

Walking through a ‘phoenix landscape’: hiker surveys reveal nuanced perceptions of wildfire effects

Alexandra M. Weill^{A,B}, Lauren M. Watson^A and Andrew M. Latimer^A

^ADepartment of Plant Sciences, University of California Davis, 1 Shields Avenue, Davis, CA 95616, USA.

^BCorresponding author. Email: amweill@ucdavis.edu

Abstract. Public opinion of wildfire is often perceived to be negative and in support of fire suppression, even though research suggests public opinions have become more positive over the past few decades. However, most prior work on this topic has focused on homeowners in forested regions. In this study, we shift the lens to hikers in a chaparral- and oak-savannah-dominated landscape that burned at high severity in 2015. We surveyed hikers before and after their hike about their familiarity and perceptions of local fire, and wildfire in the nation at large. We found hikers were familiar with topics such as prescribed fire and basic fire ecology, but knew little about local ecology or fire regimes. Post-hike perceptions of fire and feelings about wildfire in the USA were complex and heterogeneous, not predominantly negative. Contrary to frequent media descriptions of post-fire landscapes as ‘devastated’ or ‘moonscapes,’ many participants described the burned landscape with awe and admiration. These results suggest that residents of fire-prone landscapes may benefit from programming that emphasises benefits and challenges of fire in the local landscape and incorporates visits to local burned sites throughout the recovery period.

Received 3 April 2019, accepted 14 February 2020, published online 18 March 2020

Introduction

The histories of humans and fire are tightly intertwined; for most of human history, people have been setting fires and learning to live in fire-prone landscapes (Bowman *et al.* 2009). In the 21st century, climate change and development at the wildland–urban interface (WUI), combined with past land management, have made fire management an ever more difficult problem to solve (Westerling and Bryant 2008; Liu *et al.* 2010; North *et al.* 2015). The recent increase in social science literature related to wildfire (McCaffrey and Olsen 2012; Paveglio *et al.* 2015; Dupéy and Smith 2018; Meldrum *et al.* 2018) reflects a growing understanding that the disconnect between fire science and fire management is a social problem (Moritz *et al.* 2014) and that addressing wildfire-related challenges requires integration across the natural and social sciences (Smith *et al.* 2016).

Much of the research into the social problem of fire management has centred on human perceptions of wildfire and fire management practices. Though public support was low in the past, acceptance of fire as part of natural landscapes and support for modern fire management practices such as prescribed fire is in fact the majority opinion in many fire-prone systems (Muleady-Mecham *et al.* 2004; Absher *et al.* 2010; Toman *et al.* 2011; Moskwa *et al.* 2016; Meldrum *et al.* 2018). Yet the story is incomplete: in a 2018 review of perceptions and behaviours related to wildfire in forests, Dupéy and Smith found that half of the papers reviewed focused on homeowners or residents, with only 9% focused on the general public and 3% on recreationalists. Most literature in this field is also limited to forested ecosystems. In contrast, we know little about public

perceptions in non-forested systems such as the shrublands, woodlands, and grasslands that surround many of California’s most populated regions and where many of the most destructive fires burn. Mediterranean shrublands, in particular, have a different fire history and different management needs than forest systems (e.g. prescribed fire is thought to be ineffective or damaging to chaparral) (Keeley 2005; Keeley and Syphard 2019). The few studies of fire perceptions in these vegetation types touch only generally on fire risk and hazard reduction (Gardner and Cortner 1985). In light of these gaps, the first aim of this study was to use a case study in a Northern California recreation site dominated by shrubland and woodland to learn what visitors to the site knew and perceived about fire ecology, management and fire’s effects on local landscapes.

The secondary focus of this study was how in-person interaction with local burned landscapes affects perceptions of fire’s effects. Direct engagement with a recently burned landscape can have strong effects on perceptions of fire, but there has been limited research in this area. Hands-on, interactive field trips and workshops have been found to be effective means of wildfire education (Parkinson *et al.* 2003; Smith and McMurray 2004) and participation in post-fire recovery programs has been shown to help citizens recover and connect with the landscape (Ryan and Hamin 2006). The few studies that have looked at the effects of field trips or site visits on perceptions of fire, fire management and post-fire landscape recovery in forested systems have indicated that these types of interactions can have positive effects on acceptance of prescribed fire (Toman *et al.* 2004; McCaffrey *et al.* 2008).

The questions we explored in this study were:

1. How familiar are visitors to a locally popular California hiking trail with wildfire-related topics and how do they perceive wildfire and fire's effects on the landscape?
2. Do perceptions of wildfire and fire effects differ before and after spending time in a recently burned landscape? If so, in what ways do perceptions change?

Methods

Study site

Our study site was a hiking trail primarily contained within a University of California-run natural reserve, Stebbins Cold Canyon Reserve ('Stebbins'), in Winters, CA. The reserve is located in the Northern California Coast range, ~60 kilometres from Sacramento and 100 kilometres from the San Francisco Bay Area. Stebbins is open to the public full time and includes a popular hiking trail that received up to 60 000 hikers annually before the wildfire in 2015 and reduced numbers in the post-fire years, with roughly 25 000 visitors in 2015, 35 000 in 2016, and 45 000 in 2017 (J. Clary, pers. comm., 7 November 2017). The reserve attracts a diverse range of visitors from a region that includes the nearby cities of Sacramento, Davis, Vacaville, Napa and Fairfield, as well as from the north-eastern parts of the San Francisco Bay Area. Hikers have a wide range of backgrounds, ages and hiking abilities, as the trail is one of the few publicly accessible trails in the region. The main hiking trail is ~8 kilometres long, with a mostly flat section that runs along a creek through a canyon and a steep climb up to a ridgetop with views of nearby Lake Berryessa. Habitats on the trail include riparian woodland, oak woodland and chaparral (Greene and Huntzinger 2004).

Stebbins burned in the Wragg Fire, which was sparked by a vehicle along a road bordering the reserve on 22 July 2015. The fire burned 8051 acres, 47% at high severity, before full containment on 5 August 2015 (California Department of Forestry and Fire Protection 2015; USDA Forest Service 2017). The fire destroyed or damaged seven structures (one residence and six outbuildings (Johnson 2015)), but there were no reported injuries or fatalities (California Department of Forestry and Fire Protection 2015). The entirety of the main loop trail at Stebbins is within the fire perimeter, though one section follows the edge of the fire. After the fire, the reserve was closed to the public until 15 May 2016 for restoration and safety reasons.

This study was designed to take advantage of the wildfire event as a case study for hiker perceptions of fire effects on northern Californian shrublands and woodlands. As a rare university research reserve that is fully open to the public, research focused on hikers at Stebbins benefits from support of the university reserve system while attracting diverse participants from outside the university. In addition, this hiking trail largely attracts people who live in the region rather than tourists, allowing for consideration of local perceptions of a local fire without limiting the sample to homeowners.

Survey methods

Surveying took place in two modes: in-person near the trailhead and through a survey box attached to informational signage next

to the start of the trail. In-person surveying took place over two Saturdays in May 2016, with the first day occurring when the reserve was formally re-opened to the public following the post-fire closure. Researchers stationed near the beginning of the trail asked passing hikers to take a brief pre-hike survey as they began their hike and a post-hike survey as they exited. Hikers who completed a pre-hike survey only were sent a post-hike survey within a few days by email if they provided an email address on their pre-hike survey. Participants were instructed to leave a name or nickname with which to match before and after surveys, though some participants did not do so. Approximately 70–75% of hikers who walked by agreed to take the survey (99 people total) and 68 (69%) of those who took a pre-hike survey in person also took a post-hike survey that could be matched, either in person or via email. A total of 28 post-hike surveys were completed via email. Participants who declined on their way in or who were already hiking when the survey began were allowed to take a post-hike survey only. A total of 85 unmatched post-hike surveys came from this group and from those who took the pre-hike survey but did not leave a name for matching.

After June 2016, participants could take the survey using a survey drop box set up at the trailhead. Information about the survey and instructions were posted on a colourful sign next to the box, along with pencils and the two parts of the survey, differentiated by coloured paper. The survey box remained up until July 2017, which was 2 years after the fire, and was then removed. During this time, 305 people filled out the pre-hike survey, with 100 (36%) also filling out a post-hike survey that could be matched. An additional 120 people completed the post-hike survey only or completed two unmatchable surveys using the drop box.

In addition to hiker surveys, surveys were also distributed to two guided walk groups from UC Davis in October 2016 and a group that participated in a 'BioBlitz' citizen science activity in April 2017. These groups spent time hiking in the same reserve and trails as hikers, for similar amounts of time. They received the same surveys as the hikers, with the pre-hike surveys distributed before and post-hike surveys after the activity. For the guided walk groups, the total numbers of surveys were 47 before and 50 after, with 38 matchable. For the Bioblitz participants, there were 14 before surveys, 13 after and 11 that were matchable.

We tested whether group (hiker, guided walk or Bioblitz) or subgroup (hiker in-person vs survey drop box, class trip vs club trip) influenced survey results using ordinal regressions (Christensen 2015) with group and subgroup as predictors. We found that group and subgroup were not significant predictors of perceptions or change in perceptions, with the exception of perceptions of fire effects on plants. Surveys from in-person hikers had more negative perceptions for plants than the drop box group (β coefficient = -0.65 , $P < 0.05$). In light of the lack of strong differences among groups, we chose to combine all these groups into a single hiker group in all results reported below. These bring the total of pre-hike surveys to 465, the total post-hike surveys to 436 and the total of matched surveys to 217.

For analysis of questions in the pre-hike survey or post-hike survey only, we used all the available data, regardless of whether participants had taken both surveys. Though we encouraged participants to take both parts of the survey, we chose to allow

participants to take only one and include results from these larger groups to get a better representation of familiarity with wildfire topics for hikers at Stebbins and a broader range of post-hike responses. For the perceptions questions that appeared on both surveys for the purpose of comparing responses before and after the hike, we used only the matched surveys. As a result, there are in effect three different (but overlapping) sample groups in this analysis (all the people who took a pre-hike survey, all who took a post-hike survey and those who took both).

The study was given exempt status by the Internal Review Board of the University of California, Davis.

Survey contents

The survey (see Supplementary Material) was an original, two-part survey designed so that participants could complete it in 5–10 minutes at the trailhead before and after a hike. The pre-hike survey focused on experiences and background familiarity related to Stebbins and wildfire and asked participants to predict how the Wragg Fire may have affected the reserve. For experiences, participants were asked about the last time they had visited the reserve and whether they had experienced wildfire near their homes, fire education programs or prior visits to burned areas. For background familiarity, participants were asked to rate their own familiarity with several wildfire- and fire management-related topics, including fire suppression, defensible space, fire behaviour, prescribed or planned fire, fire history of California ('California fire regimes' in some early surveys), plant or animal responses to fire, chaparral/shrubland ecology and fire use for resource benefit. Each was measured on a 5-point Likert-type scale with 1 = 'No knowledge' and 5 = 'I could teach a class about this'. For perceptions, participants were asked how they thought the fire affected plants, animals, soil and water, and the hiking experience on a 5-point Likert-type scale from 1 = 'very negative' to 5 = 'very positive'.

The post-hike survey repeated the questions about how the fire had affected different aspects of the environment and perception of wildfire in the USA, but also asked participants whether they had thought about or discussed the fire during their hike and to rate their overall experience ('very negative' to 'very positive'). There were also three open-ended questions on the post-hike survey. The first asked them to describe the environment they had observed in their own words; 81% of participants did so. The other two open-ended questions were marked as 'optional' and encouraged participants to comment on their wildfire ratings and their overall experience: 59% and 57% of participants, respectively, chose to provide a textual answer to these questions.

Analysis

Survey data were entered into Microsoft Excel and converted from checkboxes or marks on a textual scale (e.g. 'very negative' to 'very positive') to numerical representations (0 or 1 for checkboxes, 1–5 for ratings). Each survey respondent was given a participant ID; names and contact information were stored separately. Surveys were included even if some questions were left blank. Missing answers were distributed across the different questions, likely due to accidentally skipping questions, though familiarity questions (mostly the front page of the survey) had

Table 1. Summary statistics for familiarity questions and pre-hike perceptions questions, based on all pre-hike surveys ($n = 465$)

| Question | n | Mean | s.d. | Skewness | Kurtosis |
|-------------------------------|-----|------|------|----------|----------|
| Familiarity | | | | | |
| Fire suppression | 452 | 2.60 | 1.03 | -0.10 | -1.01 |
| Defensible space | 451 | 2.33 | 1.18 | 0.27 | -1.21 |
| Fire behaviour | 451 | 2.42 | 1.02 | 0.18 | -0.79 |
| Prescribed fire | 450 | 2.89 | 1.05 | -0.36 | -0.62 |
| Fire history of CA | 141 | 2.45 | 0.96 | 0.17 | -0.74 |
| CA fire regimes | 310 | 2.16 | 1.15 | 0.59 | -0.86 |
| Plant and animal responses | 449 | 2.65 | 1.09 | 0.02 | -0.85 |
| Chaparral/shrubland ecology | 452 | 2.41 | 1.21 | 0.26 | -1.12 |
| Fire use for resource benefit | 445 | 2.57 | 1.14 | 0.05 | -1.10 |
| Pre-hike perceptions | | | | | |
| Plants | 444 | 3.14 | 1.08 | -0.30 | -0.51 |
| Animals | 441 | 2.55 | 0.99 | 0.23 | -0.32 |
| Soil and water | 442 | 2.88 | 1.08 | 0.11 | -0.65 |
| Hiking experience | 440 | 2.54 | 1.01 | 0.34 | -0.22 |
| Wildfire in the USA | 444 | 2.89 | 1.03 | -0.01 | -0.24 |

Table 2. Summary statistics for post-hike perceptions questions, based on all post-hike surveys ($n = 436$)

| Question | n | Mean | s.d. | Skewness | Kurtosis |
|-----------------------|-----|------|------|----------|----------|
| Post-hike perceptions | | | | | |
| Plants | 428 | 3.18 | 1.12 | -0.29 | -0.55 |
| Animals | 424 | 2.69 | 0.99 | 0.05 | -0.26 |
| Soil and water | 427 | 3.00 | 1.04 | 0.07 | -0.54 |
| Hiking experience | 422 | 3.10 | 1.05 | 0.01 | -0.51 |
| Wildfire in the USA | 425 | 3.07 | 1.03 | -0.17 | -0.31 |

higher response rates than perceptions questions (back page). Missing answers were entered as NA and not included in analysis relevant to that question (pairwise deletion). Total responses (n) used for each question can be found in Table 1 and Table 2. Data were analysed and visualised using R version 3.4.0 (R Core Team 2017).

Quantitative data were visualised using the Likert package (Bryer and Speerschneider 2016) and ggplot2 (Wickham 2016). Summary statistics were calculated for each question using the fBasics package (Wuertz *et al.* 2017). All pre-hike surveys were used in analyses of pre-hike survey questions, including familiarity and pre-hike perceptions. Likewise, all post-hike surveys were used to assess post-hike questions, including post-hike perceptions and general experience questions.

To assess the effect of hiking in the reserve on perceptions of wildfire effects and fire in the USA, we used only the 'matched' dataset, from participants who completed pre-hike and post-hike surveys. Comparisons of before and after hike data were analysed using both a Student's t -test and Mann-Whitney U tests. The results were generally consistent regardless of the statistical test, so we report results from the t -test only. Because sample means are of limited use for this dataset (e.g. a mean of 0 could come from a mix of strongly positive and negative changes), we also calculated the mean absolute value change

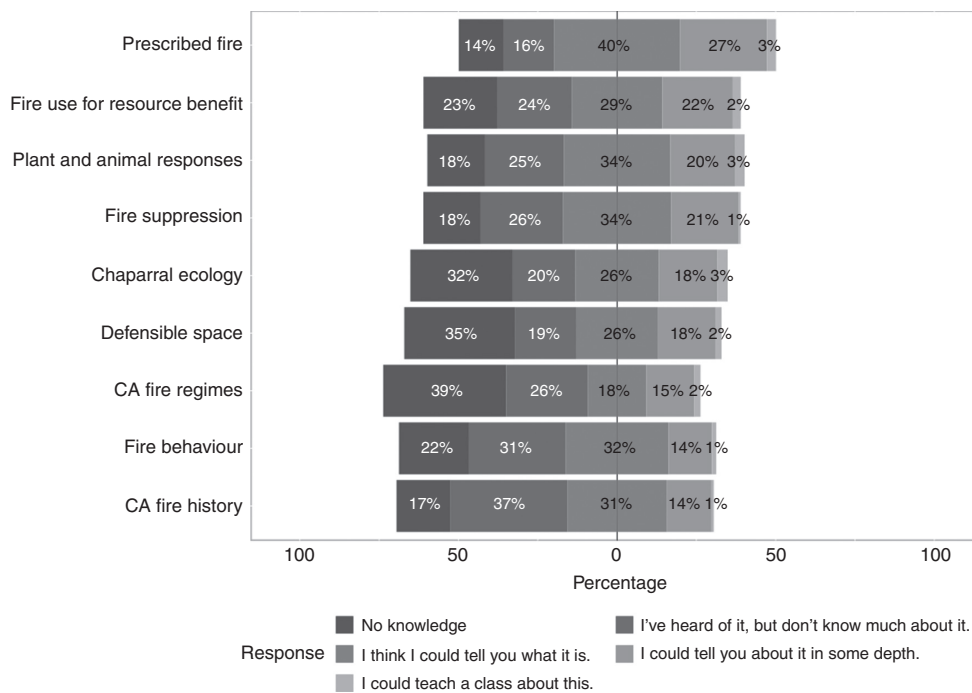


Fig. 1. Self-rated familiarity with wildfire topics for hikers at Stebbins Reserve for all pre-hike surveys. Note: due to rounding, numbers may not total to exactly 100%.

for each question and generated descriptive statistics for these values. Missing data were not excluded. Finally, we generated transition matrices that show the proportion of participants selecting each response before the hike that selected each response after the hike (e.g. the proportion of those who picked 'very negative' before the hike who switched to 'somewhat negative' after the hike).

Qualitative data came from the three open-ended questions on the post-hike survey (see Supplementary Material). We used all post-hike surveys in the analysis of qualitative data. For each question, we used open coding to identify common themes in the text, as well as themes expected based on previous research. Most themes were identified in advance as concepts we expected to see (e.g. positive effects of fire, devastation and destruction, fire suppression) or were looking for (e.g. chaparral-specific fire ecology, climate change), based our experience in studying and discussing wildfire with the public. A few themes emerged from reading the responses (e.g. qualms); when this occurred, all surveys were reassessed for the presence of these new themes. A theme was only marked once per respondent for each question, regardless of its length or how much space was given to that theme. Every survey was coded by the same two researchers. In the case of disagreement, a single coder (Weill) had authority to decide whether a response fitted a particular theme.

Results

Prior experiences with wildfire and fire education

For participants who filled out the pre-hike survey, 58% were first-time visitors to the reserve, meaning that they had never seen the reserve before the fire. Among the returning visitors,

22% had already visited the reserve after it had burned but before taking the survey (some of whom indicated a visit during the time that the reserve was closed to the public). The remaining 33% who answered the question had visited before the fire (3% skipped the question).

For pre-hike survey participants, the most common experience was a prior visit to a burned area, with 57% having had this experience. Similar portions of participants had participated in a fire safety education program (16%) or a fire ecology education program (17%). Responses about the two types of fire education were correlated: roughly half of the group with fire safety education also had fire ecology education (54%) and vice versa (53%). Only 12% of participants said they had been evacuated because of wildfire or had experienced a fire near their homes. Participants who had experienced a fire near their homes were more likely to have participated in fire safety education (43%), fire ecology education (39%) or a prior visit to a burned area (80%) than the group as a whole.

Familiarity with wildfire topics

Participants were asked to rate their own familiarity with several wildfire-related topics by selecting the most appropriate measure from five statements: 1 = 'No knowledge', 2 = 'I've heard of it, but don't know much about it', 3 = 'I think I could tell you what it is', 4 = 'I could tell you about it in some depth', and 5 = 'I could teach a class about this' (Fig. 1). Summary statistics for familiarity topics (Table 1) show that participants covered the full range of possible responses and that the mean rating was between 2 ('I've heard of it.') and 3 ('I think I could tell you what it is.'). Participants were most familiar with prescribed fire, with 70% of hikers able to say

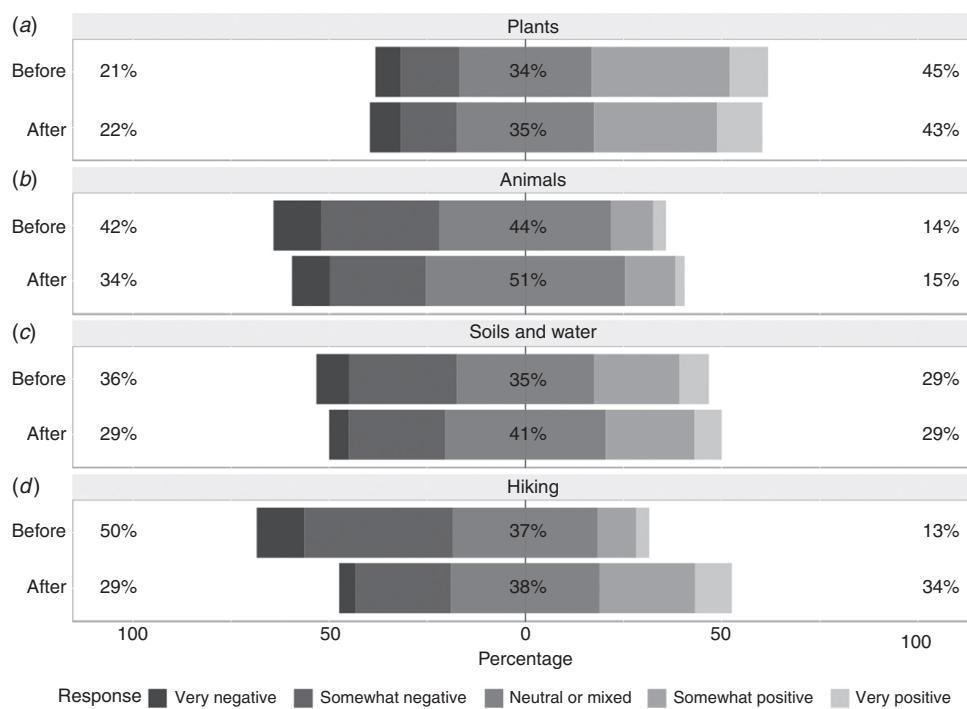


Fig. 2. Perceptions of wildfire effects at Stebbins Reserve before and after hiking in the recently burned reserve for matched before/after surveys, with percentages rating effects as either negative (left), neutral or mixed (centre) or positive (right). Note: due to rounding, numbers may not total to exactly 100%.

what prescribed fire was (‘I think I could tell you what it is’) or rating their knowledge at higher familiarity level. A majority of participants also said they could describe plant and animal responses to fire (57%), fire suppression (56%), and fire use for resource benefit (53%), though these majorities were smaller than for prescribed fire (Fig. 1). Smaller proportions of participants said they could describe California fire regimes (35%), California fire history (46%), chaparral ecology (47%), defensible space (46%) and fire behaviour (47%) (Fig. 1). Many of the topics had roughly half of the participants able to identify the topic; however, much smaller percentages were able to describe the concepts in depth. Many more participants could describe California fire history than California fire regimes; the numbers who could explain the topics in depth were similar (15% and 17% respectively) (Fig. 1).

Pre-hike perceptions of fire effects and wildfire in the USA

In pre-hike surveys, perceptions of fire effects were mixed, with a mean negative rating (< 3 on a 5-point Likert scale where 1 = ‘Very negative’, 2 = ‘Somewhat negative’, 3 = ‘Neutral or mixed’, 4 = ‘Somewhat positive’ and 5 = ‘Very positive’) for all topics except plants (Table 1). Participants identified that fire had neutral or mixed effects on plants (M = 3.14 and s.d. = 1.08), but perceptions were more negative for animals (M = 2.55, s.d. = 0.99), hiking experience (M = 2.54, s.d. = 1.01) and soil and water (M = 2.89, s.d. = 1.09) (Table 1). For wildfire in the USA, perceptions were mostly negative or neutral/mixed (M = 2.89 on a 1–5 Likert scale centred at 3, s.d. = 1.03) (Table 1).

Post-hike perceptions of fire effects and wildfire in the USA

In post-hike surveys, mean responses were negative to mixed (< neutral/mixed value of 3) for animals (M = 2.69, s.d. = 0.99) and soil and water (M = 2.89, s.d. = 1.04), but more positive for plants (M = 3.17, s.d. = 1.12) and hiking experience (M = 3.10, s.d. = 1.05) (Table 2). Hikers rated wildfire in the USA as neutral/mixed or positive (M = 3.07, s.d. = 1.03) following the hike (Table 2).

Influence of hiking on perceptions of fire effects and fire in the USA

Within the group of hikers that completed both a pre-hike and post-hike survey that could be matched, mean ratings of fire effects and wildfire in the USA were higher in the post-hike responses for every topic (M = 2.63 vs 2.74 for animals, M = 2.93 vs 3.02 for soil and water, M = 2.54 vs 3.10 for hiking experience, and M = 3.01 vs 3.14 for wildfire in the USA) except for plants (M = 3.27 pre-hike vs 3.24 post-hike for plants) (Figs 2, 3, Table 3). However, only the difference between ratings of fire effects on hiking experience were significant (M = 2.54 before vs 3.10 after, P < 0.001). Because a small difference in means could result from large negative changes cancelling out large positive changes, we also looked at the mean absolute value of rating changes. For every topic, the mean absolute value change was considerably larger than the overall mean change (Table 3).

We used transition matrices (Figs 4, 5) to look more closely at how participants changed their perception scores after hiking in the reserve, revealing patterns that were not apparent from

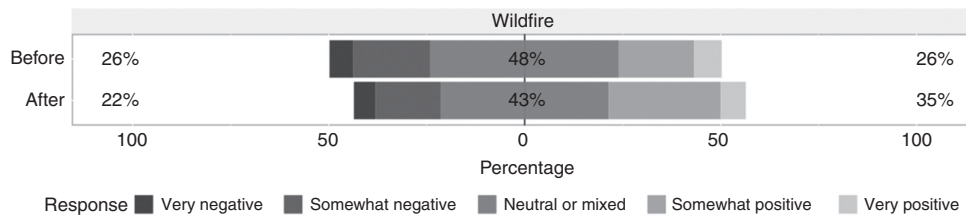


Fig. 3. Perceptions of wildfire in the USA before and after hiking in the recently burned Stebbins Reserve for matched before/after surveys, with percentages rating effects as either negative (left), neutral or mixed (centre) or positive (right). Note: due to rounding, numbers may not total to exactly 100%.

Table 3. Summary statistics for the calculated difference between post-hike and pre-hike perceptions and absolute value of this difference, for individuals in the ‘matched’ dataset only ($n = 217$)

| Question | <i>n</i> | Mean | s.d. | Range | Skewness | Kurtosis |
|--|----------|-------|------|--------|----------|----------|
| Difference between post-hike and pre-hike perceptions | | | | | | |
| Plants | 216 | -0.03 | 0.99 | [-3,3] | -0.02 | 0.67 |
| Animals | 215 | 0.11 | 0.83 | [-2,4] | 0.34 | 1.65 |
| Soil and water | 215 | 0.09 | 1.06 | [-4,3] | -0.13 | 1.05 |
| Hiking experience | 211 | 0.55 | 0.95 | [-1,4] | 0.52 | 0.18 |
| Wildfire in the USA | 214 | 0.13 | 0.76 | [-2,2] | -0.15 | 0.27 |
| Absolute value difference between post-hike and pre-hike perceptions | | | | | | |
| Plants | 216 | 0.66 | 0.73 | [0,3] | 0.90 | 0.40 |
| Animals | 215 | 0.55 | 0.62 | [0,4] | 1.12 | 2.99 |
| Soil and water | 215 | 0.73 | 0.77 | [0,3] | 1.04 | 1.28 |
| Hiking experience | 211 | 0.76 | 0.79 | [0,4] | 0.90 | 0.69 |
| Wildfire in the USA | 214 | 0.50 | 0.58 | [0,2] | 0.65 | -0.58 |

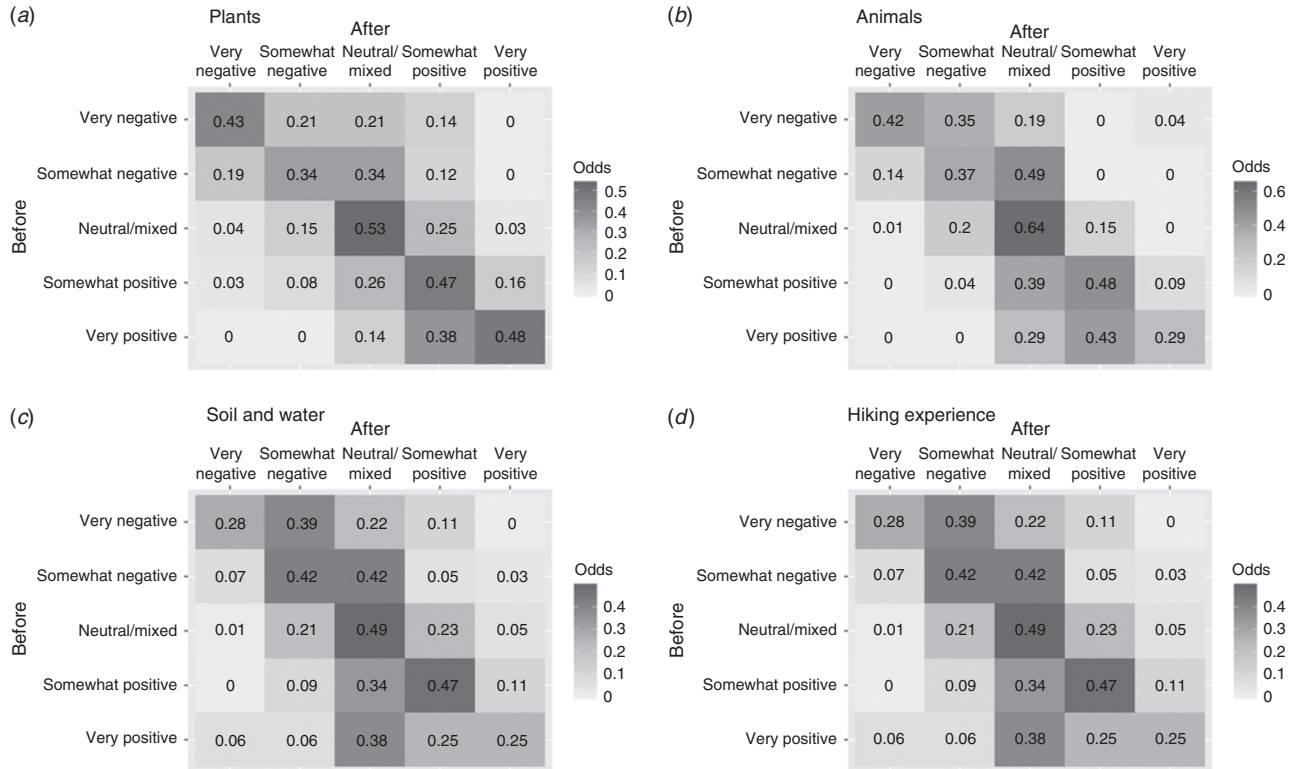


Fig. 4. Proportion of matched hikers in each pre-hike perception category switching to another category post-hike, or staying the same, for fire effects at Stebbins Reserve. Note: due to rounding, numbers may not total to exactly 100%.

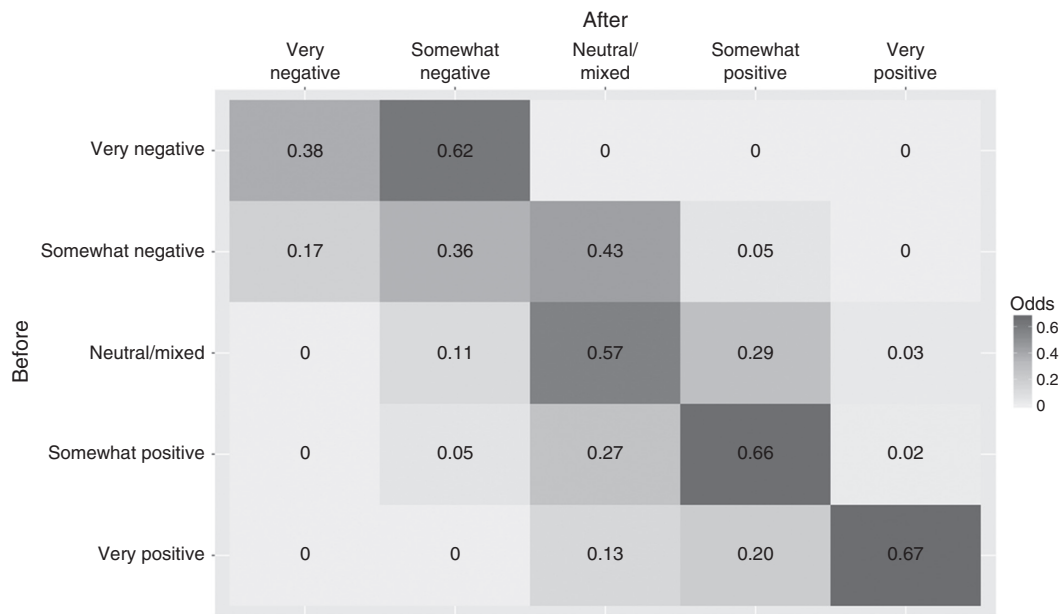


Fig. 5. Proportion of matched hikers in each pre-hike perception category switching to another category post-hike, or staying the same, for ratings of wildfire in the USA.

group means. For example, for fire effects on plants topics, the majority of participants (57%) that gave very negative ratings before the hike increased their rating. Of those who gave somewhat negative ratings pre-hike, 47% increased their ratings and only 19% reduced their ratings (Fig. 4). The other topics followed similar patterns. Though most pre- to post-survey results show a modest change in attitudes, larger shifts were prevalent among respondents who began with either ‘very negative’ or ‘very positive’ attitudes towards fire effects; these respondents fairly often (14–38%) shifted two levels to ‘neutral/mixed’ (Fig. 4).

A majority of participants (62%) who began the hike with very negative perceptions of fire in the USA increased their rating following the hike (Fig. 5). Those rating wildfire in the USA as neutral or mixed before the hike were most likely to keep that opinion after the hike, but nearly three-fold more people in this category increased their rating (32%) than decreased it (11%). Hikers who came in with a somewhat or very positive perception of fire before the hike were more likely to keep that perception than to increase or decrease it.

Overall experience

In total, 66% of participants rated their overall experience at the reserve as very positive, 22% as somewhat positive and 6% as neutral or mixed, leaving only 6% of participants rating their overall experience as negative.

Qualitative results

Perceptions of fire effects were also reflected in the qualitative data, here reported from all post-hike surveys. For the question asking participants to describe the environment at the reserve (Table 4), 353 of 436 post-hike survey participants (81%) provided a written response (19% left the question blank). The most

common theme identified in responses to this question was discussion of renewal, rebirth, recovery and the beauty of the post-fire environment (coded in 159 responses). Other themes that we identified were commentary on different, interesting or surprising features of the burned landscape (50 responses), descriptions that mixed of positive and negative reactions (28 responses) and descriptions that focused on devastation or negative fire effects (28 responses).

For the question asking participants to expand on their opinions about wildfire in the USA, 257 of 436 post-hike survey participants (59%) provided a written response (41% left the question blank). The most commonly identified theme for this question by far was the idea that fire was natural, necessary or beneficial, with 153 participants touching on this theme (Table 5). In contrast, only 99 responses described negative effects of wildfire. However, most participants who included negative themes also included positive themes as part of a more nuanced response, with a narrative of fire as a ‘necessary evil’ or one that produces both positive and negative effects (78 participants). In some cases, respondents wrote about the mixed effects of wildfire by asserting the benefits and natural role of fire, followed by word choices that seemed to express discomfort or uncertainty reconciling the idea of beneficial fire with the damage and destruction caused by fire. We referred to this subtle theme as ‘qualms’, recorded in 31 responses.

Discussion

Our first aim of this study was to learn how familiar hikers at Stebbins were with selected wildfire-related topics and how they perceived wildfire and its effects. By combining Likert-type questions with open-ended questions, we were able to identify patterns across our participants’ responses and explore what might be driving these patterns.

Table 4. Narrative themes in hiker responses to the post-fire environment

Common narrative themes expressed by responses to the question 'describe the environment you saw today' from 353 written responses (81% of 436 post-hike survey participants). Responses could be coded for more than one theme or none of the below themes

| Theme | Examples | Count |
|---|---|-------|
| Renewal, rebirth, recovery and beauty | 'This area is restoring itself.' 'Awe-inspiring. Nature at its best!' 'Renewal in nature underway.' 'Phoenix landscape' | 159 |
| Different, surprising or interesting | 'The land was obviously affected by the fire, but the destruction was less than I imagined.' 'Strangely familiar, but in a post-apocalyptic way makes it interesting and different.' 'While I knew fire was important to the CA landscape, seeing first hand was nice – boundary between burned and unburned was striking.' | 50 |
| Mix of good and bad | 'Nature is always changing sometimes sad. Today I felt hopeful.' 'The first phase of growth after fire is pretty; but I miss the trees.' 'Fire is neither good nor bad, it simply is. The plants and animals will/have recovered.' | 28 |
| Negative effects, sadness and devastation | 'Devastated, I used to love this hike.' 'Hellish' 'Sad to see the tree skeletons :(' | 28 |

Table 5. Narrative themes in feelings about wildfire

Common narrative themes expressed by responses to the question 'expand on your feelings about wildfire', following the quantitative question asking about overall perception of wildfire in the USA. The question was marked as 'optional' and 59% of the 436 post-hike survey participants provided a written response ($n = 257$). Responses could be coded for more than one theme or none of the below themes

| Theme | Examples | Responses |
|--|---|---|
| Fire as natural, necessary and beneficial | 'It has benefits to the understory plants and can refresh an ecosystem.' 'Fire is a beneficial component of California plant communities.' 'Contributes to biodiversity.' | 153 (40 describing only positive effects) |
| Concern, fear, destruction and other negative effects | 'So devastating and often man made.' 'Very bad for air quality. Bad news.' 'It destroys nature and puts people and animals in danger.' | 99 (19 describing only negative effects) |
| Fire is a necessary evil/has mixed positive and negative effects | 'It's a necessary evil.' 'I think they're necessary but from a recreational standpoint they aren't favorable.' 'Fire can have both positive and negative effects on wildlife, ecosystems, humans.' 'Complicated.' | 78 |
| Fire management in need of improvement | '100 years of fire suppression has got us in a mess.' 'Forests aren't allowed to burn and thus pose a greater hazard.' 'Need more controlled burning in the US.' 'Smokey the Bear did too good of a job.' | 60 (44 focused on fire suppression narrative) |
| I know fire is supposed to be good, but... ('qualms') | 'I know it's good but it's sad when it's out of control and people lose homes, etc.' 'I understand need to happen—but devastating!' 'Wildfire is necessary for some ecosystems but it's still sad to see dead trees and other plants.' | 31 |
| Fire effects depend on location or ignition source | 'Forest fires are an essential part of ecosystems, wildfires can be devastating.' 'Depends on the ecosystem. Could be positive, sometimes negative when intervals between fires is too long.' 'We all need to deal with long-term fire suppression in Sierra forests. Inevitable in chaparral.' | 30 |
| Concerns about climate change and drought | 'I think [of] fire as part of ecosystems, but am worried about how climate change and human changed landscapes will impact fires.' 'To the extent it's associated with climate change, I worry about it.' | 16 |

Familiarity with fire topics

We found that the majority of participants were familiar with prescribed fire, fire use, fire suppression and plant and animal responses to fire. The open-ended responses backed up these patterns: 153 participants wrote about the natural role of fire and

its benefits to plants and ecosystems and 60 participants wrote about fire management needing improvement, with 44 discussing the role of fire suppression, demonstrating their prior knowledge of these topics. Fewer participants were familiar with topics that suggested a particular environment or location;

more than half of the participants did not think they knew what chaparral ecology was and few assessed their own familiarity with California fire regimes or fire history as something they could discuss in any depth. Not only do people rate their familiarity with locally relevant fire topics at a low level, but the narratives that emerged from open-response questions overwhelmingly reflected a familiarity with wildfire in California forests and not with the shrublands and woodlands that make up the Stebbins and coast range landscape.

Responses emphasising fire as 'natural and necessary' and criticising fire suppression were common. These narratives apply more to fire in forested landscapes than to those in shrublands. Although fire has been part of chaparral landscapes such as Stebbins for thousands of years, humans have driven much of that fire activity (Keeley 2002; Greene and Huntzinger 2004). The Wragg Fire itself was sparked by a vehicle and burned less than 30 years after the last fire at the site (California Department of Forestry and Fire Protection 2017), an interval well within the historical range of variability for this region (Keeley 2005). That may not be what commenters had in mind when they used the phrase 'natural'. In some situations, people may misinterpret a landscape as the result of nature alone rather than direct management or other human causes (Hull *et al.* 2001) and this could be the case for the hikers at Stebbins. The dominance of these forest-focused narratives may make it more difficult for people to understand their local landscapes and the best management approaches for different ecosystem types.

Perceptions of fire effects and fire in the USA

We found that perceptions of fire effects and fire in the USA were highly variable and sometimes complex. Mean ratings of the Wragg Fire's effects on the reserve were mostly neutral or mixed: 28 participants described a mix of good and bad effects of the fire at Stebbins and 78 participants described mixed feelings about wildfire in the USA; 31 participants expressed the idea that fire was 'supposed to be good', but that they had difficulty reconciling this knowledge of a natural role for fire with its destruction (what we called the 'qualms narrative'). We distinguish this idea from recognising that fire can have positive and negative effects. These participants used wording that conveyed uncertainty, discomfort or distrust in the idea that fire is natural, necessary or good. Though we classified only 12% of responses to this question under this theme, and it is an intriguing rather than conclusive finding, we highlight this idea because of its implications for fire management if such a sentiment is more widespread than a brief survey question might reveal. The wording of these responses suggested that even those who have been exposed to the concept of 'good fire' can still be quite wary of the idea. Getting full buy-in for activities such as prescribed fire and managed wildfire may require more careful attention to the complex emotions of discomfort and distrust as expressed by these participants.

Our second aim was to investigate whether hiking in a recently burned area influenced of fire and its effects on the landscape. Although there were no significant differences in how hikers perceived fire effects on plants, animals or soil and water, our study suggested that hiking in a burned landscape positively affected the hikers themselves by providing a surprising and interesting hiking experience.

Influence of hiking on fire and fire effects

We found only limited evidence that hiking in a burned area could effect change in perceptions of wildfire's effects and of wildfire in the USA, with non-significant differences in mean perception ratings for most topics. This may be in part the result of positive changes cancelling out negative ones; many hikers did rate fire effects differently after the hike, but not in any consistent way. The transition matrices suggest a scenario where interacting in a burned landscape has the strongest effects on those who come in with a negative impression of fire and its effects; seeing the landscape in recovery may prompt these hikers to recognise some ecological benefits of fire or at least observe the resilience of nature. In contrast, those who already rate fire effects as positive are unlikely to see fire as more positive in a burned landscape.

Positive experiences in recovering landscapes

The one topic where there was a large and significant difference between pre- and post-hike responses was the fire's influence on the hiking experience, with the proportion of participants giving a positive rating more than twice as high in the post-hike group as in the pre-hike group (34% and 15% respectively).

This shift is reflected in the written descriptions of the environment and overall experience, with several hikers describing being pleasantly surprised by the quickly regrowing landscape. Although participants frequently described the burned plants, and occasionally used words such as 'devastated' or lamented logistical difficulties and poison oak, the most common sentiment was that the burned landscape was an interesting place to watch nature recover, where the familiar became new and where post-fire wildflowers combined with sweeping views to create a beautiful landscape.

These findings are consistent with other research on post-wildfire recreation. Though wildfires generally reduce visitor numbers to recreation sites (Bawa 2017; Kim and Jakus 2019), there are many cases where fire has positively affected numbers or visitors' experience (Schroeder and Schneider 2010; Brown *et al.* 2008). Wildfire effects on recreation change over the timeline of recovery (Englin *et al.* 2001), with a spike for novelty in the years after fire. Visitor type and site features can lead to higher trip demand in post-wildfire conditions (Bawa 2017). Stebbins has several features identified by Bawa as indicators of higher demand for burned-area trips, including young users and users belonging to environmental groups, as well as sweeping landscape views, a feature frequently noted by survey respondents at Stebbins. However, our results differ from those in several of these studies in that many visitors to Stebbins who came away with a positive experience did not expect this to be the case; they were pleasantly surprised by what they found, despite familiarity with fire's role in the natural landscape.

Study Limitations

The scope of our results is that of a case study of one fire, where hikers volunteered to participate and were not randomly selected. Our aim of assessing participants before and after a casual hike also required that the survey itself be short, limiting our information on participant backgrounds in the sample.

In addition, many participants only completed a before or after survey and not both. We chose to report unmatched data from these participants for some sections because we felt that it would give a more complete picture of the hikers at Stebbins. The trade-off is that the results actually considered three different but overlapping groups of hikers: those who completed a pre-hike survey (used for presenting results on familiarity and perceptions), those who completed a post-hike survey (used for results on post-hike perceptions and qualitative responses) and those who did both (used to compare pre-and post-hike perceptions). Although these groups had considerable overlap, they did not have the same composition and caution should be taken in comparing these results (e.g. perhaps the group that completed both surveys is more interested in science).

Therefore, our aim is not to generalise but to give an example of hiker perceptions of fire in a context with several elements underrepresented in the relevant literature: a shrubland/woodland ecosystem rather than a forested one; hikers rather than homeowners; and both quantitative and qualitative survey questions. Together, we find in these results a few consistent patterns: familiarity with forest-focused fire narratives, mixed perceptions of fire and positive hiking experiences in a burn area. We hope that future research will explore the themes that we found via more in-depth interviews or surveys and with attention to demographics.

Conclusions

1. Consistent with prior work on the perceptions of wildfire, we found that most people who interact with fire-prone landscapes have a basic understanding of wildfire topics, especially prescribed fire and the ecological role of wildfire. However, our results also suggested that general understanding of fire ecology or even support for fire suppression alternatives may belie complex underlying feelings about wildfire and its effects and or local understanding of system-specific fire history.
2. Although there is limited evidence from this case study that hiking in a burned landscape changes how an individual perceives fire as positive or negative, we did find that hiking in a burned landscape was influential, reflected in hikers reporting overwhelmingly positive experiences, which was often surprising to the hikers themselves. This pattern suggests that hikes in burned areas may benefit people who live in fire-prone areas and could serve as a vehicle to engage people in fire ecology and their local landscapes.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgements

Thank you to Mark Schwartz, Jenny Gremer and the Latimer Laboratory for feedback on this manuscript, to Heidi Ballard and the Ballard Laboratory for feedback on project design and presentation of results, and to Joanna Weill for feedback on survey design. Thank you to Katie Ohlin for assistance with data entry and organisation. Thank you to Stebbins Cold Canyon Reserve and Jeffrey Clary for hosting and supporting the project, and to the University California Reserve System for funding. Finally, thank you to all hikers, the UC Davis SEEDS program, and the 2016 UC Davis plant ecology

students who participated in this study. This research took place on the traditional lands of the Patwin people, who shaped the fire history of the region by using fire to cultivate plants and facilitate hunting.

References

- Absher JD, Vaske JJ, Shelby LB (2010) Residents' responses to wildland fire programs: a review of cognitive and behavioral studies. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-223. (Albany, CA, USA)
- Bawa RS (2017) Effects of wildfire on the value of recreation in Western North America. *Journal of Sustainable Forestry* **36**(1), 1–17. doi:10.1080/10549811.2016.1233503
- Bowman DM, Balch JK, Artaxo P, Bond WJ, Carlson JM, Cochrane MA, D'Antonio CM, DeFries RS, Doyle JC, Harrison SP, Johnston FH (2009) Fire in the Earth system. *Science* **324**, 481–484. doi:10.1126/SCIENCE.1163886
- Brown RNK, Rosenberger RS, Kline JD, Hall TE, Needham MD (2008) Visitor preferences for managing wilderness recreation after wildfire. *Journal of Forestry* **106**, 9–16.
- Bryer J, Speerschneider K (2016) Likert: analysis and visualization of Likert items. <https://CRAN.R-project.org/package=likert>.
- California Department of Forestry and Fire Protection (2015) Wragg Fire. <https://fire.ca.gov/incidents/2015/7/22/wragg-fire/>
- California Department of Forestry and Fire Protection (2017) Fire perimeter Version 16_1.
- Christensen RHB (2015) Ordinal—regression models for ordinal data. <http://www.cran.r-project.org/package=ordinal/>
- Dupéy LN, Smith JW (2018) An integrative review of empirical research on perceptions and behaviors related to prescribed burning and wildfire in the United States. *Environmental Management* **61**, 1002–1018. doi:10.1007/S00267-018-1031-8
- Englin J, Loomis J, González-Cabán A (2001) The dynamic path of recreational values following a forest fire: a comparative analysis of states in the Intermountain West. *Canadian Journal of Forest Research* **31**, 1837–1844. doi:10.1139/X01-118
- Gardner PD, Cortner HJ (1985) Wildland–urban fires in semi-arid environments: a Southern California study of homeowner perceptions and public policy preferences. In 'Forum of the Association for Arid Lands Studies, Proceedings of the Annual Meeting' (Ed. O Templer) pp. 129–33. (Texas Tech University International Center for Arid and Semi-Arid Land Studies, Lubbock, TX, USA)
- Greene CM, Huntzinger M (Eds) (2004) 'The natural history of Stebbins Cold Canyon Reserve.' (University of California Natural Reserve System, Oakland, CA, USA)
- Hull RB, Robertson DP, Kendra A (2001) Public understandings of nature: a case study of local knowledge about 'natural' forest conditions. *Society & Natural Resources* **14**, 325–340. doi:10.1080/08941920151080273
- Johnson J (2015) Wragg fire near Lake Berryessa extinguished. *The Press Democrat*. Available at <https://www.pressdemocrat.com/news/4309168-181/wragg-fire-near-lake-berryessa?sba=AAS> [Verified 31 December 2019]
- Keeley JE (2002) Native American impacts on fire regimes of the California coastal ranges. *Journal of Biogeography* **29**, 303–320. doi:10.1046/J.1365-2699.2002.00676.X
- Keeley JE (2005) Fire history of the San Francisco East Bay region and implications for landscape patterns. *International Journal of Wildland Fire* **14**, 285–296. doi:10.1071/WF05003
- Keeley JE, Syphard AD (2019) Twenty-first century California, USA, wildfires: fuel-dominated vs. wind-dominated fires. *Fire Ecology* **15**, 24. doi:10.1186/S42408-019-0041-0
- Kim MK, Jakus PM (2019) Wildfire, national park visitation, and changes in regional economic activity. *Journal of Outdoor Recreation and Tourism*. **26**, 34–42. doi:10.1016/J.JORT.2019.03.007

- Liu Y, Stanturf J, Goodrick S (2010) Trends in global wildfire potential in a changing climate. *Forest Ecology and Management* **259**, 685–697. doi:10.1016/J.FORECO.2009.09.002
- McCaffrey SM, Olsen CS (2012) Research perspectives on the public and fire management: a synthesis of current social science on eight essential questions. USDA Forest Service, Northern Research Station General Technical Report NRS-104. (Newtown Square, PA, USA)
- McCaffrey SM, Moghaddas JJ, Stephens SL (2008) Different interest group views of fuels treatments: survey results from fire and fire surrogate treatments in a Sierran mixed conifer forest, California, USA. *International Journal of Wildland Fire* **17**, 224–233. doi:10.1071/WF07005
- Meldrum JR, Brenkert-Smith H, Champ PA, Falk L, Wilson P, Barth CM (2018) Wildland–urban interface residents’ relationships with wildfire: variation within and across communities. *Society & Natural Resources* **31**, 1132–1148. doi:10.1080/08941920.2018.1456592
- Moritz MA, Batllori E, Bradstock RA, Gill AM, Handmer J, Hessburg PF, Leonard J, McCaffrey S, Odion DC, Schoennagel T, Syphard AD (2014) Learning to coexist with wildfire. *Nature* **515**, 58–66. doi:10.1038/NATURE13946
- Moskwa EC, Ahonen I, Santala V, Weber D, Robinson GM, Bardsley DK (2016) Perceptions of bushfire risk mitigation and biodiversity conservation: a systematic review of fifteen years of research. *Environmental Reviews* **24**, 219–232. doi:10.1139/ER-2015-0070
- Muleady-Mecham NE, Lee ME, Burch BD (2004) A public opinion survey on wildland fire in Grand Canyon National Park. *The George Wright Forum* **21**, 12–21.
- North MP, Stephens SL, Collins BM, Agee JK, Aplet G, Franklin JF, Fulé PZ (2015) Reform forest fire management. *Science* **349**, 1280–1281. doi:10.1126/SCIENCE.AAB2356
- Parkinson TM, Force JE, Smith JK (2003) Hands-on learning: its effectiveness in teaching the public about wildland fire. *Journal of Forestry* **101**, 21–26.
- Paveglio TB, Brenkert-Smith H, Hall T, Smith AM (2015) Understanding social impact from wildfires: advancing means for assessment. *International Journal of Wildland Fire* **24**, 212–224. doi:10.1071/WF14091
- R Core Team (2017) R: A language and environment for statistical computing. R Foundation for Statistical Computing (Vienna, Austria). Available at <http://www.R-project.org/> [Verified 21 April 2017]
- Ryan RL, Hamin E (2006) Engaging communities in post-fire restoration: forest treatments and community-agency relations after the Cerro Grande Fire. In ‘The Public and Wildland Fire Management: Social Science Findings for Managers’ (Ed. S McCaffrey) pp. 87–96. (USDA Forest Service Northern Research Station: Newtown Square, PA, USA)
- Schroeder S, Schneider IE (2010) Wildland fire and the wilderness visitor experience. *International Journal of Wilderness* **16**, 20–25.
- Smith JK, McMurray NE (2004) FireWorks educational program and its effectiveness. In ‘Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in temperate, boreal, and montane ecosystems’ (Eds RT Engstrom, KEM Galley, WJ de Groot) pp. 231–235. (Tall Timbers Research Station: Tallahassee, FL)
- Smith AM, Kolden CA, Paveglio TB, Cochrane MA, Bowman DM, Moritz MA, Kliskey AD, Alessa L, Hudak AT, Hoffman CM, Lutz JA (2016) The science of firescapes: achieving fire-resilient communities. *Bioscience* **66**, 130–146. doi:10.1093/BIOSCI/BIV182
- Toman E, Shindler B, Reed M (2004) Prescribed fire: the influence of site visits on citizen attitudes. *The Journal of Environmental Education* **35**, 13–33. doi:10.3200/JOEE.35.3.13-33
- Toman E, Stidham M, Shindler B, McCaffrey S (2011) Reducing fuels in the wildland–urban interface: community perceptions of agency fuels treatments. *International Journal of Wildland Fire* **20**, 340–349. doi:10.1071/WF10042
- USDA Forest Service (2017) VegBurnSeverity. Available at <https://www.fs.usda.gov/detail/r5/landmanagement/gis/?cid=stelprd3805100> [Verified 1 June 2017]
- Westerling AL, Bryant BP (2008) Climate change and wildfire in California. *Climatic Change* **87**, 231–249. doi:10.1007/S10584-007-9363-Z
- Wickham H (2016) ‘ggplot2: elegant graphics for data analysis.’ (Springer-Verlag: New York, NY)
- Wuertz D, Setz T, Chalabi Y (2017). fBasics: Rmetrics - markets and basic statistics. R package version 3042.89. Available at <https://CRAN.R-project.org/package=fBasics> [Verified 15 September 2019]