings Canyon National Park (Figure 1) have experienced over four decades of naturally ignited wildfire. By allowing lighting-ignited fires to burn in these isolated areas for over 45 years, managers have helped return the Illilouette Creek and Sugarloaf Creek basins to as near a natural fire regime as can be found in California. These areas provide researchers a rare opportunity to study the processes and effects of fire under relatively natural conditions. This document features a general summary of the research conducted on the Illilouette Creek and Sugarloaf Creek basins by the Stephens Lab and the Center for Fire Research and Outreach at Berkeley Forests, along with short summaries (organized by topic) of 12 peer-reviewed journal articles published from these areas.

Historically, wildfires used to burn Sierra Nevada forests fairly frequently during California's dry summers and fall. Beginning around 1900, fire suppression efforts dramatically reduced the amount of wildfire burning in California. Although it was initially effective at achieving the short-terms goal of preventing losses from forest fires, fire suppression has left a legacy of dense, homogeneous forests. Such landscapes have high water demands and fuel loads, and when burned can result in catastrophically large fires. These characteristics are undesirable in the face of projected warming and drying in the western US. Alternative forest and fire treatments based on a strategy in which wildfires are allowed to burn naturally—previously referred to as "wildland fire use"—offer one strategy to ameliorate the effects of fire suppression. Understanding the long-term effects of this strategy on fire behavior, vegetation, hydrology, forest resilience, and biodiversity is increasingly important as allowing wildfires to burn freely in remote areas becomes a more widely accepted practice. The Illilouette Creek and Sugarloaf Creek basins have allowed naturally ignited fires to run their course (to the greatest extent possible) since 1972 and 1968, respectively. Coupled with an abundance of data captured by Park staff since the implementation of this policy, these two locations have provided researchers a unique insight into how a natural fire regime effects the biotic and abiotic elements on a landscape. Members and partners of the Stephens Lab and the Center for Fire Research and Outreach at Berkeley Forests have been conducting research in the Illilouette Creek and Sugarloaf Creek basins for over twenty years, with many projects still active and ongoing. Summaries of these research efforts are presented in the following pages.



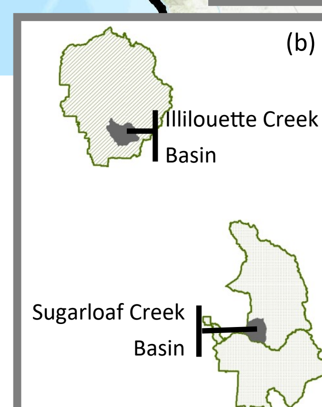


Figure 1. *(a) Location of Yosemite National Park and Sequoia and Kings Canyon National Park, and (b) the locations Illilouette and Sugarloaf Creek Basins within each park.*

Fire

Authored by Rachelle Hedges and Brandon Collins

A near-natural fire regime paired with well-documented fire history has created a setting in which researchers have been able to gain critical insights into the characteristics of fire and fuels in mid to high-elevation mixed conifer Sierra Nevada forests. To date, researchers have explored questions and published results about a variety of topics including modern versus historical fire regimes, the effects of fires on the extent of future fires, fire severity patterns, and fire scar reconstruction accuracy. This review summarizes these efforts, highlighting six different research articles on these topics.

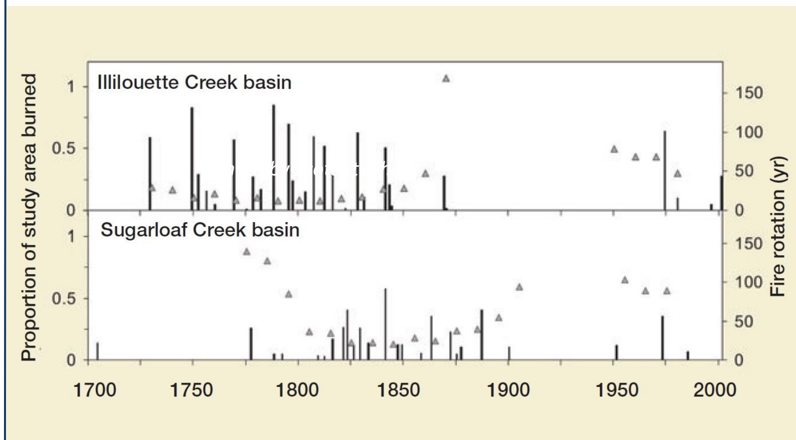


Figure 2. *Reconstructed fire extent (vertical bars) and fire rotation (gray triangles), within each study area, for years in which > 3 trees were scarred. Fire rotation is defined as the length of time necessary to burn a cumulative area equivalent to the size of the study area, and is calculated at 10-year intervals for overlapping 50-year periods.*

Wildfire has become an increasingly appealing tool for land managers in certain areas, not only as a means to restore historic fire regimes and ecosystem functions, but also to reduce costs and improve firefighter safety. To better understand how recent wildfires (those that have burned since the initiation of the current wildfire program) compare to historical fires both in frequency and extent, researchers reconstructed historical fire occurrence in the Illilouette Creek and Sugarloaf Creek basins. They then compared these reconstructions to the frequency and extent of recent wildfires. Researchers also investigated the impact the period of fire exclusion (which occurred just prior to the current management era) had on tree recruitment in these areas. Results indicated that the frequency and extent of fires since the initiation of the current wildfire program (Figure 2) approached that of historical levels, especially in the Illilouette Creek basin. These results were surprising, as tree recruitment increased significantly during the period of fire exclusion— historically, frequent fires would have moderated tree recruitment by killing small trees. In this instance, however it seems that the long fire-free interval "produced" these trees, allowing them to grow beyond the stage at which they were most vulnerable to fire. These tree did not, however, contribute to increasing levels of high severity fire.

Researchers furthered their exploration of modern-era fire behavior by studying the processes responsible for recent increases in wildfire activity in drier, mid to high-elevation mixed conifer forest types. Utilizing the robust wildfire data collected by staff at Yosemite National Park since the beginning of their current wildfire program, fire as a "self-limiting" process was examined to better understand whether the consumption of fuel by fires over time ultimately constrains the size and severity of future fires. Researchers examined which variables had the most impact on the probability of reburn, and if there were any thresholds for these variables over or

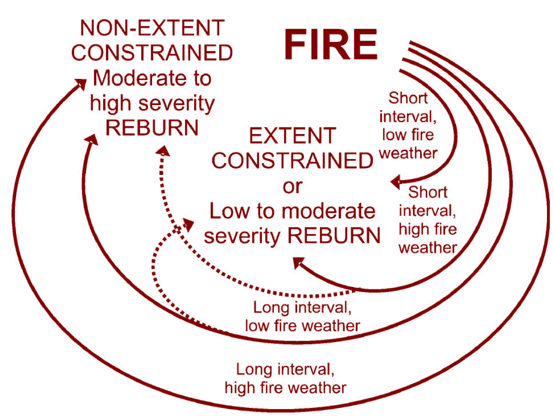


Figure 3. *Interactions between successive fires resulting in the latter fire: (1) being constrained in spatial extent by the previous fire or lessened fire severity if the previously burned area is reburned, (2) no spatial constraint of the previous fire on either the extent or severity of the latter fire. We propose the dominant factors controlling these interactions are the time between successive fires (interval) and fire weather during the latter fire. Solid lines are primary expected pathways and dashed lines are secondary pathways.*

under which fire was more or less likely to reburn. Analysis indicated that fire frequency was the most important variable for determining probability of reburn and that a short time-since-last-fire was strongly tied to a very low probability of reburn (Figure 3). The threshold researchers identified was at under nine years since time-of-last-fire, there was almost zero probability of reburn despite fire weather. However, when the time since reburn was over nine years, fire weather conditions also played an important role in determining probability of reburn. This was the first study published to estimate a threshold value for reburning.

Significant work regarding fire severity patterns has been conducted in the Illilouette and Sugarloaf Creek basins. To better understand the factors responsible for varying fire severities across the landscape, researchers examined the severity of two naturally occurring fires in the Illilouette Creek and the Sugarloaf Creek basins. Using estimates of fire severity derived from satellite imagery, the impacts of weather, topography, and vegetation on fire severity were examined. Although each fire burned with different proportions of high, moderate, and low severities (Figure 4), certain factors contributed more significantly to the different severities in both fires. Specifically, dominant vegetation type was important in determining severity throughout both fires, and to a lesser extent, wind speed and time since last burn. In the Illilouette Creek basin fire, relative humidity (a factor under "weather") also played an important role in determining fire severity.

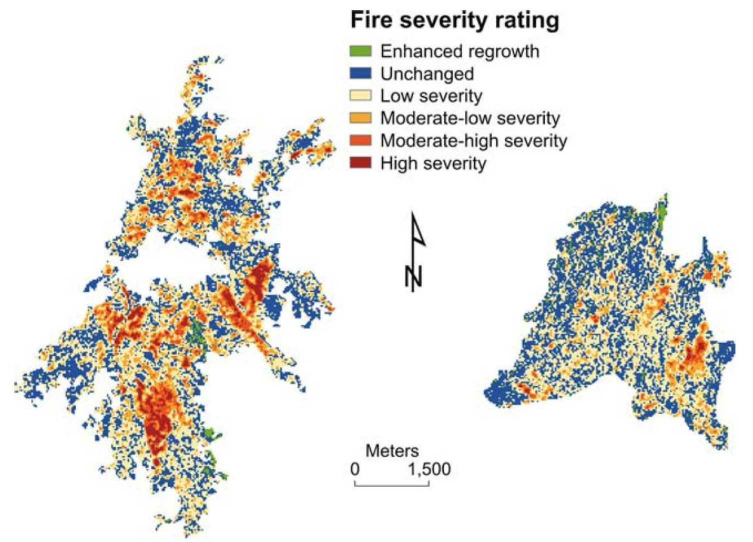


__Figure 4.__ Burn severities for fires in the Illilouette Creek (left) and Sugarloaf Creek (right) basins from 2001 and 2003 fires, respectively.

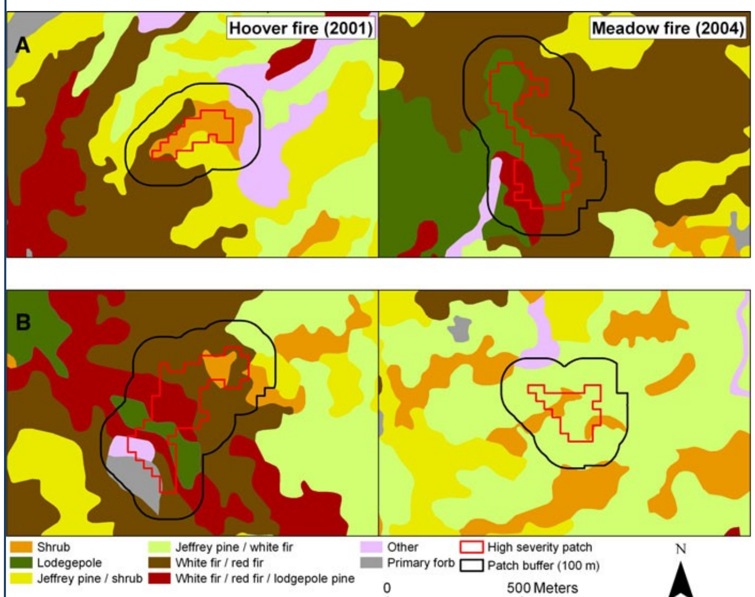


__Figure 5.__ Examples of both vegetation-constrained stand-replacing patches (a), and non-vegetation constrained stand-replacing patches (b) within the two studied fires.

Researchers furthered their investigation of fire severity patterns by examining the role of high severity fire in "mixed severity" fire regimes. Using data from one of the same and one additional naturally-occurring fires (as used in the aforementioned study) in the Illilouette Creek basin, researchers examined the proportion of landscape burned at high severity (also referred to as stand-replacing patches), and the factors influencing their occurrence throughout the burned area. Stand replacing patches accounted for approximately 15% of the burned area for each of the two fires, with significant variability in patch size, which ranged from 1 acre to over 220 acres. Small patches (<10 acres) accounted for more than 60% of the total high severity patches, however large patches (>148 acres) accounted for nearly half of the total stand-replacing patch area. Analysis also indicated that dominant vegetation type was the most influential factor in determining stand-replacing patch size, with the smaller patches occurring in areas dominated by lodgepole and Jeffrey pine, and larger patches in white and red fir stands (Figure 5). Slope position, time since last burn, and burning index also influenced patched size (Figure 5).

Researchers again utilized the robust wildfire history data collected by Park staff in the Illilouette Creek and Sugarloaf Creek basins to shed light on the uncertainty associated with fire scar reconstruction—a tool often used to inform forest management decisions. Using this data, researchers compared tree scarring patterns to over 30 years of mapped wildfires to better understand how accurately fire scar reconstruction represents both fire frequency and fire regimes, and what variables influence the presence or absence of fire scars. The comparison showed that fire scar reconstruction reasonably represented fire extent (Figure 6 and Figure 7), but under-represented fire rotation. The variable that most influenced the probability of scarring was time since last fire. Aspect and basal area also were significant variables, although to a lesser extent than time-since-last-fire. Although researchers were unable to propose a correction factor for future fire scar reconstruction efforts based on the findings in this study, this work provides vital insights into interpreting fire scar reconstructions as it is one of very few studies to test the accuracy of estimating past burned area from fire scars and actual fire perimeter data.

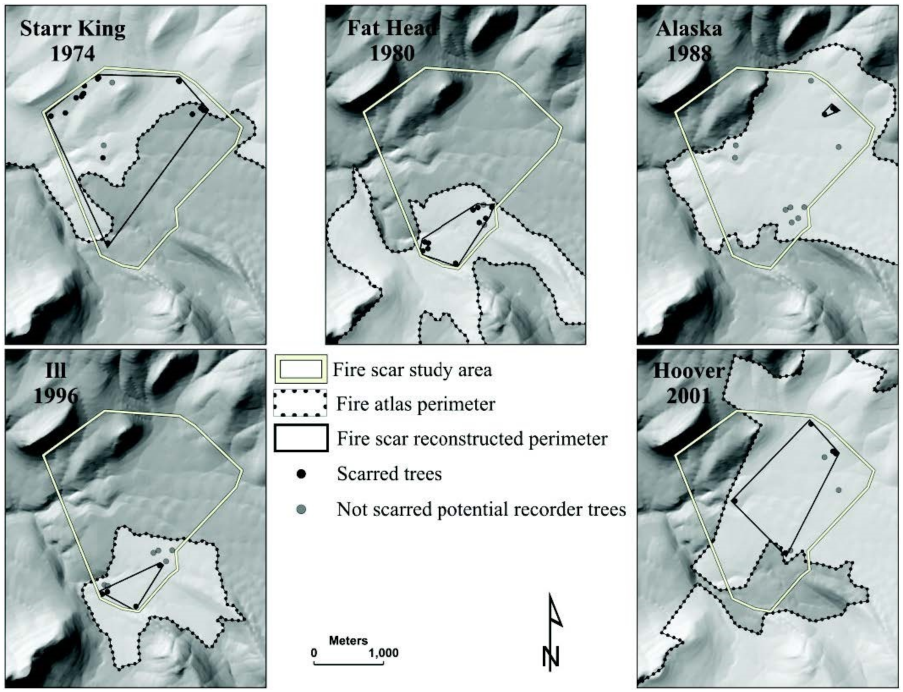


Figure 6. *Tree scarring patterns and perimeters for the five fires that burned in Illilouette Creek basin.*

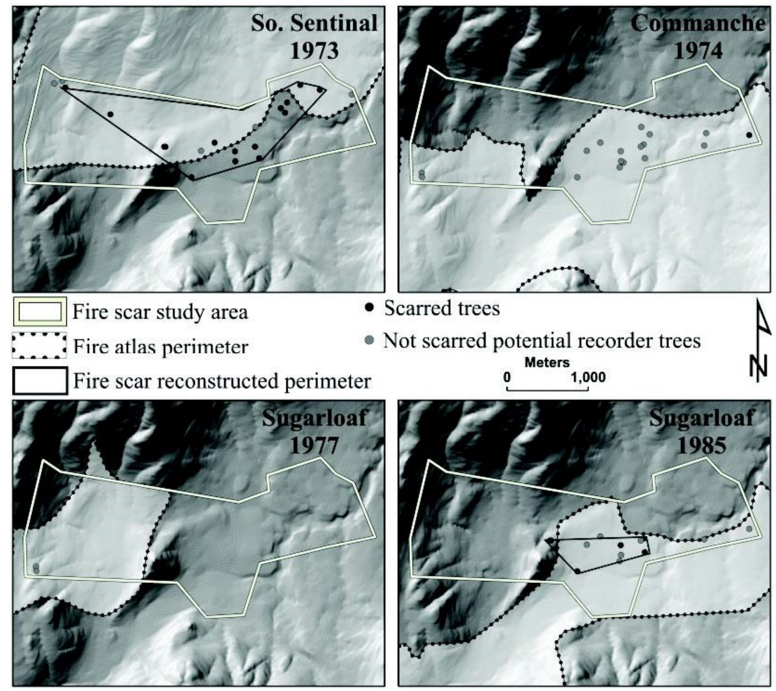


Figure 7. *Tree scarring patterns and perimeters for the four fires that burned in Sugarloaf Creek basin.*

Most recently, researchers explored how vegetation structure and composition varied across the landscape in the Illilouette Creek and Sugarloaf Creek basins. The extent to which fire and topographic characteristics explain the distribution of vegetation across the landscape in these areas was examined, as were the factors influencing surface fuel loads. Analysis identified nine distinct vegetation groups, with widely ranging basal area and tree density. While actual evapotranspiration (an indicator of site productivity) and past fire severity were noted as significant variables influencing the distribution of vegetation groups, overall it was challenging for researchers to explain specifically what drove occurrences of different vegetation conditions across the landscape. Surface fuel loads were generally low relative to reported fuel loads on long fire-suppressed forests, but also displayed high variability. Surprisingly, surface fuel loads were not linked to fire characteristics, but to forest structure and composition.

Since implementing policies to allow wildfires to burn the Illilouette Creek and Sugarloaf Creek basins over 45 years ago, land managers have allowed fire regimes to return to a near natural state. UC Berkeley researchers, staff and faculty wish to thank fire managers and parks supervisors for supporting this program. Having access to Sierra Nevada forests in such conditions has allowed researchers to examine the factors impacting fire severity, the proportions of landscape burned at different severities, how current regimes compare to historical fires, how realistic our understanding of fire history is based on fire scar reconstruction, if past fires constrain the severity and extent of future fires, and how these fire regimes impact vegetation structure and composition. These questions, and their subsequent answers, are critical to furthering our understanding of how fire historically shaped the landscape and how it continues to do so today.

Papers Summarized in this Section:

Collins, B. M., M. Kelly, J. W. van Wagtendonk, and S. L. Stephens. 2007. Spatial patterns of large natural fires in Sierra Nevada wilderness area. Landscape Ecology 22:545-557.

Collins, B. M., and S. L. Stephens. 2007. Managing natural wildfires in Sierra Nevada wilderness areas. Frontiers in Ecology and the Environment 5:523-527.

Collins, B. M., and S. L. Stephens. 2007. Fire scarring patterns in Sierra Nevada wilderness areas burned by multiple wildland fire use fires. Fire Ecology 3:53-67.

Collins, B. M., J. D. Miller, A. E. Thode, M. Kelly, J. W. van Wagtendonk, and S. L. Stephens. 2009. Interactions among wildland fires in a long-established Sierra Nevada natural fire area. Ecosystems 12:114-128.

Collins, B. M., and S. L. Stephens. 2010. Stand-replacing patches within a 'mixed severity' fire regime: quantitative characterization using recent fires in a long-established natural fire area. Landscape Ecology 25:927-939.

Collins, B. M., J. M. Lydersen, D. L. Fry, K. Wilkin, T. Moody, and S. L. Stephens. 2016. Variability in vegetation and surface fuels across mixed-conifer-dominated landscapes with over 40 years of natural fire. Forest Ecology and Management 381:74-83.

Additional Reading:

van Wagtendonk, J. W., & J. A. Lutz. 2007. Fire regime attributes of wildland fires in Yosemite National Park, USA. *Fire Ecology*, *3*(2), 34-52.

van Wagtendonk, J. W., K. A. van Wagtendonk, and A.E. Thode. 2012. Factors associated with the severity of intersecting fires in Yosemite National Park, California, USA. *Fire Ecology*, *8*(1), 11-31.

Management Implications

- Vegetation type determines burn severity more than factors such as weather and topography.
- The frequency and extent of current fires are similar to historic fires, indicating a near-natural fire regime has been re-established in the study areas.
- Fire scar reconstructions can be useful in helping managers understand past fire regimes, reasonably capturing fire extent.
- Time-since-last fire is critical in determining probability of a reburn in a given area, with the threshold being over nine years for an area to reburn.
- High severity patches will account for a small proportion (~15%) of the area burned in "mixed severity" fires. These patches vary greatly in size, with most patches being small.
- Vegetation composition and structure vary greatly across the landscape in areas with in-tact fire regimes.
- Surface fuel loads are most closely linked with forest structure and composition.

Hydrology

Authored by Gabrielle Boisramé, Rachelle Hedges and Ekaterina Rakhmatulina

The Illilouette Creek basin is the only watershed in the western United States to have experienced a near-natural wildfire regime for such a long period, and also have multi-decadal records of nearby weather and streamflow (Figure 8). Therefore, it provides a unique opportunity to study how natural fire regimes versus fire suppression impact mountain hydrology. This review summarizes the findings from five different research articles which explored different aspects of how the Illilouette Creek basin's fire history has affected its water resources.

Aerial photos spanning 1969 to 2012 reveal clear changes to the watershed's land cover (Figure 9). Repeated wildfires in the Illilouette Creek basin between 1972 and 2012 reduced forest area by 24% and increased shrubland area by 35%, while the amount of wet meadow doubled (Figure 10). The spatial patterns of these changes have created a much more diverse landscape, with different types of vegetation more evenly distributed across the landscape compared to the nearly uniform forest that dominated when the watershed was fire-suppressed. Although aerial photos only reveal changes in broad categories of canopy cover, field visits have shown that different land covers are generally associated with different types of understory plants, demonstrating the importance of these changes to increasing biodiversity.

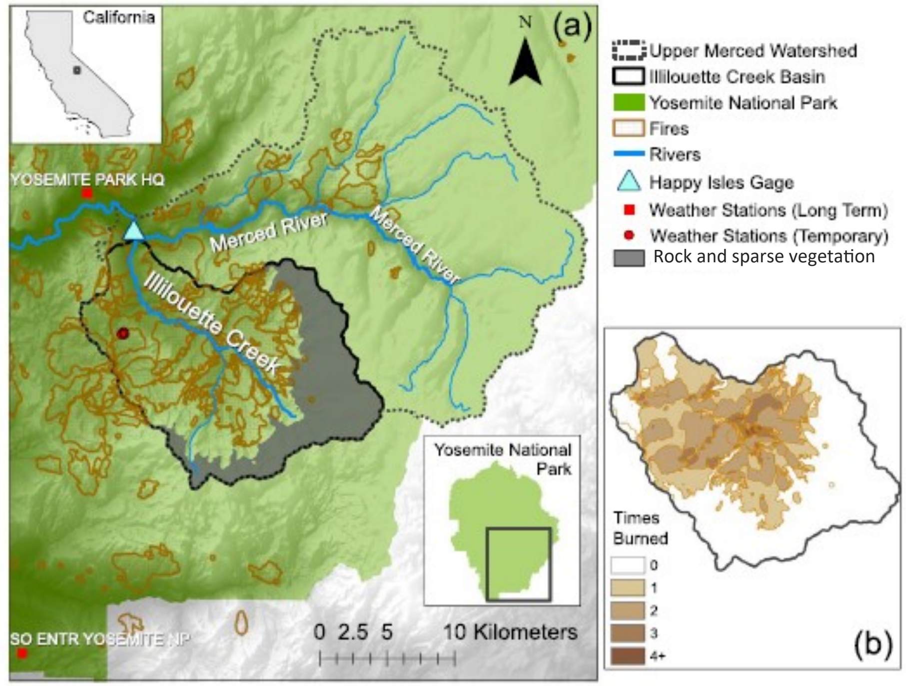


Figure 8 (above). *(a) Location of Illilouette Creek basin, weather and gaging stations used for analyses, and all fire perimeters from 1972 to 2012. (b) Map of the number of times each area of the watershed has burned between 1972 and 2012.*

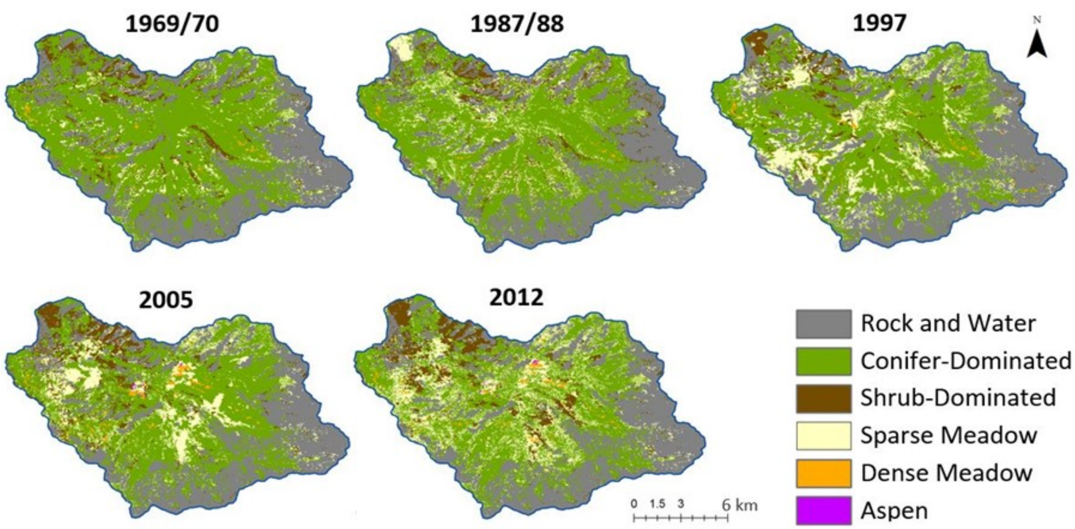


Figure 9 (left). *Vegetation maps created from aerial photography. The 1969/1970 map shows the vegetation after a long period (~100 years) of fire exclusion and suppression. All other maps show the progression of vegetation change due to multiple wildfires beginning in the 1970s.*

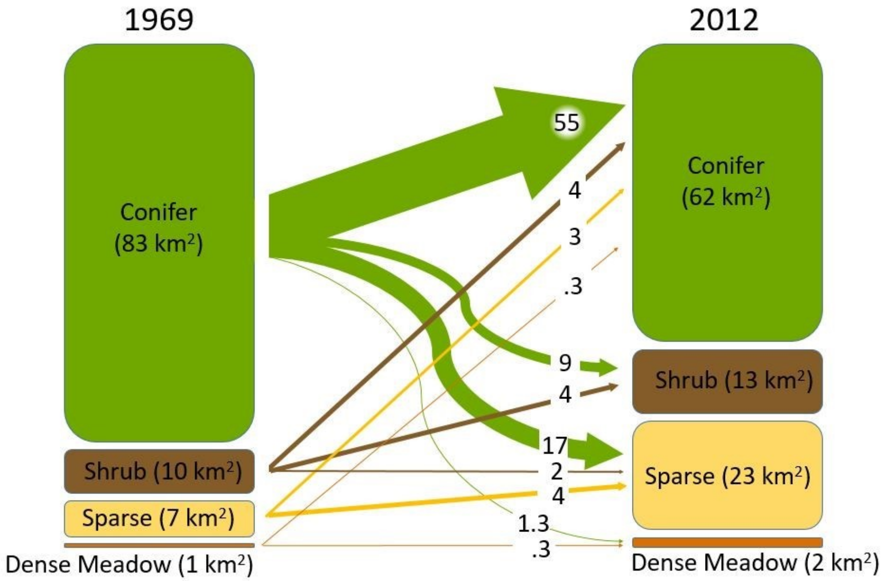


Figure 10. *Vegetation type transitions from 1969 to 2012 show that nearly half of the conifer forest cover transitioned to sparse meadows, shrublands, or dense meadows following high severity fire. Labelled arrows show the number of square km within each vegetation type in 1969 that was then classified in 2012 (after over 40 years of wildfires).*

Figure 11. *Wet meadow vegetation growing amid burned snags of the forest that formerly dominated this area.*

The study of water and fire in the Illilouette Creek basin was initially motivated by observations that wetland plants were growing in high severity burn areas that had previously been forested. This suggested a small increase in water availability. After taking thousands of surface soil moisture measurements, researchers were able to use a statistical model to show that many burned areas that are now meadows have higher soil moisture than they would have if they were still forested (e.g., Figure 11). Areas with elevated soil moisture are important for maintaining biodiversity and drought resilience in this watershed.

Comparing streamflow records from before and after fires were returned to the Illilouette Creek Basin suggests that streamflow is a few percent higher than it would be under fire suppression. California has a great deal of interannual variability in precipitation, however, which makes it difficult to attribute changes to a specific cause since streamflow is very different from year to year. Using a hydrologic model, however, researchers could separate the impacts of fire-induced land cover change from the impacts of weather variability. This modeling confirmed that the changing land cover increased streamflow slightly. Water is available for this fire-induced flow increase largely due to reduced plant water use, and also because less precipitation is intercepted in tree canopies and lost to evaporation (Figure 12). It should be noted that three comparable watersheds near the Illilouette Creek basin which have not been under the same wildfire management program (and instead have been practicing a policy of fire suppression) have seen reductions in stream flows since 1974.

While significant streamflow increases are largest in wet years (Figure 12), the post-fire forest itself appears to benefit during dry years. Both observational data and model simulations suggest that this watershed is more drought resistant than it would be if fire-suppression had continued. During the drought years of 2014 and 2015, fewer conifers died of drought-related causes in Illilouette Creek basin compared to similar, nearby watersheds that had not burned. This is likely because, after fires thinned the forests, the remaining trees faced less competition for water. An eco-hydrologic model estimated that the changes from wildfire led to less water shortage during dry years, including 2014-2015.

Snowpack is an important component of water storage for California. Wildfires can cause blackened surfaces and reduced snowpack shading, both of which may increase snowmelt. However, dense unburned forests can also raise temperatures and increase melting via longwave radiation (think of tree wells, a common danger for skiers), as well as intercept snow in their branches and prevent it from reaching the ground. The net impact of fires on snowpack can therefore be hard to predict. Hydrologic modeling showed that peak snow water equivalent (SWE) in the Illilouette Creek basin was always higher in the burned scenario, which agrees with field measurements. The model showed that the timing of final snowmelt was either earlier or later depending on specific location as well as weather; higher elevation areas kept snow longer in the burned scenario (Figure 13), as did warmer winters.

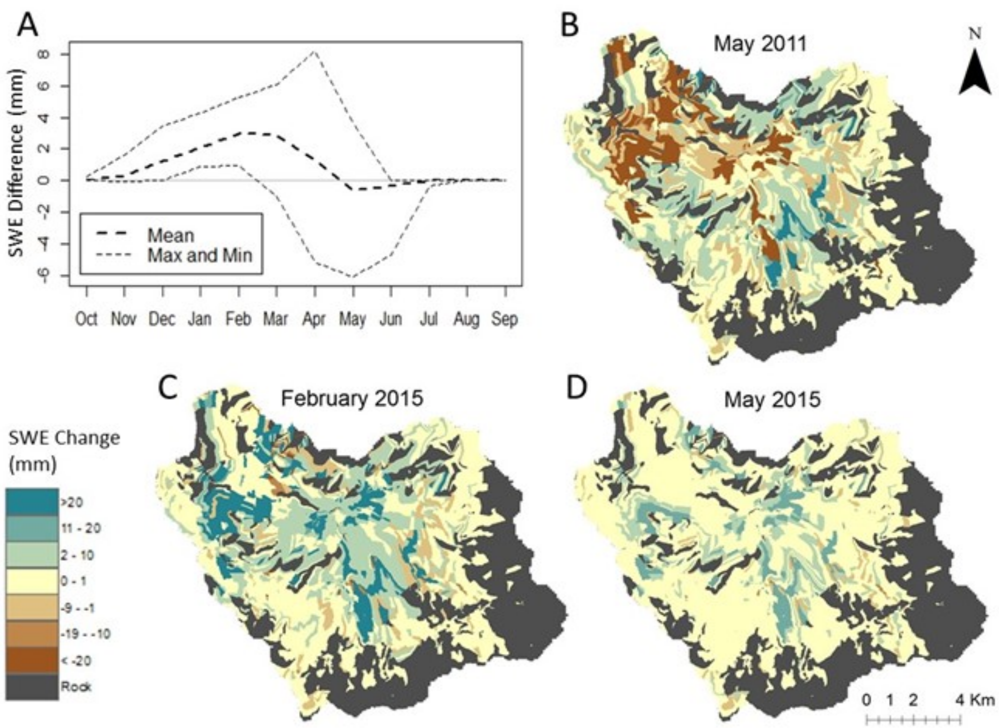


Figure 13. *The impact of fires on snow water equivalent (SWE) varied in space and time. (a) Mean difference in monthly SWE in Illilouette Creek Basin between fire-suppressed (1969) and burned (2012) vegetation covers (a positive value means deeper snowpack using 2012 vegetation compared to 1969 vegetation). Dashed lines show the range between the maximum and minimum changes across all years of weather data (1972–2017). (b–d) Maps of change in SWE for February 2015 and May of 2011 and 2015 when historical fires are included in the model compared to the unburned model scenario. Exposed rock areas which were unaffected by fire are grayed out.*

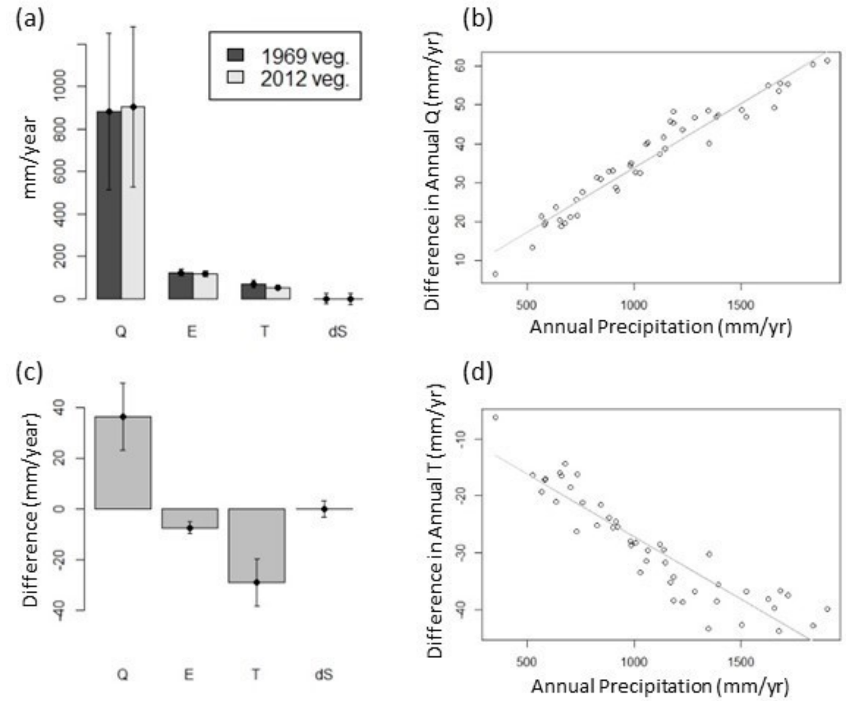


Figure 12. *(a, c) According to a hydrologic model, fires led to small, but significant, increases in streamflow (Q), driven by decreases in evaporation (E) and transpiration (T). (b, d) The level of change due to fire was higher in years with more rain and snow.*

Recent Work at Sugarloaf Creek Basin

Researchers have also been examining the response of vegetation and soil moisture to 47 years of fire use in the Sugarloaf Creek basin. In comparison to the ICB, managed wildfire in the SCB caused relatively little change in dominant vegetation and soil moisture. The differing response is due in part to more active suppression of fires in the SCB (vs. the ICB) in the past two decades. Further, fire occurrence was limited to drier mixed-conifer sites, had little effect on removing smaller trees, and often lead to sparse meadow or shrub creation, which had similar soil moisture profiles to the mixed conifer vegetation. Future fires in SCB could be managed to encourage greater tree mortality adjacent to wetlands to increase soil moisture, although the potential hydrologic benefits of the program in drier basins such as this one may be limited.

Research on the Illilouette Creek basin has shown the hydrological benefits of an in-tact fire regime in Sierra Nevada forest types. Given the many benefits of fire use, it is not unrealistic to expect that all landowners and management agencies will adopt a similar approach, as the USFS recently proposed for much of the area in their three southern Sierra National Forests.

If the policy of allowing wildfire to burn more freely is expanded throughout the Western US, however, changes in forest cover and structure such as those seen on the ICB would not occur until the middle of this century—when it is anticipated conditions will be different due to climate change. For this reason, it is important to understand if the demonstrated hydrological benefits of fire use are sensitive to these anticipated changes.

To better understand this, researchers used a regionally-based simulation system to answer three questions:

(1) How would the hydrology of the ICB respond to climate change in the absence of a fire use policy, where vegetation remains in a fire excluded state?

(2) How do the hydrological outcomes of fire use strategies in the ICB differ under future climate conditions (2030-2070), relative to those outcomes under the observed climate (1970-2010)?

(3) How sensitive are hydrological outcomes of fire use strategies for the future scenario (2030 –2070 period) to an increase in fire frequency?

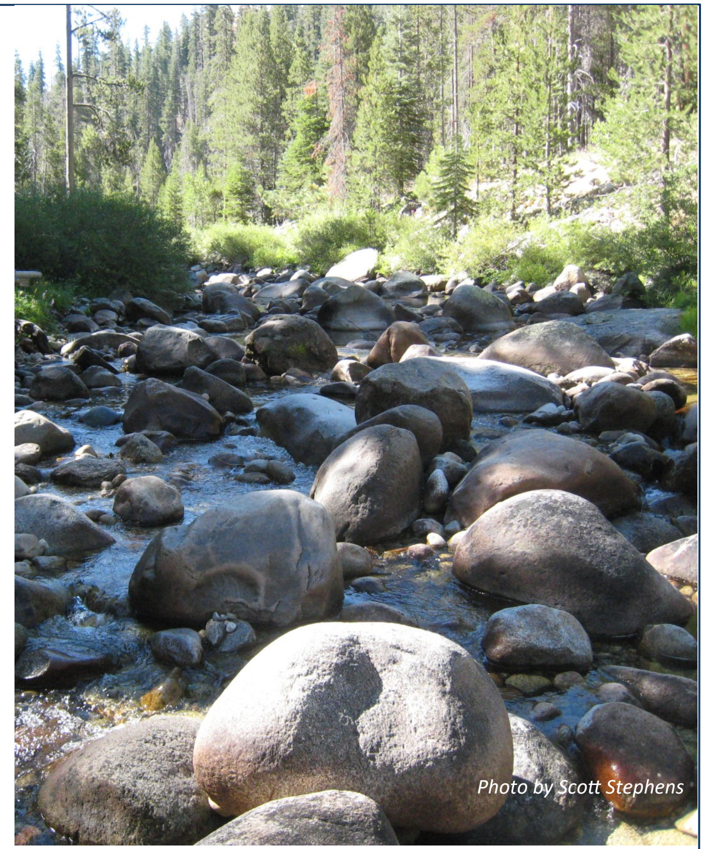


Photo by Scott Stephens

To answer these questions, researchers ran simulations over 40 years using the observed 1970-2020 climate, and for two future 2030-2070 climate scenarios—one in which greenhouse gasses begin to decline in 2040, and the other in which we continue to see a rise in greenhouse gas emissions—while manipulating other factors such as vegetation type, fire disturbance and fire frequency. Based on these simulations, researchers found that the Illilouette Creek Basin would have higher average temperatures with similar total precipitation, and the overall result of a shorter snow season.

In their investigation of question (1), which isolated the influence of climate on hydrology and assumes vegetation remains in fire-excluded state, researchers found that hydrology of the ICB was relatively similar in future climate scenarios. One notable exception was a significant decrease in snowpack, which lead to lower total evaporation in future climate scenarios.

In answer to question (2), which explores how the hydrological outcomes of fire use strategies in ICB would differ under future climate conditions relative to those outcomes under the observed climate, researchers found that —similar to the findings for question (1)— the historical fire regime produces similar reductions in evaporation and transpiration and increases in streamflow across all climates (Figure 14). Fire-induced increases in snowpack partially counteracts climate change induced reductions in snowpack (Figure 14). These results suggest that the changes currently associated with fire use in the ICB are highly comparable to those that would be predicted if the same set of fires and vegetation changes occurred under future climate conditions.

For the questions posed around how sensitive the hydrological outcomes of fire use strategies for the 2030-2070 period were to potential increases in fire frequency as part of question (3), researchers found that increases in fire frequency (due to ignitions and not fuel availability) in future climate scenarios will lead to similar hydrologic changes as historic fires, but in a shorter timeframe. With the exception of streamflow, all water balance variables experience significant change due to fire, across all climate and fire regimes, by the final simulated decade (Figure 14). Streamflow also increases when compared against fire excluded conditions under all scenarios, although not significantly for all scenarios. Except for maximum snowpack, the historical fire regime always produced the *smallest* changes in hydrological variables for each climate type than increased fire (Figure 14).

These results suggest that a fire use strategy would impact the hydrology of the ICB under future climates similarly to how the present fire regime influences hydrology - namely modest increases in streamflow, driven primarily by reductions in vapor fluxes and increased subsurface water storage. The hydrological impacts of fire use are comparable under observed climate and projected future climates, and are largely insensitive to any uncertainties regarding post-fire vegetation growth. If fire frequency were to increase over the current fire regime, the main impact would be that the basin would reach the peak hydrological change more rapidly. This study suggests that where self-limiting fire behavior can be anticipated (as it is in the ICB), the hydrological co-benefits should be considered as part of future fire policy development and cost-benefit analysis.

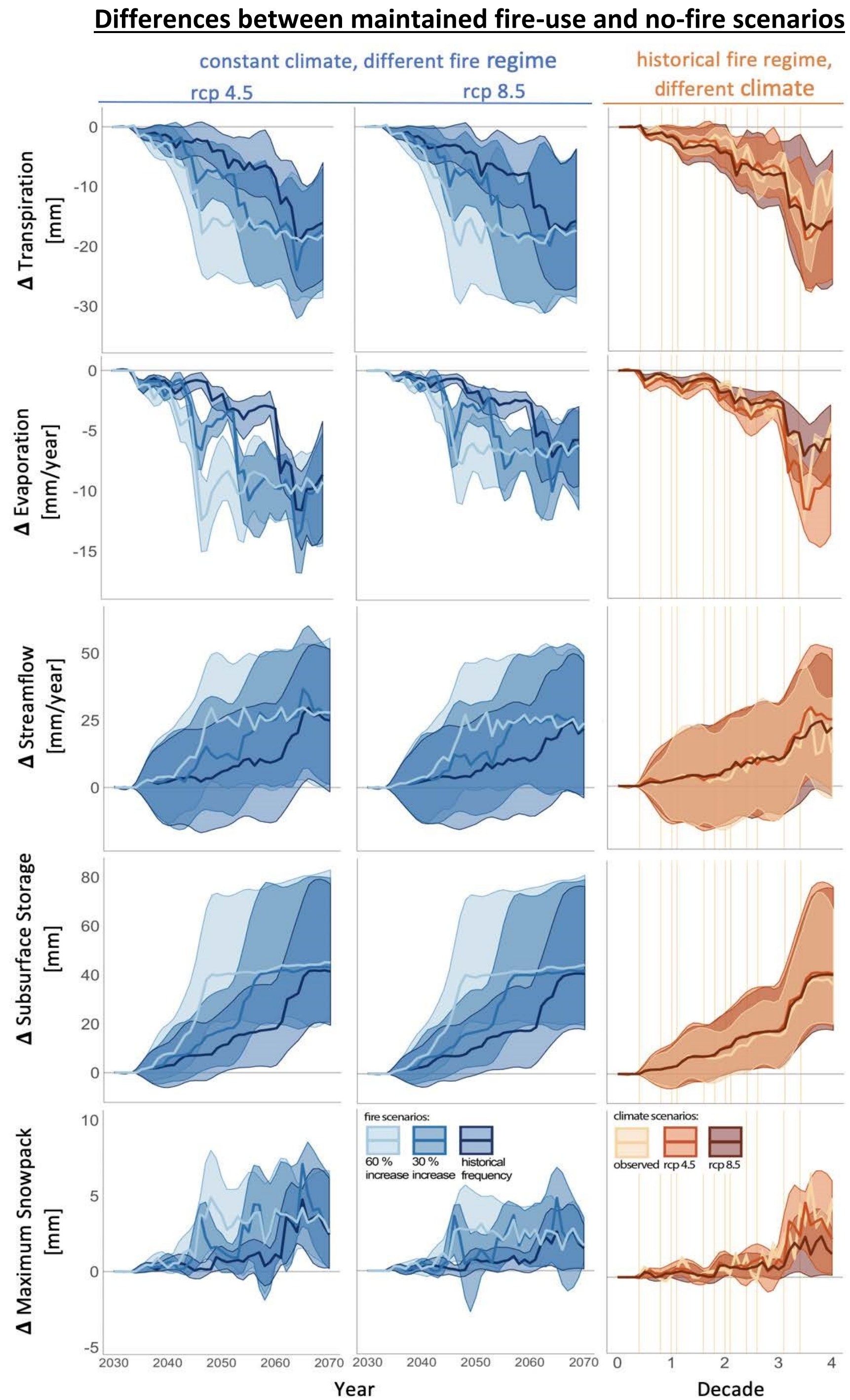


Figure 14. *All plots show the difference between the burned and excluded ICB. Plots in blue have constant climate, with a 2040 decrease in greenhouse gas emissions (rcp 4.5) in the left panel, and a "business as usual" climate scenario in the middle panel (rcp 8), but vary the fire scenario. Plots in red keep the fire frequency constant (historical), but vary the climate scenario. Vertical orange lines in the right panel indicate a historical reoccurrence. Shading indicates 95% confidence interval of the 930 model runs (93 parameter sets for each of the 10 General Circulation Models), while thick lines represent average difference. Vertical axis has the same scale for each hydrological variable. Decade 0, 1, 2, 3, and 4 refer to years 1970, 1980, 1990, 2000, and 2010 for observed climate and years 2030, 2040, 2050, 2060, and 2070 for rcp 4.5 and rcp 8.5 climates.*

Photo by Scott Stephens

In summary, the reintroduction of a near-natural wildfire regime to the Illilouette Creek basin has reduced transpiration, increased peak snowpack, increased subsurface water storage in the basin, and has modestly increased streamflow. The changes are suggestive of an overall shift toward a wetter, less drought-sensitive forest. This shift is sustained by fire: Were fire to be removed from the basin again, it is probable that woody cover and water use would again increase. The hydrological impact of the changed fire regime is thus broadly positive.

Model results exploring how fire use would impact the hydrology of the ICB under future climates (2030-2070) further support these findings. This recent research indicates that continued fire use will impact hydrology similarly to the present regime - namely modest increases in streamflow, driven primarily by reductions in vapor fluxes and increased subsurface water storage. Further, these impacts are comparable and largely insensitive to any uncertainties regarding post-fire vegetation type. If fire frequency were to *increase* over the current regime, the basin would reach the peak hydrological change more rapidly. This research suggests that, where self-limiting fire behavior can be anticipated (as it is in the ICB), the hydrological co-benefits should be considered as part of future fire policy development and cost-benefit analysis - presenting a "win-win-win" scenario in which the restored wildfire regime of Illilouette Creek basin yields benefits for water management, forest health, and reductions in fire hazard now and in the future.

Management Implications

- Vegetation change due to wildfires can cause long-term increases in peak snowpack and annual streamflow.
- Repeated wildfires lead to more diverse landscapes in terms of vegetation and water availability.
- In dry years, fires led to less change in streamflow (vs. wet years), but more reduction in drought stress.
- Watersheds in nearby areas without fire have seen a decrease in water output.
- Continued fire use in the ICB would increase peak streamflow vs. fire excluded conditions for all climate and fire regime scenarios, with no change in flood risk.
- The hydrological co-benefits of wildfires on the Illilouette may help managers build a case for adopting similar fire-use strategies throughout the Sierra Nevada.

Papers Summarized in this Section:

Boisramé, G. F., S. E. Thompson, C. Tague, and S. L. Stephens. 2019. Restoring a Natural Fire Regime Alters the Water Balance of a Sierra Nevada Catchment. Water Resources Research.

Boisramé, G. F., S. E. Thompson, and S. L. Stephens. 2018. Hydrologic responses to restored wildfire regimes revealed by soil moisture-vegetation relationships. Advances in Water Resources 112: 1242-146.

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Pollinators and Plants

Authored by Rachelle Hedges and Lauren Ponisio

Photo by Scott Stephens

To better understand how pollinator communities respond to pyrodiversity (or diversity of fire characteristics within a region) and its effects on the landscape, researchers examined the relationship between landscape diversity and richness of plant-pollinator interactions in the Illilouette Creek Basin. Additionally, researchers attempted to determine which fire characteristics, with emphasis on severity, contributed to plant-pollinator diversity, and explored whether fire diversity can buffer pollinator communities against drought induced resource scarcity.

Results indicated that pyrodiversity positively affected floral, pollinator, and interaction richness. On average, a 5% increase in pyrodiversity led to the gain of approximately one pollinator and one flowering plant species. Moreover, plant–pollinator communities in low- and moderate-severity burn areas with a high diversity of fire history had 34% more pollinator species, 33% more flowering plant species, and 14% more interactions, on average, than areas with the minimum amount of fire diversity. Spatial heterogeneity of plant and pollinator communities were also positively affected by pyrodiversity, while less pyrodiversity seemed to negatively influence richness of plant communities. Researchers also found evidence that a diverse fire regime may buffer pollinator communities against the adverse effects of drought-induced floral resource scarcity.

It is important to note that the severity of the most recent burn impacted the response of the plant-pollinator communities on a given site. Specifically, flowering plants, pollinators and their interactions responded positively to pyrodiversity only in low- to mid-severity burns, not in high-severity burn areas (Figure 15). This is likely due to the effects high-severity fires have on soil conditions, which can limit the plant species that establish and persist post-fire. At a landscape level, high-severity patches play an important role in creating plant community heterogeneity, with high severity patches featuring early successional species, low-severity patches featuring a greater number of late successional species, and moderate-severity patches featuring a mix of both.

Blogging for NatGeo

"Cannot See the Forest for the Bees" was the title of a blog post authored by the principle investigator of the pollinators and plants research for National Geographic Magazine in 2015. In her blog post, Lauren Ponisio discusses her fieldwork, the importance of pollinators in California, and the significant impact fire has had on the diversity of bee species in the Illilouette Creek basin. Read more at https://blog.nationalgeographic.org/2015/10/26/cannot-see-the-forest-for-the-bees/

NATIONAL GEOGRAPHIC

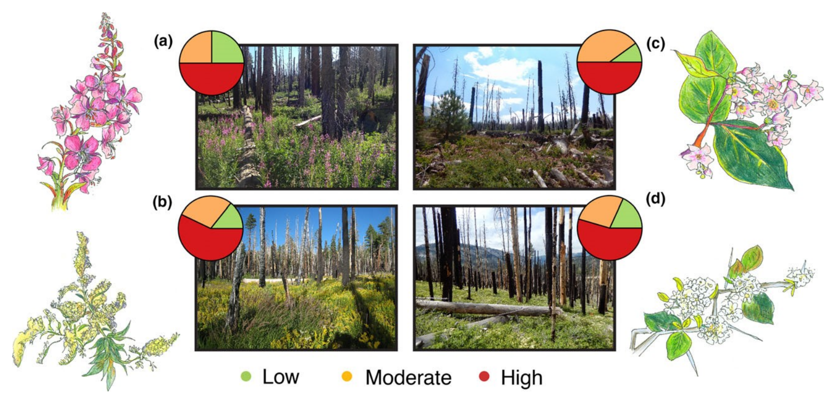

Figure 15. *The proportion of sites that burned at low, moderate, and high severity, grouped by the dominant disturbance specialist.* *(a) Epilobium angustifloium circumvagum (fireweed), (b) Solidago canadensis elongata (goldenrod), (c) Apocynum androsaemifolium (dogbane), and (d) Ceanothus cordulatus (mountain whitethorn). C. cordulatus is a nitrogen fixer. Photographs (a), (b), (d) by L. Ponisio and (c) by S. Stephens. Botanical illustrations by T. Norwood.*


Photo by Scott Stephens

Work in the Illilouette Creek basin in the field of pyrodiversity continues, with another paper currently in review for publication. In her new research, Lauren Ponisio attempts to understand what enables communities and populations to maintain function in the face of the resulting shifts in composition. The ways in which pyrodiversity shapes interaction patterns is explored, as are the impacts on the plant-pollinator community and population resistance to an increase in drought intensity. This work is of particular importance as there has been extensive theoretical work examining the importance of ecological network structure in determining resistance to perturbations, this is the first empirical test of the relationship between interaction patterns and resistance.

Management Implications

- Diverse fire characteristics, like those associated with mixed severity fire regimes, contribute to the maintenance of flowering plant and pollinator biodiversity.
- A fire regime with varying severities and characteristics across the landscape may increase spatial heterogeneity of plant and pollinator communities.
- Pyrodiversity may buffer pollinator communities against the adverse effects of drought , which will become especially important as the climate continues to warm in these areas.
- At a landscape level, high-severity patches play an important role in creating plant community heterogeneity, despite not having a positive effect on plants, pollinators and their interactions at the site-specific level.

Papers Summarized in this Section:

Citation: Ponisio, L.C., K. M. Wilkin, L. K. M'Gonigle, K. Kulhanek, L. Cook, R. Thorp, T. Griswold, C. Kremen. 2016. Pyrodiversity begets plant-pollinator community diversity. Global Change Biology, 22(5), 1794-1808.

Appreciation and Recognition

Photo by Mark Meyers

The Illilouette Creek and Sugarloaf Creek basin are incredible research sites that continue to produce novel research applicable to large areas of forested land in the western U.S. This is the direct result of thoughtful, courageous land management and wildfire use by Parks staff. The Stephens Lab and the Center for Fire Research and Outreach at Berkeley Forests are grateful to the fire staff and land managers who have allowed nature to shape this landscape over the last 45 years. Without their efforts and hard work our research would not be possible. Special thanks are extended to Jan van Wagtendonk for beginning work in the Illilouette Creek basin and inspiring the members and partners of the Stephens lab to work in these great areas.