Selection by suppression

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Abstract

Introduction

Fire suppression is an oft-cited root cause of the modern trend of larger, more severe wildfires in the yellow pine/mixed-conifer forests of California's Sierra Nevada mountain range (**???**; Safford and Stevens 2017). While this system would experience frequent, low- to moderate-severity wildfire every 8 to 15 years in the several centuries prior to Euroamerican settlement, suppression management has largely eliminated fire effects from much of western dry forested land in the past 100 years (**???**; Safford and Stevens 2017). A lack of frequent fire has led to densification of Sierra yellow pine/mixed-conifer, which increases fuel loading and homogenizes forest structure (Collins *et al.* 2016; Stephens *et al.* 2018). Fortuitous alignment of these extreme fuel conditions with earlier snowmelt, longer fire seasons, and hotter droughts (aka "climate change droughts") (Westerling 2006, 2016; Abatzoglou and Kolden 2013; Abatzoglou and Williams 2016) increases the probability that fires will generate self-propagating behavior (Coen *et al.* 2018) and burn at high severity (Koontz *et al.* 2019b) in large, contiguous patches (Stevens *et al.* 2017). The Sierra yellow pine/mixed-conifer community is ill-adapted to regenerate in the centers of high-severity patches, which are far from seed sources (Welch *et al.* 2016), and thus these megadisturbances have negative consequences for long-term forest health (Millar and Stephenson 2015; Stevens *et al.* 2017; Steel *et al.* 2018).

Despite the long-term effects of fire suppression on wildfire trends, fire suppression generally is very effective at extinguishing fires. Between 1970 and 2002, the U.S. forest service contained over 97.5% of fires before they reached 120 hectares in size (Calkin *et al.* 2005). In the Sierra yellow pine/mixed-conifer system, the vast majority of fires are managed for suppression (citation needed?) and 98.5% remain smaller than 80 hectares (Short 2017). The fires that remained small are often assumed to have burned under mild or moderate

vegetation and climate conditions, facilitating initial suppression efforts. The fires that escape initial attack and grow large account for 97.5% of the total burned area of fires managed by the U.S. Forest Service (Calkin *et al.* 2005), and are often assumed to have grown to these sizes because they were burning under more extreme conditions. Thus, the cumulative effect of fire suppression policy has led to a management paradox with respect to maintaining forest health: *we shouldn't put out the fires that we can, but we can't put out the fires that we should.*

Bimodal distribution of fire sizes under suppression policy: either the fires were quickly put out and remained very small, or they escaped suppression efforts and grew exceptionally large due to regional climate conspiring with accumulated fuel conditions. Indeed, Miller and Safford (2017) found evidence for this pattern in that the average size of all fires is much smaller under a modern fire suppression management regime compared to pre-Euroamerican settlement fires (as one might intuitively expect given the goal of suppression is to stop fires to protect life and property), but the average size of larger fires (>4 hectares) is, perhaps counter-intuitively, much greater under modern suppression management (Safford and Stevens 2017; Miller and Safford 2017). Many studies have suggested that adding more fire to the landscape is a way to return forests to pre-Euroamerican settlement resilient conditions (North *et al.* 2015; Collins *et al.* 2017; Stevens *et al.* 2017) (XXXXX Stephens) and some efforts are underway (SEKI reference? new USFS policies using some forest management units as testbeds for this idea?)

We use a new dataset of fire severity (Koontz *et al.* 2019a) to measure this "selection by suppression" effect and ask:

1) How do burning conditions (regional climate, vegetation density, vegetation continuity) vary between suppression and wildfire use fires?

2) What are the consequences of these varying conditions for wildfire effects (burn duration, fire event size, severity configurations)?

3) To what extent might prematurely extinguished suppression wildfires exhibit desireable fire effects, were they to be allowed to burn for longer? That is, are small suppression fires behaving like small wildfire use fires (and thus they should perhaps be left to burn and cover more area)?

Methods

Study system

The Sierra Nevada yellow pine/mixed-conifer (hereafter Sierra YPMC) is

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We designated Sierra YPMC using the FRID dataset and included "dry mixed-conifer", "moist mixed-conifer", and "yellow pine" vegetation types following Steel *et al.* (2018) and Koontz *et al.* (2019b)]. These classifications represent "potential vegetation" given the climate of the area, such that there is no influence of recent disturbance events (Harvey *et al.* 2016; Steel *et al.* 2018; Koontz *et al.* 2019b).

Some summary stats of the Koontz *et al.* (2019a) severity dataset.

To do:

Analysis: regional climate conditions "selection" analysis akin to measuring the selection coefficient in evolutionary biology (Lande and Arnold 1983; Schluter 1988).

Pre-selection event is the distribution of fire "traits" (regional climate; [vegetation metrics, severity configuration here as correlated traits?]) for the full population of fires. Post-selection event is the "larger" fires by the different size cutoffs. Do this analysis for both the suppression and the managed wildfire areas.

OR, alternatively:

Pre-selection trait distribution of fire size, regional climate, vegetation metrics, and the selection event is suppression– so get rid of all non-suppression fires and see the impact to the "traits" of fire size, regional climate, and vegetation metrics. I would expect disruptive selection on fire size, no selection on regional climate (suppression and managed wildfires burn under similar conditions, accounting for size), and perhaps positive selection on vegetation ("surviving" fires are burning in denser, more homogenous fuels)

If including the vegetation

"Disruptive selection" language (Schluter 1988).

Calculated the stand decay coefficent (SDC) (Collins *et al.* 2017; Stevens *et al.* 2017)

Future work?

Some summary stats of the Sierra Nevada yellow pine/mixed-conifer subset of the Short (2017) fire occurrence dataset.

Upload Sierra YPMC Short (2017) subset to Earth Engine in order to get initial burning conditions for each point using the algorithm from "remote sensing resilience" work.

Subset Short (2017) into suppression/managed wildfire based on where it burns, using method of Steel *et al.* (2018).

Use the expanded set of fires, and the relationships between fire size/SDC and covariates to extrapolate
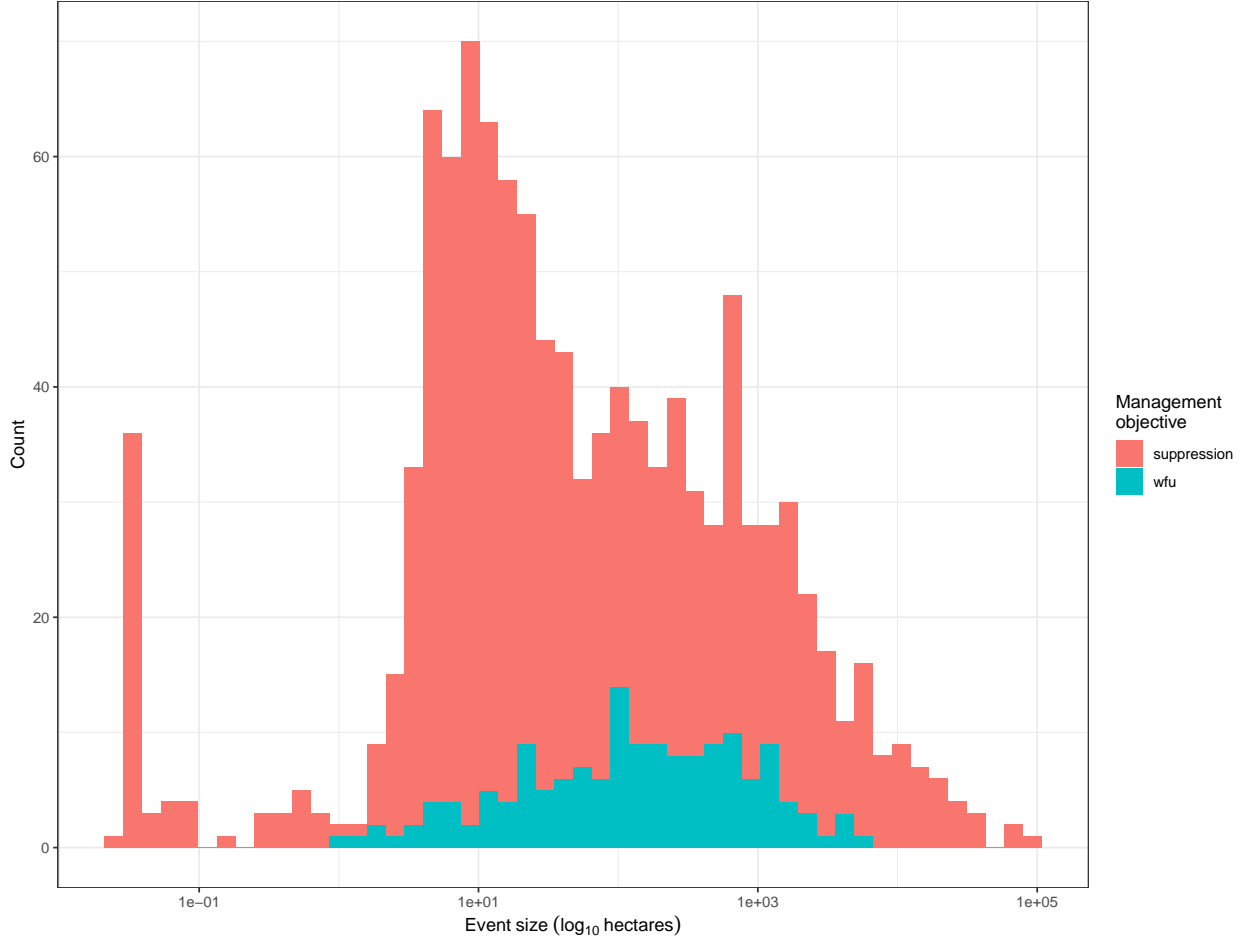
Figure 1: Distribution of log fire event size by management objective. While wildfire use fires exhibit a lognormal distribution in size, suppression fires exhibit clear multimodality.

the potential added "good fire area" that might have burned if the Short (2017) suppression fires weren't extinguished.

Results

Discussion

We have demonstrated a clear multi-modality in the fire event size distribution of wildfires managed with a suppression objective, and further measured the effect of this "selection by suppression" on the severity characteristics of these events.

Suppression leads to especially large fires because the ones that grow large are only able to do so because they burn under extreme conditions. Steel *et al.* (2018) found only a small difference in the measure of regional climate during suppression versus wildfire use fires (modeled fuel moisture), which led to the conclusion that
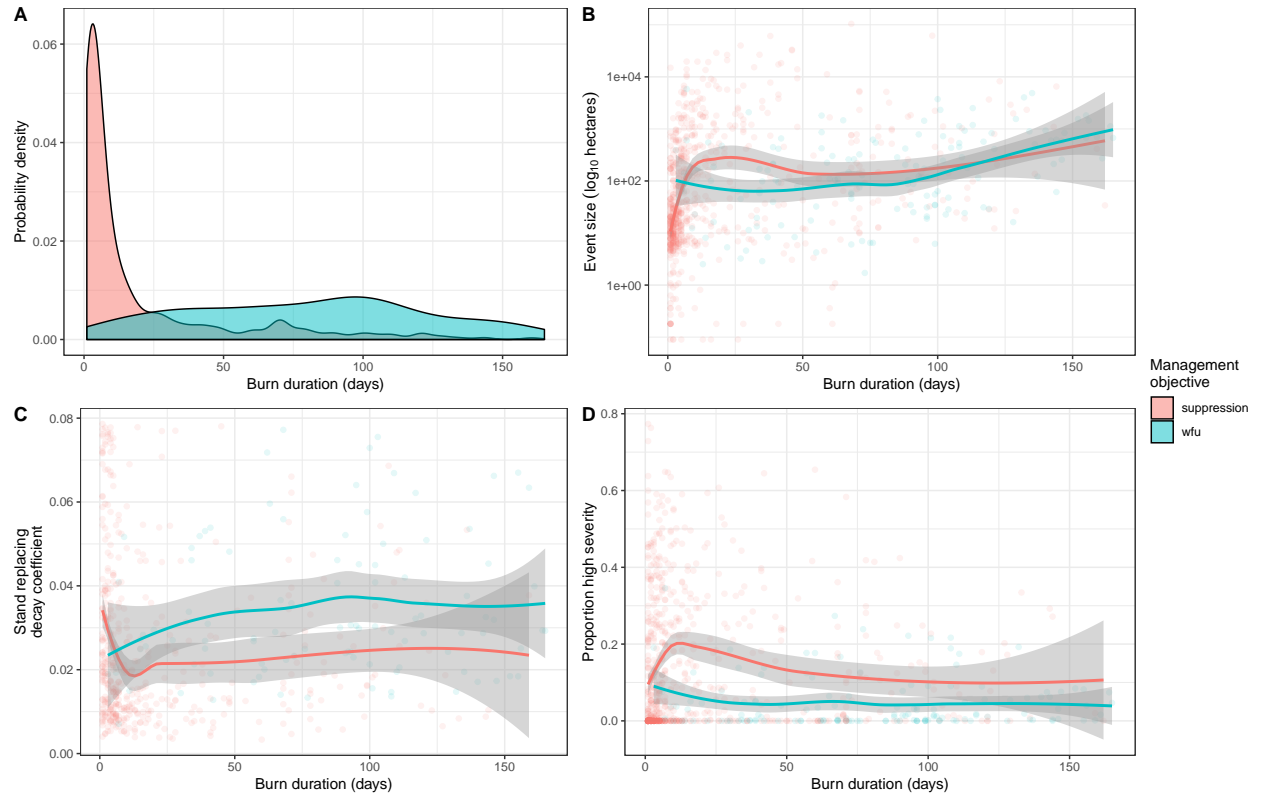
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Figure 2: A) Distribution of burn duration by management objective. Most suppression fires are quickly extinguished. B) Effect of burn duration on fire event size shows that there's a similar trajectory between suppressed and wildfire use fires except early in the burning period when suppression fires remain small. C) For fires with a high severity component, the stand replacing decay coefficient sharply declines for short-lived fires indicating that the high severity patches are larger and simpler which may reduce tree propagule pressure in the center of these patches and compromise dry forest regeneration. The SDC tends to increase with the burn duration for wildfire use fires. D) The high severity portion of the fire tends to increase with shorter-duration suppression fires, but is relatively constant across burn durations for wildfire use fires.
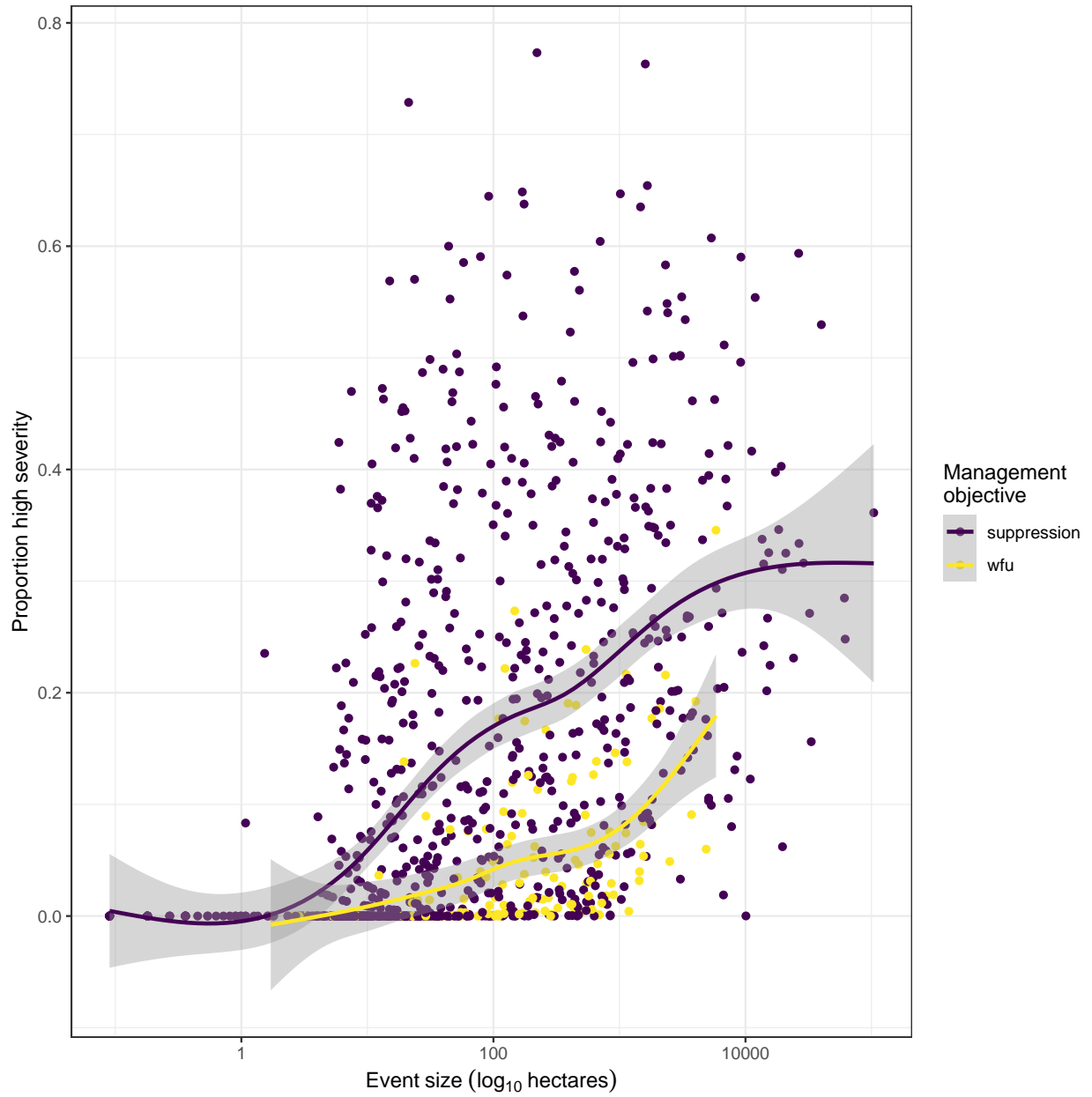
Figure 3: The effect of the fire event size on the proportion of high severity fire by management objective. The effect appears to manifest for suppression fires starting at fires around 40 hectares in size.

an "extreme fuel" effect underlied the differences in the size/configuration of high and unburned severity patches.

Essentially all of the suppression fires in Figure 2c that are within or above the confidence interval for the wildfire use fires had beneficial severity characteristics but were suppressed. Each of these fires represents potentially "lost area" of beneficial fire activity.

But that analysis only included fires greater than 80 hectares in size, which is still pretty big. Analyzing big fires made sense for that paper, because they affect the most area, but if we want to suggest "let fires burn at more moderate weather conditions" as a mitigation strategy for a century of making fuel conditions more extreme, then I think this paper would serve the purpose of measuring the degree to which good work can be done by a fire (even in extreme fuel conditions) in milder weather conditions.

"A variety of environmental and social factors influence wildfire growth and whether a fire overcomes initial attack efforts and becomes a large wildfire. However, little is known about how these factors differ between lightning-caused and human-caused wildfires." (Abatzoglou *et al.* 2018)

"As shown by Balch et al. (2017), human-caused fires occupy an environmental niche characterised by lower lightning- frequency and higher fuel moisture than lightning-caused fires. The present work complements those findings by demonstrating the likelihood of human ignitions evolving into large fires when facilitated by strong winds." (Abatzoglou *et al.* 2018)

Good starting points:

Fire occurrence data: (Short 2017) Papers on interacting effects of vegetation, regional climate, fire size, and severity patterns: (Cansler and McKenzie 2014; Harvey *et al.* 2016).

References

Abatzoglou JT and Kolden CA. 2013. Relationships between climate and macroscale area burned in the western United States. *International Journal of Wildland Fire* **22**: 1003.

Abatzoglou JT and Williams AP. 2016. Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences* **113**: 11770–5.

Abatzoglou JT, Balch JK, Bradley BA, and Kolden CA. 2018. Human-related ignitions concurrent with high winds promote large wildfires across the USA. *Int J Wildland Fire* **27**: 377–86.

Calkin DE, Gebert KM, Jones JG, and Neilson RP. 2005. Forest Service Large Fire Area Burned and

125 Suppression Expenditure Trends, 19702002. *j for* **103**: 179–83.

126 Cansler CA and McKenzie D. 2014. Climate, fire size, and biophysical setting control fire severity and spatial

127 pattern in the northern Cascade Range, USA. *Ecological Applications* **24**: 1037–56.

128 Coen JL, Stavros EN, and Fites-Kaufman JA. 2018. Deconstructing the King megafire. *Ecological Applications*

129 **28**: 1565–80.

130 Collins BM, Lydersen JM, and Fry DL *et al.* 2016. Variability in vegetation and surface fuels across

131 mixed-conifer-dominated landscapes with over 40 years of natural fire. *Forest Ecology and Management* **381**:

132 74–83.

133 Collins BM, Stevens JT, and Miller JD *et al.* 2017. Alternative characterization of forest fire regimes:

134 Incorporating spatial patterns. *Landscape Ecology* **32**: 1543–52.

135 Harvey BJ, Donato DC, and Turner MG. 2016. Drivers and trends in landscape patterns of stand-replacing

136 fire in forests of the US Northern Rocky Mountains (1984-2010). *Landscape Ecology* **31**: 2367–83.

137 Koontz MJ, Fick SE, and Werner CM *et al.* 2019a. Wildfire severity, vegetation characteristics, and regional

138 climate for fires covering more than 4 hectares burning in yellow pine/mixed-conifer forests of the Sierra

139 Nevada, California, USA from 1984 to 2017. *Open Science Framework.*

140 Koontz MJ, North MP, and Werner CM *et al.* 2019b. Local variability of vegetation structure increases forest

141 resilience to wildfire. *EcoEvoRxiv.*

142 Lande R and Arnold SJ. 1983. THE MEASUREMENT OF SELECTION ON CORRELATED CHARAC-

143 TERS. *Evolution* **37**: 1210–26.

144 Millar CI and Stephenson NL. 2015. Temperate forest health in an era of emerging megadisturbance. *Science*

145 **349**: 823–6.

146 Miller JD and Safford HD. 2017. Corroborating Evidence of a Pre-Euro-American Low- to Moderate-Severity

147 Fire Regime in Yellow PineMixed Conifer Forests of the Sierra Nevada, California, USA. *Fire Ecology* **13**:

148 58–90.

149 North MP, Stephens SL, and Collins BM *et al.* 2015. Reform forest fire management. *Science* **349**: 1280–1.

150 Safford HD and Stevens JT. 2017. Natural Range of Variation for Yellow Pine and Mixed-Conifer Forests in

the Sierra Nevada, Southern Cascades, and Modoc and Inyo National Forests, California, USA.

Schluter D. 1988. Estimating the Form of Natural Selection on a Quantitative Trait. *Evolution* **42**: 849.

Short KC. 2017. Spatial wildfire occurrence data for the United States, 1992-2015 [FPA_FOD_20170508] (4th Edition).

Steel ZL, Koontz MJ, and Safford HD. 2018. The changing landscape of wildfire: Burn pattern trends and implications for California's yellow pine and mixed conifer forests. *Landscape Ecology* **33**: 1159–76.

Stephens SL, Collins BM, and Fettig CJ *et al.* 2018. Drought, Tree Mortality, and Wildfire in Forests Adapted to Frequent Fire. *BioScience* **68**: 77–88.

Stevens JT, Collins BM, and Miller JD *et al.* 2017. Changing spatial patterns of stand-replacing fire in California conifer forests. *Forest Ecology and Management* **406**: 28–36.

Welch KR, Safford HD, and Young TP. 2016. Predicting conifer establishment post wildfire in mixed conifer forests of the North American Mediterranean-climate zone. *Ecosphere* **7**: e01609.

Westerling AL. 2006. Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. *Science* **313**: 940–3.

Westerling AL. 2016. Increasing western US forest wildfire activity: Sensitivity to changes in the timing of spring. *Philosophical Transactions of the Royal Society B: Biological Sciences* **371**: 20150178.