Restoring wildfire to the Sierra Nevada: Impacts on water resources and drought response

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Outline

- Fire in Western mountains
- Fire – land cover – water interactions
- The Illilouette Creek Basin’s unusual fire history
- Effects of fire on the landscape
- Changing streamflow and soil moisture
- Microclimate effects of fire
- Hydrological model results
- Observed forest health
Fire in Western Mountain Watersheds

- Historically, fires were frequent, small, and mixed severity.
- Suppression alters forests adapted to frequent fires and allows fuel build-up.

Adapted from S. L. Stephens, R. E. Martin, N. E. Clinton, Prehistoric fire area and emissions from California’s forests, woodlands, shrublands, and grasslands. Forest Ecology Management 251, 205 (2007).
Fire in Western Mountain Watersheds

Dense, homogeneous forest

Infrequent, large, severe fires, hydrology effects well studied.

Rim Fire after 1 year (https://californiahiker.smugmug.com)

Frequent, mixed severity fires, virtually no previous work.

Illilouette Creek Basin
The Illilouette Basin

- Rare example of natural fire regime (suppression ended 1973).
- Only one other similar site exists, and it lacks streamflow records.
- **Question:** How have these fires affected streamflow, summer soil moisture, and response to drought?
Fire + Plants + Water = ?
Fire + Plants + Water = ?
Fire + Plants + Water = ?
Jigsaw Puzzle of Fires

Map created by Kate Wilkin and Shane Fairchild
Changes in Land Cover

1969/70

1987/88

1997

2005

2012

Legend
- Rock and Water
- Conifer-Dominated
- Shrub-Dominated
- Sparse Grassland
- Dense Grassland
- Aspen
Changes in Land Cover

![Area (km²) over time for different land cover types: Conifer, Shrub, Sparse Meadow, and Dense Meadow from 1969 to 2012.](chart.png)
Changes in Land Cover

Landscape Evenness Indices

Index Value

Year


SHEI SIEI
Seeing the Forest Without the Trees

Diverse post-fire vegetation and drought-resistant wetlands.
Back to the hydrological questions...
Runoff ratio (flow/precip.) changes before and after 1973:

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Difference</th>
<th>P-Value</th>
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</thead>
<tbody>
<tr>
<td>Upper Merced</td>
<td>0.0%</td>
<td>0.65</td>
</tr>
<tr>
<td>MF</td>
<td>-6%</td>
<td>0.05</td>
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<tr>
<td>SF</td>
<td>-9%</td>
<td>0.06</td>
</tr>
<tr>
<td>Cole Creek</td>
<td>-12%</td>
<td>0.02</td>
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Source: Boisramé et al. 2016. Managed wildfire effects on forest resilience and water in the Sierra Nevada. Ecosystems. DOI: 10.1007/s10021-016-0048-1
Soil moisture measurements
Soil Moisture and Land Cover

- Conifer: 5%
- Conifer -> Shrubs: 5%
- Conifer -> Sparse: 3%
- Conifer -> Meadow: 20%
- Meadow: 40%

Veg. Map

Soil Water Content
Modeled Soil Moisture

2015

Change from 1970 to 2015

Modeled VWC

ICB Boundary

Legend:

-0.14 to -0.1
-0.09 to -0.01
-0.009 to 0
0 to 0.01
0.011 to 0.1
0.11 to 0.2
0.21 to 0.28

0 to 7 Kilometers

0 1.25 2.5 5 Kilometers
Microclimate Effects of Fire
Microclimate Effects of Fire

Daily Mean 60cm Soil Moisture

- Meadow
- Shrub
- Trees
Microclimate Effects of Fire

Snow Depth from Time Lapse Cameras

- Meadow
- Shrub
- Trees

Manual Surveys
Microclimate Effects of Fire

- Shrub
- Meadow
- Trees

Percent Snow Coverage

Graph showing changes in snow coverage from 10/11/2015 to 4/28/2016.
Temperature Difference Between Forest and Shrub Sites

Night (Warmer Under Trees)        Day (Warmer in Burned Areas)
RHESSys Model
Regional Hydro-Ecologic Simulation System

Tague and Band (2004)
Differences in Water Balance When Fire Included in Model

Streamflow Change (mm/year)

Mean Flow
890 mm/year

Soil Water Storage Change (mm)

Mean Storage
1700 mm
Differences in Water Balance When Fire Included in Model

Soil Evaporation Change (mm/year)
- Mean
- 95% Confidence
- Fire

Transpiration Change (mm/year)
- Mean T
- 70 mm/year

Water Year
Differences in Water Balance

Mean CWD 170 mm/year

Mean Peak SWE 590 mm
Spatially Variability Snow Changes
Spatially Variability Snow Changes
Spatially Variability Snow Changes

February 2015

Snow Change (mm)

- 21 - 92
- 6 - 20
- 2 - 5
- 0 - 1
- -4 - -1
- -19 - -5
- -71 - -20

ICB

0 1 2 4 Kilometers
Fire Impacts on Drought Mortality

- USFS aerial surveys map tree mortality each summer.
- Unusually high mortality in 2015 throughout Sierra Nevada.
2014 mortality. Figure from: Boisramé et al. 2016. Managed wildfire effects on forest resilience and water in the Sierra Nevada. Ecosystems. DOI: 10.1007/s10021-016-0048-1
Control watersheds had up to 50 times more dead trees per forested acre in 2015.
Conclusions

- Landscape still in transition
- Fire history and topography determine local response to fire
- Overall, fire appears to be increasing discharge and soil moisture, and increasing drought resilience...
Conclusions

This area’s resistance to drought is demonstrated by …

- limited individual fire extent
- increased streamflow and soil moisture
- a diverse landscape
- deeper, more persistent snow
- low disease-related tree mortality
Thank you to Yosemite National Park for creating the amazing place that is the Illilouette Creek Basin, and allowing us to conduct research there.

This project was supported by the Philomathia Foundation and Joint Fire Sciences Program.


Valuable guidance provided by Sally Thompson, Scott Stephens, Brandon Collins, Naomi Tague, and Maggi Kelly.
Extra slides with more details...
Soil Moisture Measurements
Soil Moisture Relation to Vegetation

May Soil Moisture

June Soil Moisture

Jul/Aug Soil Moisture
Soil Moisture and Fire History

Dry Conifers

Shrubs

Wetlands
## Impacts on Drought Mortality: More Details

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Conifer Area (km²)</th>
<th>Dead Trees 2014</th>
<th>Dead/km² 2014</th>
<th>Dead Trees 2015</th>
<th>Dead/km² 2015</th>
<th>Ratio 2014</th>
<th>Ratio 2015</th>
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