REVIEW OF CALIFORNIA WILDFIRE EVACUATIONS FROM 2017 TO 2019

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16. Abstract

Between 2017 and 2019, California experienced a series of devastating wildfires that together led over one million people to be ordered to evacuate. Due to the speed of many of these wildfires, residents across California found themselves in challenging evacuation situations, often at night and with little time to escape. These evacuations placed considerable stress on public resources and infrastructure for both transportation and sheltering. In the face of these clear challenges, transportation and emergency management agencies across California have widely varying levels of preparedness for major disasters, and nearly all agencies do not have the public resources to adequately and swiftly evacuate all populations in danger. To holistically address these challenges and bolster current disaster and evacuation planning, preparedness, and response in California, we summarize the evacuations of eleven major wildfires in California between 2017 and 2019 and offer a cross-comparison to highlight key similarities and differences. We present results of new empirical data we collected via an online survey of individuals impacted by: 1) the 2017 October Northern California Wildfires (n=79), 2) the 2017 December Southern California Wildfires (n=226), and 3) the 2018 Carr Wildfire (n=284). These data reveal the decision-making of individuals in these wildfires including choices related to evacuating or staying, departure timing, route, sheltering, destination, transportation mode, and reentry timing. We also present results related to communication and messaging, non-evacuee behavior, and opinion of government response. Using the summarized case studies and empirical evidence, we present a series of recommendations for agencies to prepare for, respond to, and recover from wildfires.

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Executive Summary

Recent wildfires in California have exposed critical challenges in evacuating populations to safety. From 2017 to 2019, 11 large-scale wildfires in California each required the evacuation of 10,000 or more people (Table ES1). In most cases, local agencies and resources were overwhelmed by the speed and scale of the fires. In this report, we document these wildfires through case study analysis, focusing on the evacuation process. We supplement this work by presenting descriptive statistics of individuals impacted by the 2017 October Northern California Wildfires (n=79), the 2017 December Southern California Wildfires (n=226), and the 2018 Carr Wildfire (n=284).

First, we present case studies summarizing the evacuations during 11 wildfires between 2017 and 2019 in California. We found that for 11 major wildfires with the largest evacuations over the three-year span:

- Approximately 1.1 million people combined were ordered to evacuate;
  - 100,000 or more people were ordered to evacuate from five wildfires;
  - Between 10,000 and 99,999 people were ordered to evacuate from six wildfires;
- Approximately 1.48 million acres combined were burned; and
- Over 30,000 structures were destroyed.

Table ES1: Major California Wildfires from 2017 to 2019

Wildfire	Location	Dates	Acres Burned	Structures Destroyed	Approximate Evacuees*
Northern California Wildfires	Napa, Sonoma, Solano Counties	October 8, 2017 – October 31, 2017	144,987+	7,101+	100,000
Southern California Wildfires	Ventura, Santa Barbara, Los Angeles Counties	December 4, 2017 - December 15, 2017	303,983+	1,112+	286,000
Carr Fire	Shasta and Trinity Counties	July 23, 2018 – August 30, 2018	229,651	1,614	39,000
Mendocino Complex Fire	Mendocino, Lake, Glenn, and Colusa Counties	July 27, 2018 – September 19, 2018	459,123	280	17,000
Camp Fire	Butte County	November 8, 2018 – November 25, 2018	153,336	18,804	52,000
Woolsey Fire	Ventura and Los Angeles Counties	November 8, 2018 – November 21, 2018	96,949	1,643	250,000
Hill Fire	Ventura County	November 8, 2018 – November 16, 2018	4,531	4	17,000
Saddle Ridge Fire	Los Angeles County	October 10, 2019 – October 31, 2019	8,799	19	100,000
Kincade Fire	Sonoma County	October 23, 2019 – November 6, 2019	77,758	374	200,000
Tick Fire	Los Angeles County	October 24, 2019 – October 31, 2019	4,615	22	50,000
Getty Fire	Los Angeles County	October 28, 2019 – November 5, 2019	745	10	25,000

* Refers to the number of people who were ordered to evacuate

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Analysis of the 11 wildfires revealed key similarities including:

- Human involvement in the ignition and/or inadvertent spread of fires;
- High vegetation and fuel levels and high winds that exacerbated the spread of fires;
- Rapid fire spread along the wildland-urban interface (WUI);
- Challenges in communicating evacuation orders to residents;
- Significant evacuations via personal vehicles leading to congestion;
- Assistance (or potential assistance) from transit agencies in evacuating residents;
- Roadway and debris impediments to evacuating;
- Assistance by the American Red Cross and local organizations for sheltering and reentry;
- Rapid filling of public evacuation shelters; and
- Resource offers by a variety of organizations, but lack of formalized reentry plans.

The case studies also revealed characteristics of each wildfire that led to differences in communication, transportation, and sheltering response. These differences indicate that a toolkit of transportation strategies needs to be flexible.

Communication

- Agencies chose not to use the Wireless Emergency Alert (WEA) system due to concerns that the WEA would reach larger than necessary geographic areas (2017 Northern California Wildfires);
- Poor mobile phone service in a mostly rural area posed challenges in reaching evacuees (2018 Mendocino Complex Fire);
- Destruction of telephone lines and loss of power decreased communication capacity and hindered communication measures (2018 Camp Fire); and
- Lack of power due to a Pacific Gas and Electric (PG&E) public safety power shutoff (PSPS) event made communication (via mobile phones and landlines) very difficult (2019 Kincade Fire).

Evacuation

- Debris blocked a road that serves as a single exit for a community, and residents had to be helicoptered to safety (2017 Northern California Wildfires);
- People with select medical needs (e.g., premature babies) were evacuated early to specialized facilities (2018 Carr Fire);
- Fire moved so quickly that many people had to evacuate on foot (2018 Camp Fire);
- Los Angeles implemented local programs (e.g., Red Flag Parking Program) to increase road capacity (2018 Woolsey Fire; 2019 Getty Fire); and
- Officials implemented contraflow on the Pacific Coast Highway to increase capacity and ease congestion (2018 Woolsey Fire).

Sheltering

- Large livestock in the area required shelter and were cared for by animal non-profits and local shelters (2018 Mendocino Complex Fire; 2018 Carr Fire);
- Shelters were threatened by poor weather conditions and spread of illnesses (2018 Camp Fire); and
- A local university implemented a shelter-in-place plan rather than evacuate (2018 Woolsey Fire).

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Second, we present descriptive statistics of both evacuees and non-evacuees from three major California wildfires in 2017 and 2018: 1) the 2017 October Northern California Wildfires (n=79), 2) the 2017 December Southern California Wildfires (n=226), and 3) the 2018 Carr Wildfire (n=284). These statistics begin to build a clearer picture of individual behavior (e.g., evacuate or stay), communication (e.g., type and source of evacuation orders received), use of logistical resources (e.g., transportation mode and shelter resources), evacuation characteristics (e.g., destination and route), and return to impacted areas (e.g., reentry) for wildfires. Results are presented below as a range that incorporates all three wildfires. Further details on the corresponding results for each wildfire can be found in the main report. Key results include:

- A non-compliance rate (i.e., individuals who received a mandatory evacuation order but did not evacuate) ranging between 3% and 13%;
- A shadow evacuation rate (i.e., individuals who did not receive a mandatory evacuation order but evacuated) ranging between 29% and 75%;
- A within county evacuation rate ranging between 66% and 70%;
- Spikes in evacuation departure days ranging between 33% and 78% of evacuees leaving on a single day, depending on the wildfire;
- Variable evacuation departure times with 51% to 73% departing at night between 6:00 p.m. and 5:59 a.m., depending on the wildfire;
- Preference to shelter with family or a friend (49% to 70%) and at a hotel or motel (13% to 23%);
- Initial sheltering through a peer-to-peer service, such as Airbnb (0.4% to 3%) and low use of public shelters (2% to 5%);
- Predominate use of one vehicle (34% to 45%) and two or more vehicles (49% to 62%) to evacuate;
- Variable use of routes as the primary road type of travel but generally higher use of highways (32% to 62%), no majority type (17% to 35%), and major roads (15% to 27%);
- A low GPS-navigation usage rate ranging between 8% and 19% for routing; and
- A wide spread of reentry days (with 3% to 32% returning two weeks or more after the initial wildfire outbreak) and only 22% to 33% of respondents stating they received information to return from an official source.

Results also indicate that agencies were only moderately successful in issuing evacuation orders, communicating to the public, and managing transportation. Specific communication and opinion of government response results include:

- A moderately high rate of respondents (59% to 79%) who received a mandatory evacuation order and who found the message to be extremely clear;
- A moderately low rate of respondents (37% to 45%) who received a voluntary evacuation order and who found the message to be extremely clear;
- A wide distribution of communication methods for mandatory orders, with four different platforms (two wildfires) and seven different platforms (one wildfire) each reaching 25% or more of respondents;
- Highly variable avenues of receiving information for mandatory evacuation orders that significantly differed by wildfire such as reverse 911 calls (8% to 39%); text messages (29% to 50%); social media (15% to 34%); alerts from a subscribed service (12% to 42%); and internet websites (8% to 38%);

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- Receipt of mandatory evacuation orders directly through personal interactions with public officials (30% to 42%) and secondary sources such as friends, neighbors, and extended family (27% to 38%);
- A low rate of receiving mandatory evacuation orders through television announcements (13% to 21%);
- A high rate of seeking additional information, ranging from 30% to 50% and 62% to 67% of respondents for mandatory and voluntary evacuation orders respectively;
- Moderately low overall opinion of an extremely effective or very effective government management of roads (29% to 42%), shelters (37% to 40%), and overall evacuation (39% to 49%); and
- Low overall opinion of an extremely effective or very effective government management of communication (23% to 35%) and evacuation of carless populations (10% to 13%).

Non-evacuees were also asked why they decided not to evacuate. Key reasons given for not evacuating include:

- Not receiving any evacuation orders (30% to 71%)
- Not wanting to leave (27% to 39%)
- Wanting to protect property (17% to 37%)
- Having some work requirements during the fire (0% to 24%)
- Not wanting to go to a public shelter (0% to 16%)
- Being unsure where they could take a pet (7% to 10%)
- Not wanting to sit in traffic (5% to 8%)
- Not having the money to evacuate (3% to 6%)

The report concludes with a series of recommendations based on the case studies and the results from the wildfire evacuation surveys. Several key recommendations are included in Table ES2. Overall, agencies need a unique toolkit of strategies to effectively evacuate residents from wildfires. This research is a first step in assisting governments to prepare for, respond to, and recover from wildfires.

Table ES2: Key Recommendations

Topic Area	Recommendation
Evacuation Orders and Communication	Agencies should leverage mandatory evacuation orders, improve evacuation order communication, and rapidly distribute orders to increase compliance. Evacuation orders should contain additional information (e.g., available shelters, current road closures, safety tips, reminders to help others) to improve the evacuation.
Evacuation Orders and Communication	Evacuation orders, especially when both voluntary and mandatory orders are issued, need to have clear geographical boundaries and departure times to reduce shadow evacuations. Orders also need to be distributed rapidly.
Evacuation Orders and Communication	All communication with the public should be quickly distributed and consistent across platforms and in a variety of languages. Agencies should

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	maintain a high media presence and control rumors to improve communication flow. Agencies should also consider alternative low-tech communication methods including door-to-door notifications, radios, static sirens, and mobile sirens (via emergency vehicles or drones) to prepare for power outages.
Evacuation Orders and Communication	To decrease defending behavior, agencies should develop information and education campaigns about the risks of defending and the impacts it has on firefighting ability. Agencies could consider workshops, public forums, and school-based programs to encourage safe behavior for wildfires for a variety of communities.
Departure Timing	Agencies need to be prepared for evacuations that occur at any time of day, including more chaotic nighttime evacuations. Given the high variability of when wildfires occur, agencies need to be able to ramp up resources, staff, and communication very quickly at any time of day.
Transportation Mode	Transportation response and evacuation models need to account for multi-vehicle households when designing capacity-increasing measures. Agencies should also consider leveraging potential spare capacity in extra vehicles to help carless households.
Destination and Route	Agencies, including state agencies, should deploy congestion reduction measures closer to the impact area of the fire, in high-risk neighborhoods, and along major arterial roads. In cases where highways are close to the impact area, resources should also be deployed to increase highway capacity.
Sheltering	Agencies should increase accommodation capacity by working with the American Red Cross, other non-governmental organizations, community-based organizations (e.g., churches), private companies (e.g., Airbnb), and private citizens.
Sheltering	Agencies should ensure that public shelters have resources (e.g., Americans with Disabilities Act [ADA] accessible facilities, medical supplies, trained staff) for access and functional needs (AFN) populations and space for pets. Shelters should be pre-designated if pets are allowed.
Reentry	Reentry plans need a communication element to transmit procedures for returning to evacuees. Similar to evacuation orders, reentry information should be communicated consistently across multiple platforms.
Work Requirements	Agencies should work with employers to reduce work requirements for evacuees and increase flexible schedules (e.g., telecommuting) during emergency events to increase evacuation rates.

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About the UC Institute of Transportation Studies

The University of California Institute of Transportation Studies (UC ITS) is a network of faculty, research and administrative staff, and students dedicated to advancing the state of the art in transportation engineering, planning, and policy for the people of California. Established by the Legislature in 1947, ITS has branches at UC Berkeley, UC Davis, UC Irvine, and UCLA.

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Key Terms

ARC	American Red Cross
Cal Fire	California Department of Forestry and Fire Protection
CBO	Community-Based Organization
FEMA	Federal Emergency Management Agency
NGO	Non-Governmental Organization
PG&E	Pacific Gas and Electric
PSPS	Public Safety Power Shutoff
SCE	Southern California Edison
WEA	Wireless Emergency Alerts
WUI	Wildland-Urban Interface

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Introduction

Between 2017 and 2019, California experienced a series of devastating wildfires that together forced the evacuation of over one million people (Table ES1). Due to the speed of many of these wildfires, residents across California found themselves in dangerous situations, often at night and with little time to evacuate. These evacuations placed considerable stress on public resources and infrastructure for both transportation and sheltering. At the same time, transportation and emergency management agencies across the state have widely varying levels of preparedness for major disasters, and nearly all agencies do not have the public resources to adequately and swiftly evacuate all populations in danger. Agencies in California and across the United States are also ill-equipped to evacuate vulnerable populations who do not have the ability or means to evacuate. To holistically address these challenges and bolster current disaster and evacuation planning, preparedness, and response in California, we collected information on the evacuations of 11 major California wildfires from 2017 to 2019 and empirical data for individuals who were impacted by three of these major wildfires.

A significant amount of case study research and analysis of wildfires has used qualitative methods with the direct purposes of building preparedness (McGee and Russell, 2003), improving communication (Taylor et al., 2005; Cohn et al., 2006; Stidham et al., 2011), understanding social dynamics within the wildfire context (Goodman and Proudley, 2008; Cote and McGee, 2014; McCaffrey et al., 2015), and considering alternative strategies to evacuations (Paveglio et al., 2010). These studies, which employ qualitative data from the United States, Canada, or Australia, offer key conclusions (Table 1) that could be used by agencies in developing improved transportation, communication, and sheltering in wildfires. Concurrently, multiple studies have focused on framework development and policies for wildfire evacuations, including lessons learned from previous wildfires (Table 2). Early examples of descriptive statistics for fires include Fischer III et al. (1995) for the Ephrata Fire in Pennsylvania and Benight et al. (2004) for the 2002 Colorado Wildfires. More recently, research across various geographies has focused on developing discrete choice models using data from evacuees and non-evacuees to assess the factors that influence behavior (Strahan, 2017; Toledo et al., 2018; McCaffrey et al., 2018; Lovreglio et al., 2019; Wong et al., 2020a). A brief review of these discrete choice studies, along with research that used hypothetical wildfire data, is presented in Wong et al. (2020a), while a full review of wildfire evacuation behavior studies can be found in McLennan et al. (2018).

Additional research in wildfire evacuations has extended to simulation and traffic modeling (Cova and Johnson, 2002; Wolshon and Marchive III, 2007; Chen and Zhan, 2008; Beloglazov et al., 2016; Ronchi et al., 2017; Intini et al., 2019; Gwynne et al., 2019; Ronchi et al., 2019), transportation response strategies (Cova and Johnson, 2003; Shahabi and Wilson, 2018) including trigger models for evacuations (Dennison et al., 2007; Larsen et al., 2011; Li et al., 2015; Li et al., 2019), and framing of decision-making (Nguyen et al., 2018; Folk et al., 2019; Lovreglio et al., 2019).

Despite these studies in wildfire evacuations, two key gaps exist. First, case studies and reviews of evacuation processes focused on wildfire evacuations remain largely missing in the literature, and national reports (which are usually available for major hurricanes) are not widely available for wildfires. Moreover, research has focused on a single wildfire at a time, missing potential connections and conclusions derived from multiple wildfires. We address this first key gap by summarizing 11 major wildfire evacuations in California and offering a cross-comparison of key similarities and differences among fires. Second, non-evacuee and evacuee actions in California wildfires, particularly related to evacuation behavior, receipt of

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information, and logistical decisions are not fully known. The case studies only provide a timeline of events and an analysis of evacuation processes, not the decisions of individuals impacted by the California wildfires. We address this second gap by presenting descriptive statistics results of three surveys distributed to individuals impacted by three major California wildfires. These results offer preliminary understanding of evacuee choice-making and can be used to inform evacuation modeling and simulations.

For the remainder of this work, we first present in-depth case study descriptions of the primary wildfires that impacted California from 2017 to 2019. For these case studies, we focus our attention on the evacuation process, communication, and wildfire timeline. To supplement these case studies, we distributed an online survey to individuals impacted by the 2017 October Northern California Wildfires (n=79), the 2017 December Southern California Wildfires (n=226), and the 2018 Carr Wildfire (n=284). Using these data, we present key descriptive statistics for evacuation decision-making, communication and messaging, and government response. From the case studies and descriptive statistics, we provide practice-ready recommendations for agencies to improve their evacuation response.

Table 1: Key Qualitative Studies on Wildfire Evacuations

Authors (Year)	Topic	Key Location(s)	Key Conclusions
McGee and Russell (2003)	Preparedness	Rural Australia (North Central Victoria)	Long-time residents were generally more prepared due to social networks, previous experience, and involvement in local fire brigades. Agency involvement and directives encouraged community preparedness, which led to year-round preparation, especially for those who wanted to stay and defend. Demographics within communities should be monitored, as groups respond differently to community adaption programs and communication.
Taylor et al. (2005)	Information and Communication	Bridge Fire (2003) in the San Bernardino Mountains, California	Individuals relied on multiple local sources (including social contacts) for information on severity, size, and direction of the fire. Generalized information was of little value to at-risk individuals. News media was often viewed as inaccurate for evacuation purposes. The Incident Management Team should distribute information as broadly as possible in real time. Local-information networks should be established and encouraged to communicate directly with fire crews.

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Cohn et al. (2006)	Information and Communication	Hayman Fire (2002) in Teller County, Colorado; Rodeo-Chediski Fire (2002) in Northern Arizona; Bucksnort/Cave Gulch Fire (2000) in Helena, Montana	Officials and evacuees emphasized the need for clear communication and evacuation time estimates for residents. Electronic communication should be reinforced with verbal, written, and door-to-door notices. Specific information on evacuation status and the level of impact gives residents time to confirm evacuation orders. Real-time information on the evacuation and post-fire impact was useful for evacuees. Escorted trips into impacted areas reduced unauthorized entries and reassured property owners. Evacuees should be prepared to be away from home upwards of two weeks after the fire.
Goodman and Proudley (2008)	Social Context	Wangary Fire (2005) in South Australia	Preparedness should not only focus on actions but also on the roles taken by members of the household in defending and/or evacuating. Individuals with prior fire experience more readily recognized visual fire cues, sought information from informal networks, and had home defense for fires.
Paveglio et al. (2010)	Alternative Strategies	Wilderness Ranch, Idaho	Alternative evacuation strategies (e.g., staying and defending) are highly place-based, and their success is dependent on structural/physical and social characteristics of the community. Alternatives can differ vastly between jurisdictions, and the development of strategies must involve significant interaction between the community, emergency managers, and fire officials to determine all available options and promote informational exchange on preparedness and training. Self-reliant communities and those with a diverse mix of skills and abilities are better positioned to take over some firefighting responsibilities and develop alternative strategies.

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Stidham et al. (2011)	Information and Communication	Black Crater Fire (2006) in Oregon; Blue Springs Fire (2005) in Utah	Long-term relationships between homeowner associations and authorities (including federal authorities) produced effective communication channels for evacuation orders. Up-to-date and detailed information on fire progression provided reassurance to evacuees. Uncertainty was one of the primary stressors for evacuees. Without communication and transparency, fire management was blamed for some damages, and persistent rumors led to distrust and resentment toward local officials.
McLennan et al. (2012)	Behavior	Murrindindi Wildfire (2009) in Victoria, Australia	People were more likely to stay and defend if they had a prior commitment to a defending plan and believed that it was too late to evacuate. A significant number of people who attempted to stay and defend still had to flee, indicating that defenders need alternate plans. People were more likely to leave due to a trigger event that significantly increased fire threat, such as knowledge of others leaving or receiving information about the location of the fire from trusted sources.
Cote and McGee (2014)	Social Context	Mt. Lorne, Yukon, Canada	A significant number of individuals intended to stay and defend in a wildfire, despite lacking knowledge of how to defend property. Agencies should more proactively work with residents to help them understand wildfire risks and prepare them to stay or evacuate. Livestock loss was a major concern for rural residents, encouraging staying rather than evacuating.

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McCaffrey et al. (2015)	Social Context	Painted Rocks, Montana; Ventura County, California; Santa Barbara, California; Santa Fe, New Mexico	The primary concerns about evacuations were the potential for a late evacuation and the logistical costs of an evacuation. Alternative evacuation strategies (i.e., staying and defending) were seen to reduce logistical costs, increase homeowner control, and augment firefighting capabilities. Staying and defending approaches were viewed as full of unknown risks by officials. Residents (unlike officials) believed community members could understand the nuances of staying and defending.

Table 2: Key Wildfire Policy and Framework Literature

Authors (Year)	Topic	Key Location(s)	Key Conclusions
Keeley et al. (2004)	Lessons Learned	Southern California	Massive wildfires have occurred previously in many fire-prone areas, and future planning should focus on the cyclical nature of fires. Traditional fuel breaks or fuel reductions will not stop large fires in extreme weather events, and fuel manipulation should focus on creating safe and defensible space. Future development should recognize that wildfires in California are natural events, and fire management is severely limited in preventing, slowing, and stopping wildfires.
MacGregor et al. (2007)	Risk Perception Framework	Western United States	Agencies seeking to change self-protective behavior should focus on the unique socio-cultural characteristics of their local jurisdictions. Risk-related interventions (i.e., media events, programs, brochures) increased public awareness of risks. Interventions to change attitudes and behavior should be both long-term and targeted to specific populations.

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Mutch et al. (2011)	Communication Framework	Painted Rocks, New Mexico; Rancho Santa Fe, California	Most policy in the United States has focused on evacuations, not on alternative strategies such as staying and defending. Several US areas have implemented the "Prepare, Go Early, or Stay and Defend" strategy that is popular in Australia. Recent devastating wildfires in Australia require further examination of the feasibility and life-saving ability of strategy for the US context.
Paveglio et al. (2012)	Alternative Evacuation Strategies	Australia and United States	Populations in high-risk areas do not implement personal mitigation measures, even though they know about possible actions. Both evacuation and alternative strategies require clear and targeted messages for different populations. Translating nationally consistent preparedness campaigns (such as "Ready, Set, Go" and "Prepare, Act, Survive") tends to leave out unique local characteristics. Disinvestment in alternative strategies may reduce fire mitigation behaviors, while wildfire approach and terminology changes may decrease trust of fire management.
de Araujo et al. (2014)	Traffic Control Framework	Colorado Springs, Colorado	Contraflow operations are only necessary for the most constrained neighborhoods with severe bottlenecks. Baseline strategies such as egress route restriction to evacuation traffic and entry restriction of non-emergency responders into areas was enough for most neighborhoods. Evacuation zones should be developed along fire lines with distinctive geographical differences.

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Woo et al. (2017)	Lessons Learned	Fort McMurray, Alberta, Canada	Traffic analysis indicated that wildfire evacuations followed an S-curve and that evacuations occurred quickly within 12 hours. Contraflow operations increased capacity, but additional route management could have reduced congestion. Contraflow operations require preplanning to reduce unsafe traffic situations and ensure emergency vehicle access. The success of air transportation (upwards of 23,000 evacuated by air convoys) suggests that a multi-modal approach could be beneficial for sparsely populated geographical areas.

California Case Studies

To provide contextual background to the decision-making of wildfire evacuees, we summarize 11 recent wildfires in California between 2017 and 2019, beginning with the Northern California Wildfires (i.e., primarily composed of the Tubbs, Atlas, and Nuns Fires) in October 2017. These wildfires were chosen because of their recent significance and large number of evacuees. We provide an overview of these wildfires in Table 3. We note that official sources and secondary sources are often updating exact wildfire statistics, causes, and other key details. Consequently, some information in these case studies may change over time.

2017 October Northern California Wildfires

In October 2017, a series of large and fast-moving wildfires broke out in Northern California in Napa, Sonoma, and Solano Counties, leading to one of the deadliest wildfire disasters in California history (Serna, 2018a). Altogether, the Tubbs, Nuns, and Atlas fires (i.e., primary fires) burned over 140,000 acres; required the evacuation of about 100,000 people; caused approximately $15 billion in damages; and killed 44 people (Associated Press, 2017; Bonos et al., 2017; Cal Fire, 2018a; Cal Fire, 2018b; Cal Fire, 2018c; Serna, 2018a). The Tubbs, Nuns, and Atlas Fires ignited in rapid succession on October 8, overwhelming fire resources and emergency management officials. The Tubbs Fire ignited near Calistoga, California due to a failed private electrical system, spreading rapidly toward Santa Rosa due to high winds and low humidity (Cal Fire, 2018c). Local utility provider, Pacific Gas and Electric (PG&E), was not found at fault for the Tubbs Fire. Due to an overwhelming number of calls of reported fires and multiple fires throughout the area, the California Department of Forestry and Fire Protection (Cal Fire) was unable to devote an adequate amount of resources to fight the Tubbs Fire (Wagner et al., 2017; Lewis et al., 2018). The Nuns Fire ignited in the community of Glen Ellen, California due to a downed tree on a power line conductor (Cal Fire, 2018b), later merging with five other smaller fires. The Atlas Fire ignited near the Atlas Peak area due to trees falling on power lines owned by PG&E in two different locations (Cal Fire, 2018a). The Atlas Fire spread rapidly down dry and hilly terrain into the area surrounding the city of Napa. Cal Fire and local fire resources attempted to contain all three major fires (along with several smaller fires), but deteriorating weather conditions and wind gusts over 70 miles per hour (mph) caused all fires to spread rapidly, straining firefighting resources (Lewis et al., 2018).

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Table 3: Overview of Major 2017 – 2019 California Wildfires

	Northern California Wildfires	Southern California Wildfires	Carr Fire	Mendocino Complex Fire	Camp Fire	Woolsey Fire	Hill Fire	Saddle Ridge Fire	Kincade Fire	Tick Fire	Getty Fire
Location	Napa, Sonoma, Solano Counties	Ventura, Santa Barbara, Los Angeles Counties	Shasta, Trinity Counties	Mendocino, Lake, Glenn, Colusa Counties	Butte County	Ventura and Los Angeles Counties	Ventura County	Los Angeles County	Sonoma County	Los Angeles County	Los Angeles County
Dates	October 8, 2017 – October 31, 2017	December 4, 2017 - December 15, 2017	July 23, 2018 – August 30, 2018	July 27, 2018 – September 19, 2018	November 8, 2018 – November 25, 2018	November 8, 2018 – November 21, 2018	November 8, 2018 – November 16, 2018	October 10, 2019 – October 31, 2019	October 23, 2019 – November 6, 2019	October 24, 2019 – October 31, 2019	October 28, 2019 – November 5, 2019
Acres Burned	Atlas: 51,624 (Cal Fire, 2018a) Nuns: 56,556 (Cal Fire, 2018b) Tubbs: 36,807 (Cal Fire, 2018c)	Creek: 15,619 (Cal Fire, 2018d) Rye: 6,049 (Cal Fire, 2018e) Skirball: 422 (Cal Fire, 2018f) Thomas: 281,893 (Cal Fire, 2018g)	229,651 (Cal Fire, 2018h)	459,123 (Callahan, 2018)	153,336 (Cal Fire, 2018j, 2018)	96,949 (Cal Fire, 2018k)	4,531 (Cal Fire, 2018l)	8,799 (Cal Fire, 2019a)	77,758 (Cal Fire, 2019b)	4,615 (Rosenfeld, 2019)	745 (Stewart, 2019)
Structures Destroyed	Atlas: 120 (Cal Fire, 2018a) Nuns Fire: 1,355 (Cal Fire 2018b) Tubbs: 5,626 (Cal Fire, 2018c)	Creek: 37 (Cal Fire, 2018d) Rye: 6 (Cal Fire, 2018e) Skirball: 6 (Cal Fire, 2018f) Thomas: 1,063 (Cal Fire, 2018g)	1,614 (Cal Fire, 2018h)	280 (Callahan, 2018)	18,804 (Cal Fire 2018j, 2018)	1,643 (Cal Fire, 2018k)	4 (Cal Fire, 2018l)	19 (Cal Fire, 2019a)	374 (Cal Fire, 2019b)	22 (SF Chronicle, 2019)	10 (Stewart, 2019)
Approx. People Ordered to Evacuate	100,000 (Bonos et al., 2017)	Creek: 150,000 (Chandler, 2017) Rye: 3,900 (Austin, 2017)* Skirball: 46,000 (KPCC Staff, 2017) Thomas: 87,000 (Stokes, 2017)	39,000 (Bransford and Caron, 2018)	17,000 (Morris and Espinoza, 2019)	52,000 (Stead Sellers et al., 2018)	250,000 (County of Los Angeles, 2018)	17,000 (Holland, 2018)	100,000 (Kenne and Bogel-Burroughs; 2019)	200,000 (Asimov, 2019)	50,000 (LAist Staff, 2019)	25,000 (Shapiro et al., 2019)
Fatalities	44 (Associated Press, 2017)	2 (Serna, 2019a)	8 (Schultz, 2018)	1 (McGough, 2018)	85 (Chan and Sterling, 2019)	3 (Cosgrove, 2018a)	0	1 (Salahieh and Lyster, 2019)	0	0	0

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Cause	Atlas: Trees falling on Pacific Gas & Electric power lines (Cal Fire, 2018a) Nuns: Downed tree on electric lines (Cal Fire, 2018b) Tubbs: Sparks from private electrical system (Cal Fire, 2018c)	Creek: Under investigation (St. John and Mejia, 2017) Rye: Under investigation (Holt and Dave, 2017) Skirball: Illegal cooking fire (Los Angeles Fire Department, 2017) Thomas: Slapping of Southern California Edison power lines (Serna, 2019a)	Sparks from a vehicle with a flat tire (Agbonile, 2018)	Sparks from a hammer (Ranch), unknown (River) (Arango and Medina, 2018)	Transmission tower hook failure (Van Derbeken, 2019)	Likely caused by a malfunction of Southern California Edison's electrical equipment (Rokos, 2019)	Human activity (ABC7 Staff, 2018)	Under investigation (Cosgrove, 2019c)	Under investigation (Stanglin, 2019)	Under investigation (Rosenfeld, 2019)	Tree branch hitting electrical lines (Stewart, 2019)

* 1,300 households were ordered to evacuate (Austin, 2017), multiplied by the approximate average number of persons per household (3) for Santa Clarita (U.S. Census Bureau, 2019)

Photo 1: Severe congestion from evacuating vehicles from the 2018 Carr Fire (Source: Redding Record Searchlight)

Photo 2: Traffic along the Pacific Coast Highway during the 2018 Woolsey Fire (Source: Cassie Denham)

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The swift growth of the fires from deteriorating weather conditions heightened the importance of efficient communication. However, significant communication challenges arose due to delays in receiving messages; concerns that certain communication systems – such as the Wireless Emergency Alert (WEA) system – would reach wider geographic areas than necessary; difficulty in establishing multi-jurisdictional coordination between emergency operation centers (e.g., between the City of Santa Rosa, Sonoma County Office of Emergency Management, and the Sonoma County Sheriff's Office); and poor adoption of modern communication technologies (Sonoma County Civil Grand Jury, 2018). These communication issues caused significant delays in the distribution of mandatory evacuation orders. Without official evacuation notices, neighbors and emergency personnel resorted to community action tactics to notify people through police and fire sirens, loudspeakers, car horns, megaphones, and door-to-door notifications (Sonoma County Civil Grand Jury, 2018).

The 2017 October Northern California Wildfires led to the evacuation of about 100,000 people in Sonoma, Napa, and Solano Counties (Bonos et al., 2017), along with the evacuation of several regional medical facilities (Sonoma County Civil Grand Jury, 2018). Residents faced significant challenges while evacuating including power outages preventing people from opening their garage doors, downed trees trapping people in their vehicles, congestion on evacuation routes, and road closures (Lewis, 2018). The speed of the fires forced some people to abandon their vehicles and evacuate on foot (Lewis, 2018). A challenge specific to the Atlas Fire was Atlas Peak Road, which serves as the only entrance and exit to the community. People trapped on this road had to be helicoptered to safety (Lewis, 2018). Local and regional transit services were able to evacuate people from assisted living facilities, apartments, homes, and hospitals in the Napa, Yountville, and Calistoga areas (Napa Valley Register, 2017).

People evacuated to shelters at the Petaluma Fairgrounds, Finley Community Center in Santa Rosa, Napa County Fairgrounds in Calistoga, Crosswalk Community Church in Napa, and additional shelters in Marin and Solano Counties (Digitale, 2017; Santa Rosa Police Department, 2017; Sorci and Kipling, 2017). The American Red Cross (ARC) arrived later than anticipated, since the organization was concurrently providing aid for another disaster in the state (Sonoma County Civil Grand Jury, 2018). While containment grew slowly for all fires, light rain in the region on October 19 allowed firefighters to gain a better foothold (Kohli, 2017). The primary fires – the Tubbs, Nuns, and Atlas Fires – reached 100% containment by October 31, 2017, although most residents were able to return home before that date (Rossmann, 2017).

2017 December Southern California Wildfires

The 2017 December Southern California Wildfires were made up of four major fires – the Thomas, Creek, Skirball, and Rye Fires – that surrounded the Greater Los Angeles metropolitan area and led to over 286,000 evacuations (Chandler, 2017; Austin, 2017; KPCC Staff, 2017; Stokes, 2017). A fifth major fire, the Lilac Fire, concurrently impacted San Diego County. The Thomas Fire was first to ignite, beginning in the evening of December 4. The fire was caused by strong winds, leading high-voltage power lines owned by Southern California Edison, a local utility company, to slap together (Serna, 2019a). The "line slap" caused hot and molten materials to fall into the dry brush below, sparking the destructive Thomas Fire (Serna, 2019a). The Thomas Fire would later become the largest fire in California history, burning 281,893 acres (Cal Fire, 2017g). A few hours later on December 4, the Creek Fire began on the hillside of Little Tujunga Canyon near Kagel Canyon (Cal Fire, 2017d; St. John and Mejia, 2017). While some witnesses claim the fire began from sparks from a transmission line, the cause of the fire remains under investigation. The Rye Fire began shortly after and proceeded to consume 3,000 acres within five hours (Woods II and Yee, 2017;

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Cal Fire, 2018e). As of December 2019, the cause of the Rye Fire was still under investigation. Two days later, on December 6, the Skirball Fire began (Los Angeles Fire Department, 2017). The Skirball Fire was caused by an illegal cooking fire at a brush-filled campsite near a freeway overpass and heavily impacted the Bel-Air neighborhood in Los Angeles (Los Angeles Fire Department, 2017; Cal Fire, 2018f).

During the Thomas Fire, the Ventura County Sheriff's Office of Emergency Services set up a hotline to handle the large volume of emergency calls. Despite this effort, many individuals did not know about the hotline, especially if they were not registered for subscription-based emergency alerts (Carlson, 2018). The strong Santa Ana winds (up to 70 mph) led to rapid fire spread over the next several days, resulting in mandatory evacuations of large areas of Ventura, Ojai, Carpinteria, Montecito, and Santa Barbara from the Thomas Fire (Fritz, 2017). The widespread evacuation orders in the Ventura area due to the Thomas Fire led to congestion on several major roadways and arterial streets (O'Neal, 2017). Residents evacuating from the Skirball Fire faced similar challenges with congestion as people evacuated from a 3.2-mile zone at the same time (Etehad et al., 2017). In addition, nearly 20 square miles of residential property were evacuated for the Creek Fire (Mejia and Serna, 2017). An additional 1,300 homes were evacuated to protect residents from the Rye Fire (Etehad and Nelson, 2017). Many local transit operators reduced service due to the smoke and embers in the air. However, Gold Coast Transit maintained bus service to Community Memorial Hospital and Ventura County Medical Center and was prepared to use its buses and wheelchair-equipped vans for evacuations if requested by emergency personnel (Gold Coast Transit, 2017). Six shelters were opened to house evacuees of the Southern California Wildfires (O'Neal, 2017). Despite the lower loss of life from the 2017 December Southern California Wildfires, a series of mudslides in Montecito in January 2018 killed 23 people (Ventura County Star, 2018). The mudslides were caused by significant rainfall in the Thomas Fire burn scar, leading to unstable soil conditions and a rapid flow of mud and debris through neighborhoods.

Carr Fire

The Carr Fire began on July 23, 2018 in Shasta County, California and was caused by sparks from a vehicle with a flat tire (Agbonile, 2018; Schleuss et al., 2018). The fire was not contained until August 30, meanwhile burning over 229,000 acres; destroying about 1,600 structures; leading to the evacuation of approximately 39,000 people; causing the death of eight people; and costing an estimated $1.5 billion in damages (Bransford and Caron, 2018; Cal Fire, 2018h; Schultz, 2018). The Carr Fire moved slowly at first, but its growth was fueled by low humidity (under 10%), high temperatures (100+ degrees Fahrenheit), and dry vegetation (Schultz and Shulman, 2018). The Carr Fire advanced rapidly to the east, resulting in the evacuation of French Gulch, Old Shasta, and Keswick (Espino et al., 2018). Conditions worsened significantly, leading officials to evacuate multiple urban neighborhoods in Redding. The fire jumped the Sacramento River, partially due to fire whirls and fire tornados with winds upwards of 140 mph. The intensity of flames also created a localized weather system (NPS, 2018). Through the efforts of 4,500 firefighting personnel and favorable weather conditions, movement through Redding and northern and western rural communities was slowed, and the Carr Fire was finally contained at the end of August 2018 (NPS, 2018).

During the height of the wildfire, the Shasta County Sheriff's Office employed a variety of techniques to communicate with residents including door-to-door alerts, Code Red reverse-911 calls, a county-based emergency alert system, and the WEA system provided by the Federal Emergency Management Agency (FEMA). While WEA included mobile phones and reached the largest geographic area, some residents who

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did not need to evacuate still received mandatory evacuation orders (Cal Fire, 2018h). Communication confusion was furthered by the erratic behavior of the fire and significant delays in residents receiving evacuation orders. Residents reported receiving orders anywhere between 30 minutes to 12 hours before they needed to evacuate (Serna, 2018b). A Los Angeles Times investigation identified additional communication flaws such as the use of an outdated landline and mobile phone list (Serna and Sahagun, 2018). During the evacuation, evacuees encountered significant challenges with blocked or congested roadways (Johnson et al., 2018). Many people evacuated to local shelters at Shasta College, Simpson University, Cross Point Community Church, Foothill High School and Trinity High School (Schleuss et al., 2018). While the Carr Fire burned multiple neighborhoods of Redding, the majority of the city including the downtown was saved.

Mendocino Complex Fire

The Mendocino Complex Fire, the largest wildfire in California history, burned nearly 460,000 acres in Mendocino, Lake, Colusa, and Glenn Counties in Northern California (Callahan, 2018). The fire threatened 1,050 structures; destroyed 280 structures; and caused three injuries and one death (Callahan, 2018; McGough, 2018; Cal Fire, 2018i). The Mendocino Complex Fire was comprised of two fires burning at the same time – the River Fire and the Ranch Fire (Calfas, 2018). The Ranch Fire was caused by sparks from a hammer hitting a metal stake into the ground (Arango and Medina, 2018; Serna, 2019b), while the cause of the River Fire remains unknown. Due to a weather system that brought hot, dry, and windy conditions to the area, the fire spread rapidly (Cal Fire, 2018i). The fire burned for 54 days, from July 27 to September 19, before being 100% contained (McGough, 2018). The Mendocino Complex Fire required the evacuation of 17,000 people before its complete containment (Morris and Espinoza, 2018).

Government agencies alerted residents to the Mendocino Complex Fire through multiple mechanisms including: door-to-door notifications; loudspeakers on emergency vehicles; WEA; and a county-based emergency alert system (Sanchez and Thanawala, 2018). The alert systems faced shortcomings due to preregistration requirements and the lack of mobile phone service in some areas (Sanchez and Thanawala, 2018). The Habematolel Pomo Native American tribe also assisted in notifying residents in the Upper Lake area by going door-to-door to inform people of evacuation orders; helped people evacuate when needed; and marked empty homes for law enforcement officers (Johnson et al., 2018).

Some residents chose to stay to protect their homes from the fire and looters, safeguard their animals, and continue to run businesses (Arango, 2018). Other residents expressed mistrust of government mandated evacuations, leading some to remain behind (Arango, 2018). Residents who remained in their homes, particularly those who stayed to hose down their property to protect it from fire, challenged firefighting efforts by decreasing water available in fire hydrants (Arango, 2018). With a significant number of abandoned pets and livestock, the American Society for the Prevention of Cruelty to Animals (ASPCA) partnered with Lake County Care and Control to rescue and shelter domesticated animals who had been left behind, lost, or displaced by the Mendocino Complex Fire (Robertson, 2018). By August 7, this partnership had collected more than 2,500 animals from local residences, and the animals were cared for in specialized trailers (Robertson, 2018). While structural damages were much lower for the Mendocino Complex Fire than other California fires, over $200 million was spent on fire suppression. The rural environment, while increasing the number of acres burned, limited evacuations and threats to urban structures.

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Camp Fire

In November 2018, the Camp Fire severely impacted Butte County in California and the town of Paradise, burning a total of 153,336 acres (Cal Fire, 2018j; Wootson, 2018). The Camp Fire was caused by the failure of a steel hook on a PG&E transmission tower (Van Derbeken, 2018; Eavis, 2019). The Camp Fire led to a rapid and chaotic evacuation of 52,000 people and caused the death of 85 people, making it the deadliest wildfire in California and one of the deadliest wildfires in United States history (Stead Sellers et al., 2018; Wootson, 2018; Chan and Sterling, 2019). The Camp Fire left 18,804 structures destroyed in its wake, more than 13,000 of which were single-family residences (Cal Fire 2018j; Ravani, 2018; Alexander, 2019).

The town of Paradise had recently developed an evacuation plan that included a variety of communication tools to alert residents of a mandatory evacuation (Emergency Services Information, 2017). However, these communication tools faced shortcomings during the Camp Fire due to damaged power lines, residents using the bandwidth on the remaining lines to make phone calls , limited emergency dispatcher staff, lack of citizen registration for alerts, and a telephone system that could not handle the capacity of some alert systems (e.g., CodeRed – a messaging system designed to release a message to hundreds of thousands of phones per minute) (St. John and Serna, 2018; Krieger, 2018). Strong winds (40 to 50 mph) and low humidity (11 to 20%) led to the rapid growth of the fire, and officials were unable to notify all neighborhoods in time (Krieger, 2018; Belles, 2018).

Despite plans to conduct a phased evacuation, Paradise residents were forced to evacuate all at the same time, leading to considerable congestion on evacuation routes. Routes were already congested due to the rapid movement of the fire, obstructions on the roadways, and fire-impacted routes (St. John and Serna, 2018; Serna et al., 2018). As the fire continued to grow and congestion increased, people were forced to drive on road shoulders to avoid the flames and sometimes to escape on foot. Evacuees took shelter across the area, particularly in Chico, at families' and friends' residences, hotels, campsites, make-shift shelters in parking lots, and ARC shelters (Wootson, 2018). Some shelters faced considerable difficulties in maintaining quality of life due to adverse weather conditions and spread of illness (Stead Sellers et al., 2018). Additional information about the Camp Fire can be found in Zhao et al. (2019).

Woolsey Fire

The Woolsey Fire began on November 8, 2018 in Ventura County, California, and was likely caused by a malfunction in one of Southern California Edison's power lines (Cosgrove, 2019a; Cosgrove, 2019b; Rokos, 2019). The fire grew rapidly due to strong Santa Ana winds (Chandler, 2018). These winds, paired with low humidity (5%) and ample amounts of dry fuels, quickly spread the fire through Ventura and Los Angeles Counties (Chandler, 2018). Los Angeles County stated that the previous years of drought and construction of buildings in high fire-risk areas added to the destruction. The Woolsey Fire burned from November 8 to November 21, leading to an evacuation of about 250,000 people (County of Los Angeles, 2018). The fire was fought by 300 Los Angeles County firefighters, with the aid of approximately 3,000 firefighters from outside the county and state (County of Los Angeles, 2018). By the time it was contained, the Woolsey Fire burned nearly 97,000 acres and destroyed approximately 1,600 structures (Cal Fire, 2018k; Cosgrove, 2019a; Rokos, 2019). The fire demonstrated the need to prepare physical infrastructure and communication resources for residents (County of Los Angeles, 2019). The fire also exposed gaps in firefighting resources, as the concurrent Hill Fire received the bulk of firefighting resources early on, playing a key role in the rapid development of the Woolsey Fire (Cosgrove, 2019a).

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Most people evacuated from the Woolsey fire via personal vehicles (Sawicki, 2018). This led to heavy congestion, particularly on the Pacific Coast Highway, which acted as the main evacuation route for thousands of people in a 14-mile zone and especially near Malibu (Sawicki, 2018; Walker, 2018). Through a coordinated effort between multiple agencies and jurisdictions, officials were eventually able to change all lanes of the Pacific Coast Highway to flow away from the fire through contraflow (Sawicki, 2018; Walker, 2018). Some non-governmental organizations (NGOs) intervened and helped transport people during and after the Woolsey Fire. These organizations, including United Way and the ARC, partnered with private sharing economy companies including Lyft and Uber (Wong and Shaheen, 2019a; Wong and Shaheen, 2019b). The ARC opened eight shelters for evacuees of the Woolsey and Hill fires (American Red Cross, 2019). ARC volunteers continued to assist after shelters were closed by offering one-on-one support for victims and delivering emergency and recovery supplies to areas affected by the fires.

Hill Fire

The Hill Fire broke out on November 8, 2018 in a rural area of the Santa Rosa Valley in Ventura County (Cal Fire, 2019l; Bay Area News Group, 2018). The fire, attributed to human causes, burned for eight days, charring approximately 4,500 acres (ABC7 Staff, 2018; Hersko, 2018; Cal Fire, 2018l). In addition to the acreage burned, the Hill Fire threatened 400 buildings, destroyed four buildings, and necessitated the evacuation of 17,000 people (Cal Fire, 2018l; Public Information Officer Ventura County Fire Department, 2018a). The rapid growth of the fire was caused by low humidity and strong Santa Ana winds (Licas and Gundran, 2018). In addition, on the same day that the Hill Fire ignited, the Woolsey Fire sparked 15 miles to the east (Cosgrove, 2019a). The two simultaneously burning fires led to the division of firefighting resources and necessitated the request for aid from outside the Ventura County area (Cosgrove, 2019a). As of December 2019, officials had not identified the cause of the Hill Fire beyond that it was started by human actions (Campos, 2018; Hersko, 2018).

During the fire, the Ventura County Fire Department encouraged people to sign up to receive emergency alerts, provided information hotlines, and leveraged social media accounts in both English and Spanish (Ventura County Fire, 2018; Public Information Officer Ventura County Fire Department, 2018b). The Hill Fire led to the closure of four schools and multiple roads in the area, including Highway 101 (Jackson and Hamasaki, 2018). Two evacuation centers were established for evacuees, and three shelters were established for animals (Lloyd, 2018). Private organizations including Uber, Lyft, and Airbnb also offered assistance to evacuees for the general areas impacted by the Woolsey and Hill Fires (Wong and Shaheen, 2019a; Wong and Shaheen, 2019b). While the Hill Fire was slowed and contained quickly, the decision to focus more on the Hill Fire during the initial outbreak diverted key resources away from the Woolsey Fire (Cosgrove, 2019a).

Saddle Ridge Fire

The Saddle Ridge Fire burned from October 10, 2019 to October 31, 2019 in the San Fernando Valley area of Los Angeles County (Cal Fire, 2019a). The Saddle Ridge Fire burned 8,799 acres; damaged 88 structures; destroyed 19 structures; and injured eight people (Cal Fire, 2019a; Plachta, 2019). In addition, one person died due to cardiac arrest while trying to protect their home from the fire (Salahieh and Lyster, 2019). Approximately 23,000 homes and 100,000 people were evacuated, but a significant number of people disregarded the orders and stayed behind to protect their homes (Keene and Bogel-Burroughs, 2019; Miller et al., 2019). As of December 2019, the cause of the fire was still under investigation, although authorities have determined that it began under a transmission tower (Cosgrove, 2019c). In addition,

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reports found that the Southern California Edison electrical system was impacted minutes before the fire ignited (Shalby, 2019). Strong Santa Ana winds and low humidity (around 12%) led the fire to become very "dynamic" and move swiftly (CBS Staff, 2019). The area impacted had been identified by Cal Fire as a "very high fire hazard severity zone" (CBS Staff, 2019). Residents reported poor communication, and many neighborhoods were evacuated by authorities driving through streets with a bullhorn (CBS Staff, 2019). Eight shelters were opened for evacuees, although many reached capacity shortly after the fire started (Plachta, 2019). Cooler temperatures, cool coastal winds, and higher humidity levels helped firefighters gain control over the fire (Miller et al., 2019).

Kincade Fire

The Kincade Fire began on October 23, 2019 and burned until November 6, 2019 in the Geyserville area of Sonoma County (Cal Fire, 2019b). By the time of its containment, the fire had burned 77,758 acres; damaged 60 structures; destroyed 374 structures; injured four people; and required the evacuation of 200,000 people (Cal Fire, 2019b; Asimov, 2019). As of December 2019, the cause of the Kincade Fire had not been determined, but PG&E remains under investigation as the potential cause. PG&E had turned off power to many (but not all) power lines in Sonoma County as a proactive measure to prevent wildfires (Stanglin, 2019). However, the line near where the Kincade Fire sparked was still in service. PG&E registered an outage on the line seven minutes before the fire began (Stanglin, 2019).

The power outages for nearly 28,000 residents in the area led to challenges with communication and firefighting (Alexander and Cassidy, 2019). About 17% of cell towers in Sonoma County lost power, while a significant number of landlines were out of service (Krieger, 2019). Residents depended on flashlights and camping lights to navigate through their homes and on streets as they tried to evacuate. These challenges were amplified by thick smoke and falling ash (Alexander and Cassidy, 2019). In addition, residents could not charge their phones and laptops and were unable to receive emergency notification alerts (Alexander and Cassidy, 2019). Firefighters were equally challenged by the power outages. Firefighters were unable to use electricity-based devices (e.g., phones, computers) to communicate and draw water from electric pumps (Alexander and Cassidy, 2019). Evacuees faced challenges finding housing due to power outages, fully booked hotels, and packed shelters (Sweeney, 2019). Community aid shelters, such as one in Healdsburg, distributed resources provided by local organizations, non-profits, and public agencies (Schmitt, 2019).

Tick Fire

The Tick Fire began on October 24, 2019 in the Santa Clarita Valley of Los Angeles County and reached containment a week later (San Francisco Chronicle, 2019). The cause of the fire is under investigation (Rosenfeld, 2019). Shortly before the ignition of the fire, residents experienced loud booms, followed by a plume of smoke and flames (Rosenfeld, 2019). By the time of containment, the Tick Fire burned 4,615 acres; destroyed 22 structures; threatened 600 structures; and necessitated the evacuation of approximately 50,000 residents (Rosenfeld, 2019; SF Chronicle, 2019; LAist Staff, 2019a; Jennings, 2019; Federal Emergency Management Agency, 2019b). The spread of the Tick Fire was aided by strong Santa Ana winds, which pushed the fire into residential neighborhoods (Jennings, 2019). The Tick Fire led to the opening of two shelters for evacuees in the nearby town of Santa Clarita and four animal shelters. The Tick Fire also led to the closure of two roads and the closure of schools in four school districts (LAist Staff, 2019a).

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Southern California Edison, the utility provider for the area, turned off power to the area as a precautionary measure to stop the spread of the fire. This power shutoff led to challenges in communicating and evacuating as the Tick Fire grew. Many of the emergency communication methods used in Los Angeles County relied on the Internet and cell towers, making the methods vulnerable to power outages (Gerber and Rainey, 2019). Smoke and poor street lighting added to confusion and congestion during the evacuation (Gerber and Rainey, 2019). As people moved toward safety, the ARC, along with partner organizations, provided aid and supplied over 4,900 overnight stays; served more than 10,100 meals; and connected 1,200 people with family members (American Red Cross, 2019). A variety of private companies offered support for housing, transportation, and storage to those affected by the Tick Fire. These companies included Airbnb, U-Haul, Lyft, and Uber (Fortin-Caldera, 2019).

Getty Fire

The Getty Fire began on October 28, 2019 and burned until reaching containment about one week later (Stewart, 2019). The Getty Fire was started by strong wind gusts, which caused a tree branch to hit Los Angeles Department of Water and Power electricity lines (Stewart, 2019). The fire was located in the Brentwood and Pacific Palisades neighborhoods of Los Angeles, some of the most populous neighborhoods in the area (Irfan, 2019). The Getty Fire threatened 10,000 homes; damaged 15 residences; destroyed 10 residences; injured five firefighters; burned a total of 745 acres; and required the evacuation of nearly 25,000 people (Stewart, 2019; Shapiro et al., 2019). The National Weather Service issued an extreme red flag warning the day after the Getty Fire broke out, based on the humidity, temperatures, and wind speeds of the environment (LAist Staff, 2019b). Los Angeles followed suit and put into place its Red Flag Parking Program, which tickets people for parking in identified "Very High Fire Severity Zones" (LAist Staff, 2019b).

The Getty Center (a modern art museum) was used as a staging area, rest area, and logistics base for firefighting personnel (Gelt, 2019). The museum and art within were protected by a series of mitigation techniques including: preemptive brush clearing; fire-resistant landscape; a million-gallon water reserve system; fire-resistant building exterior; and a sophisticated air filtration system (Gelt, 2019). The Getty Fire also threatened major transportation assets, including the I-405 highway (Irfan, 2019). Five shelters for people and three shelters for animals were opened to assist evacuees (LAist Staff, 2019b).

Los Angeles' emergency alert system, which sends alerts to smartphones, received criticism for sending out a Spanish notification five hours after an English alert was released and for the inequitable design of the system (Shyong, 2019). The system was Roman character based, excluding other languages, and specifically targeted smartphones (Shyong, 2019). The Los Angeles Fire Department and Police Department also received criticism for allowing domestic workers (e.g., housekeepers, gardeners) to enter or remain in evacuated areas (Shyong, 2019).

Comparison of California Wildfire Case Studies

Key Similarities

Comparing across California case studies, we found several similarities indicating critical issues that will likely arise in future California wildfires (Table 4). These similarities may also be present for other wildfires in the United States beyond California. We first found that all wildfires were directly or indirectly started by humans. The ignition involved actions directly related to humans (e.g., sparks created by a hammer, sparks created by a vehicle with a flat tire) or more indirectly related by debris hitting power lines. The variety of human causes indicates that humans will continue to play an outsized role in starting wildfires,

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as compared to natural sources (e.g., lightning). We found fires spread very rapidly in all cases, fueled by dry vegetation and high winds. Low humidity and high temperatures often exacerbated these fires. Fire also spread rapidly along the WUI (wildland-urban interface), causing significant evacuations and threatening neighborhoods and cities. Regarding communication, we found that jurisdictions had a variety of options to communicate with the public, but not all methods were selected. In a number of wildfires, this led to severe communication challenges that resulted in significant delays in issuing mandatory evacuation orders. Regardless of the wildfire, communication challenges were present, but the degree differed depending on the scale of the fire and the preparedness of the jurisdiction.

For the evacuation process, we found that areas containing difficult roads faced challenges in evacuating. Moreover, neighborhoods with single exits and roads with debris were difficult to evacuate, often leading to severe congestion. This congestion was exacerbated by the preference to evacuate with personal vehicles. Despite this preference, transit agencies across California deployed resources to help evacuate residents or were ready to assist if called to help. Increased integration of public transit with emergency management may help to further improve transit-assisted evacuations. For sheltering, the ARC played an instrumental role in sheltering evacuees across wildfires. Finally, for reentry, we found that a number of organizations (including community-based organizations [CBOs] and non-governmental organizations [NGOs]) and government agencies offered assistance during the reentry and recovery process. However, formalized reentry plans were severely lacking, leading to confusion over when residents would be allowed to return.

Additional Characteristics

Along with these similarities, each wildfire exhibited characteristics relevant to fire context, geographical factors, and evacuation process (Tables 5 to 7). We note that these tables do not necessarily show unique differences. Indeed, many fires exhibited similar challenges and issues (e.g., power outages, full shelters). Rather, the tables describe by fire the most relevant characteristics for cause, fire behavior, communication, evacuation, sheltering, and reentry. More in-depth characteristics for each wildfire can be found in the variety of sources provided following each table. Additional characteristics will be issued in a working paper by the International Association of Fire Safety Science, which collects case studies of wildfires across the world.

Overall, we found not all causes of major California wildfires were associated with electrical power. Several other causes, including sparks from a vehicle with a flat tire (Carr Fire) and a hammer (Mendocino Complex Fire), would not have been avoided if power had been shut off. Fire behavior also differed between the fires. For example, fire whirls were reported for the Carr Fire, which caused additional fire spread. Early reports of a more intense fire (the Hill Fire) caused a significant diversion of resources away from the Woolsey Fire, making the Woolsey Fire much more destructive. In addition, some wildfires involved significant house-to-house fire spread (particularly the Camp Fire), which increased property damage.

Several wildfires impacted areas that were also subjected to public safety power shutoff (PSPS) events. The lack of power hampered communications as cell towers and landlines lost connection. Reduced lights also decreased visibility during the evacuations. One critical lesson from these fires is that mechanisms need to be in place to communicate with residents without power. Low-tech options including sirens or door-to-door notifications may be necessary to alert residents. Communication methods also varied across wildfires, with some agencies relying on social media while others implemented the WEA system.

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While it is unclear which single method is most effective, multiple methods are preferred to reach as many residents as possible. We also found that agencies had differing abilities to communicate in other languages, with officials communicating effectively in Spanish (Hill Fire) but failing to release multilingual orders at the same time or in enough languages (Getty Fire). Despite ongoing challenges, communication of mandatory evacuation orders has generally improved over the past three years, due in part to lessons learned and improved emergency response plans.

Regarding evacuations, we found several transportation responses that were not implemented in all wildfires. First, during the Atlas Fire (part of the 2017 Northern California Wildfires), trees fell across Atlas Peak road, the only exit road for some residents, and residents were rescued by helicopter. The response highlights the need for flexible transportation options. In several fires, hospitals were pre-evacuated to ensure continuity of care for those who faced the highest risk from smoke or a power outage (Carr Fire). In the Mendocino Complex Fire, a significant number of residents did not evacuate due to their fear of looting and mistrust of the government. These concerns need to be addressed in future wildfires, particularly in rural areas of California with a stronger culture of independence. During the Camp Fire, congestion was particularly bad for officials, and some residents had to evacuate on foot. On the other hand, officials in Los Angeles instituted a Red Flag Parking Program to clear vehicles parked on major evacuation and first responder routes (Woolsey Fire, Getty Fire). Officials also conducted a contraflow process on the Pacific Coast Highway for the Woolsey Fire. In several unique instances, entire interstates were forced closed by wildfires such as Highway 101 (Hill Fire), parts of highways in the San Fernando Valley (Saddle Ridge Fire), and Interstate 5 (Tick Fire). Overall, dense smoke from several fires in 2019 (Kincade Fire, Tick Fire) significantly lowered visibility and added risk to the evacuation process.

Table 4: Key Similarities Across All Major 2017 to 2019 California Wildfires

	Key Similarities Across Wildfires
Cause	Humans, either directly or indirectly, were involved in the fires' ignition and spread.
Fire Behavior	High levels of dry vegetation and high winds exacerbated the spread of fires.
Communication	Jurisdictions had a variety of communication options they could employ, but not all were selected for each wildfire, leading to communication challenges.
Evacuation	Areas with single road entry, windy roads, or debris-blocked roads were difficult to evacuate. Most people evacuated via personal vehicle, and most evacuees experienced significant congestion. Local transportation agencies assisted (or were willing to assist) in most evacuations.
Sheltering	The ARC and local organizations were instrumental in providing aid via shelters. Shelters filled quickly with evacuees.
Reentry	Residents were offered resources for reentry from a variety of organizations (e.g., public agencies, private organizations), but formalized plans were lacking.

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Table 5: Key Characteristics Across Major 2017 California Wildfires

	2017 October Northern California Wildfires	2017 December Southern California Wildfires
Cause	Downed trees on power lines and faulty private electrical equipment ignited the fires.	Slapping of Southern California Edison's power lines, an illegal cooking fire, and unknown causes led to the ignition of the fires.
Fire Behavior	Fire spread rapidly over manmade fire break (Highway 101).	Santa Ana winds spread the flames quickly.
Communication	Agencies chose not to use the WEA system due to concerns that the WEA would reach larger than necessary geographic areas. Agencies faced challenges with coordinating across jurisdictions.	Agencies offered a hotline as the primary way to communicate with residents, but residents who had not registered for subscription alert services may not have known about the hotline.
Evacuation	Debris blocked a road that serves as a single exit for a community and residents had to be helicoptered to safety. Some residents were unable to access their vehicles due to lack of power (i.e., unable to open garage doors) and rapid spread of fire.	Officials quickly ordered evacuations for large numbers of residents. Ambulances evacuated people from medical centers.
Sheltering	Several shelters were under threat of fire.	Multiple fires burning concurrently stretched the resources of the shelters.
Reentry	Local transit agencies offered free transportation service to assist people in the reentry process. Many residents reentered before the fire was at 100% containment.	The shorter duration of several fires allowed people to reenter relatively quickly.

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Sources	Bonos et al., 2017; Digitale, 2017; Golden Gate Transit, 2017; Lewis et al., 2018; Lewis, 2018; Morris, 2018; Napa Valley Register, 2017; O'Neill et al., 2018; Petaluma Argus-Courier, 2017; Press Democrat, 2018; Rodriguez et al., 2017; Sonoma County Civil Grand Jury, 2018; The Greater Marin, 2017; Watkins et al., 2017; Waxmann, 2017	Carlson, 2018; Chandler, 2017; Daily News Staff, 2017a, 2017b; Gold Coast Transit, 2017; Holt and Dave, 2017; Mejia and Serna, 2017; Myers, 2017; O'Neal, 2017; The New York Times, 2017; Yam and Vives, 2017

Table 6: Key Characteristics Across Major 2018 California Wildfires

	Carr Fire	Mendocino Complex Fire	Camp Fire	Woolsey Fire	Hill Fire
Cause	The fire was caused by sparks from a vehicle with a flat tire.	One fire was caused by sparks from a hammer.	PG&E transmission tower hook failure caused the fire.	The fire was likely caused by the failure of a Southern California Edison (SCE) power line.	The cause of the fire is currently unknown but attributed to human activity.
Fire Behavior	The intensity of the fire and wind gusts led to fire whirls, which caused additional spread and a jump over the Sacramento River.	The River and Ranch Fires burned simultaneously, including through remote areas of the Mendocino National Forest. A state of emergency was declared by the California governor due to sheer size of the fires.	The large footprint of the fire destroyed much of the area's housing stock. In some instances, fire spread from house to house.	Construction in high-risk areas allowed the fire to spread rapidly from house to house. Firefighting resources were divided between the Woolsey and Hill Fires, decreasing response capabilities.	The fire was classified as a higher threat than the nearby Woolsey Fire and therefore received more firefighting resources.

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Communication	Communication gaps occurred due to challenges predicting the fire's course and shortcomings of alert systems (e.g., outdated phone lists).	Lack of mobile phone service in a mostly rural area posed challenges for communication. The localized alert system had some shortcomings (e.g., only reaching pre-registered mobile phones).	Destruction of telephone lines and loss of power decreased communication capacity and hindered communication measures. Existing telecommunications infrastructure could not support CodeRed alert system.	Agencies, with limited methods for communication, used outlets including social media and pre-registered emergency alert lists.	Local public agencies used their social media accounts to keep residents informed. Alerts were sent out in Spanish and English.
Evacuation	First responders caused congestion on major evacuation routes as they attempted to respond to the fire. Buses were used to evacuate local medical centers. People with select needs (e.g., premature babies) were evacuated early to specialized facilities.	Some residents actively chose not to evacuate for a variety of reasons (e.g., fear of looting, mistrust of government).	Narrow, windy roads led to large amounts of congestion. Bottlenecks occurred within Paradise and near Chico. Fire moved so quickly that many people had to evacuate on foot.	Officials implemented contraflow on the Pacific Coast Highway to increase capacity and ease congestion. Los Angeles implemented local programs (e.g., Red Flag Parking Program) to increase road capacity.	Closure of a major freeway (Highway 101) increased evacuation congestion.

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Sheltering	Shelters reached capacity quickly due to the number of evacuees. One shelter had to be evacuated since it became part of the evacuation zone. Some shelters also allowed pets and large animals.	Large livestock in the area required shelter and were cared for by animal non-profits and local shelters. Shelters lacked accommodations for people with specific medical requirements (e.g., oxygen tanks).	A variety of shelter types were employed including hotels, ARC-sponsored shelters, friends' and families' homes, and makeshift shelters (e.g., in parking lots). Shelters were threatened by poor weather conditions and spread of illnesses.	A local university implemented a shelter-in-place plan rather than evacuate. Companies (e.g., Verizon) offered resources such as calling centers through the shelters.	FEMA employed its texting-based sheltering system to help people find shelters. Shelters provided protective gear such as N-95 masks.
Reentry	Damage to roadways delayed the reentry process.	Some local hospital staff did not evacuate and stayed onsite to maintain the building and prepare it for reentry. The ARC offered reentry services, including assistance with insurance claims.	Destruction of the area led it to be classified as a health concern, delaying reentry efforts.	ARC offered supplies to damaged and destroyed areas.	The county provided some residents with information on resources for reentry.
Sources	Cal Fire, 2018h; Chapman, 2018; Espino et al., 2018; KCRA, 2018; KTVU, 2018; Ramey, 2018; Schleuss et al., 2018; Schultz and Shulman, 2018; Serna, 2018b; Serna and Sahagun, 2018; Shulman, 2018;	Arango, 2018; Cal Fire, 2018i; Johnson et al., 2018; Larson, 2018; Pugh 2019; Robertson, 2018; Sanchez and Thanawala, 2018; Steade, 2018	Almukhtar et al., 2018; Chico Enterprise-Record, 2019; Krieger, 2018; Krieger and Debolt, 2019; Newberry, 2019; Serna, 2018; St. John and Wootson, 2018; St. John and Serna, 2018; Stead Sellers et al., 2018; Serna et al., 2018	American Red Cross, 2018; Chandler, 2018; County of Los Angeles, 2018; Los Angeles Fire Department, 2018; Malibu City, 2018; Mejia, 2018; Mejia et al., 2018; Pepperdine University, 2018; Reyes-Velarde, 2018	Cal Fire, 2018l; Federal Emergency Management Agency, 2018; Lloyd, 2018; Public Information Officer Ventura County Fire Department, 2018a, 2018b; Ventura County Fire, 2018

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Table 7: Key Characteristics Across Major 2019 California Wildfires

	Saddle Ridge Fire	Kincade Fire	Tick Fire	Getty Fire
Cause	The cause of the fire is under investigation.	The cause of the fire is under investigation.	The cause of the fire is under investigation.	Strong winds broke a tree branch, which hit a power line.
Fire Behavior	The fire was highly dynamic with erratic behavior close to neighborhoods.	The fire impacted areas without power due to the PSPS event instituted by PG&E.	The fire threatened Interstate 5, causing officials to close it in both directions.	Damage was exacerbated by weather conditions, and the fire threatened Interstate 405.
Communication	Most people were alerted via neighbors and police.	Lack of power made communication (via mobile phones and landlines) very difficult.	Communication challenges were exacerbated by power outages.	The alert system, incapable of handling multiple languages, was criticized for being inequitable.
Evacuation	Due to poor communication, residents had little notice to evacuate.	Thick smoke and lack of power increased evacuation risks.	Dense smoke lowered visibility and made evacuating a challenge.	Los Angeles implemented its Red Flag Parking Program to increase road capacity.
Sheltering	Shelters were quickly filled to capacity.	Due to the large number of evacuees, many shelters and hotels were full in the area.	A significant number of animal shelters were opened.	Local recreation centers were used as shelters.

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Reentry	Los Angeles County provided residents with reentry resources (e.g., mental health counseling sessions, health referral, disaster assistance programs).	Evacuees had to show proof of residency to return.	The fire was contained relatively quickly, allowing people to return.	Some residents and employees were allowed to reenter evacuation zones early.
Sources	CBS Staff, 2019; Cosgrove, 2019c; Federal Emergency Management Agency, 2019a; Kenne and Bogel-Burroughs, 2019; Miller et al., 2019; Platcha, 2019; Rosenberg, 2019; Salahieh and Lyster, 2019; Shalby, 2019	Alexander and Cassidy, 2019; Asimov, 2019; Ghisolfi, 2019; Schmitt, 2019; Stanglin, 2019	American Red Cross, 2019; Federal Emergency Management Agency, 2019b; Fortin-Caldera, 2019; Gerber and Rainey, 2019; Jennings, 2019; LAist Staff, 2019a; Reyes-Velarde, 2019b; Rosenfeld, 2019; SF Chronicle, 2019;	Gelt, 2019; Irfan, 2019; LAist Staff, 2019b; Fry and Vives, 2019; Shapiro et al., 2019; Shyong, 2019; Stewart, 2019

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For sheltering, large livestock in certain areas received sheltering and care alongside smaller pets (Mendocino Complex Fire, Carr Fire). We also found that shelters for the majority of wildfires allowed pets. Shelter conditions were particularly bad for the Camp Fire, as multiple tent shelters had to be constructed. Poor weather conditions and minimal hygiene resources led to the rapid spread of illness (norovirus). Another unique sheltering event was the shelter-in-place plan implemented by Pepperdine University (Woolsey Fire). Regarding reentry, we were unable to find specific details about the process for each wildfire. We do note, however, that sharing economy companies (in particular Airbnb, Lyft, and Uber) were highly active in the recovery and relief from several fires. Recent research (Wong and Shaheen, 2019a; Wong and Shaheen, 2019b; Wong et al., 2020b) found companies active in the: 2017 October Northern California Wildfires (Airbnb, Lyft, Uber); 2017 December Southern California Wildfires (Airbnb, Lyft, Uber); Mendocino Complex Fire (Airbnb); Carr Fire (Airbnb, Lyft); Camp Fire (Airbnb, Lyft); and Woolsey and Hill Fires (Airbnb, Lyft, Uber). In addition, sharing economy companies were active in 2019 California wildfires as seen in Table 8.

Table 8: Sharing Economy Company Actions in Major 2019 California Wildfires

	Saddle Ridge Fire	Kincade Fire	Tick Fire	Getty Fire
Actions by Airbnb	Activated "Open Homes Program" (Airbnb, 2019a)	Activated "Open Homes Program" (Airbnb, 2019b)	Activated "Open Homes Program" (Airbnb, 2019c)	Activated "Open Homes Program" (Airbnb, 2019c)
Actions by Lyft	Offered two free rides of up to $15 each to local shelters through "Wheels for All Program" (Quednow, 2019)	Offered two free rides of up to $15 each to local shelters through "Wheels for All Program." Provided the same ride option to public centers for the PSPS event across the Bay Area (Lyft Blog, 2019)	Offered two free rides of up to $15 each to local shelters through "Wheels for All Program" (NBC Los Angeles, 2019)	Offered two free rides of up to $15 each to local shelters through "Wheels for All Program" (NBC Los Angeles, 2019)
Actions by Uber	None	Offered two free rides up to $20 each to and from evacuation centers (Garber, 2019)	Offered two free rides up to $20 each to and from evacuation centers (Garber, 2019)	Offered two free rides up to $20 each to and from evacuation centers (Garber, 2019)

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California Wildfire Surveys

Within the context established by the California wildfire case studies, we next present the California Wildfire surveys and corresponding results. Given the lack of available data on evacuee actions, we distributed an online survey to individuals impacted by: 1) the 2017 October Northern California Wildfires, 2) the 2017 December Southern California Wildfires, and 3) the 2018 Carr Wildfire. Surveys were distributed with the assistance of local partners (i.e., transportation agencies, emergency management agencies, local city and county governments, CBOs, and news outlets). The purpose of using local partners was to distribute the survey as widely as possible to the general population. Partners were also used to avoid the cost of finding survey respondents through a survey management service. A service would likely have elicited few responses, since wildfires are highly localized. Partners were allowed to post the survey using electronic communication methods including but not limited to: Facebook, Twitter, Nextdoor, agency websites, news websites, email listservs, and alert subscription services. In the surveys, we asked respondents a range of questions related to their evacuation choices, risk perceptions, and willingness to share resources in evacuations. More information about results related to the feasibility of the sharing economy in evacuations can be found in Wong and Shaheen (2019a, 2019b). Additional analysis of the choices of individuals can be found in Wong et al. (2020a) using regret minimization. Table 9 presents the characteristics of each survey. Demographic characteristics of respondents are provided in Tables A1 and A2 in the Appendix. In the next sections, we present descriptive statistics from the surveys on key evacuation choices, communication methods, non-evacuee opinions, and government response. Table 10 displays the primary decisions across the three wildfire cases. We note that for all descriptive statistics, percentages may not add to 100% due to rounding. We also note two limitations of this research. First, the surveys contain self-selection bias (i.e., respondents opted into the survey). Second, not all respondents' demographic characteristics are representative of the population impacted by the wildfires.

Table 9: California Wildfire Surveys

	2017 Northern California Wildfires	2017 Southern California Wildfires	2018 Carr Wildfire
Survey Timeline	March to April 2018	March to July 2018	March to April 2019
Targeted Counties	Sonoma, Napa, Solano	Ventura, Santa Barbara, Los Angeles	Shasta, Trinity
Targeted Fires	Tubbs, Nuns, Atlas	Thomas, Creek, Skirball	Carr
Incentive (Drawing)	Five $200 gift cards	Five $200 gift cards	Ten $250 gift cards
Responses	284	552	647
Finished Responses	92	303	338
Finish Rate	32%	55%	52%
Sample Size (*after cleaning*)	79	226	284
Distribution Method	Online via transportation and emergency management agencies, CBOs, NGOs and local media		

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Table 10: Key Evacuation Choices of Survey Respondents

	2017 Northern California Wildfires	2017 Southern California Wildfires	2018 Carr Wildfire
Sample Size (All Respondents)	*n=79*	*n=226*	*n=284*
Evacuation Choice			
Evacuated	46.8%	77.4%	89.4%
Did Not Evacuate	53.2%	22.6%	10.6%
Sample Size (Evacuees Only)	*n=37*	*n=175*	*n=254*
Departure Timing by Hour			
12:00 AM - 5:59 AM	48.6%	23.4%	9.1%
6:00 AM - 11:59 AM	27.0%	24.6%	7.9%
12:00 PM - 5:59 PM	10.8%	24.6%	19.7%
6:00 PM - 11:59 PM	13.5%	27.4%	63.4%
Shelter Type			
Friend's residence	24.3%	30.3%	39.8%
Family member's residence	24.3%	32.6%	29.9%
Hotel or motel	21.6%	22.9%	13.4%
Public shelter	5.4%	3.4%	2.4%
Second residence	0.0%	2.9%	3.1%
Portable vehicle (e.g., camper, recreational vehicle [RV])	8.1%	4.0%	5.1%
Peer-to-peer service (e.g., Airbnb)	2.7%	1.1%	0.4%
Other	13.5%	2.9%	5.9%
Primary Route by Road Type			
Highways	32.4%	62.3%	38.2%
Major roads	27.0%	15.4%	16.9%
Local roads	2.7%	4.0%	4.7%
Rural roads	10.8%	1.1%	4.7%
No majority type	27.0%	17.1%	35.4%
Usage of GPS for Routing			
Yes, and followed route	18.9%	18.3%	7.5%
Yes, but rarely followed route	2.7%	4.6%	5.5%
No	78.4%	77.1%	87.0%
Multiple Destinations			
Yes	45.9%	41.7%	48.4%
No	54.1%	58.3%	51.6%

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Returned Home			
Yes	91.9%	92.6%	96.9%
No	8.1%	7.4%	3.1%
Within County Evacuation			
Yes	70.3%	66.3%	66.1%
No	29.7%	33.7%	33.9%
Mode Choice*			
One personal vehicle	40.5%	45.1%	33.9%
Two personal vehicles	43.2%	40.6%	45.3%
More than two personal vehicles	13.5%	8.6%	16.5%
Aircraft	0.0%	0.6%	0.0%
Rental car	2.7%	0.6%	0.0%
RV	0.0%	1.1%	2.4%
Truck and trailer	0.0%	2.3%	0.0%
Non-household carpool	0.0%	1.1%	1.2%
Carsharing (e.g., Zipcar, Enterprise CarShare, GIG Car Share)	0.0%	0.0%	0.4%
Walk	0.0%	0.0%	0.4%

*Other transportation mode options asked in the survey but received no responses: bus; rail (e.g., light/heavy, subway/metro, trolley; shuttle service; motorcycle/scooter; bicycle; ridesourcing/TNC (e.g., Uber, Lyft)

Evacuate or Stay

In the 2017 Southern California Wildfires and the 2018 Carr Wildfire, a significant number of respondents evacuated from the wildfire at 77.4% and 89.4% respectively. These values are somewhat dependent on the sampling, which makes it difficult to extrapolate numbers out to the general population. However, to gain more specific insight, we ran a simple bivariate cross tabulation with evacuation decision and mandatory order (Table 11). Two numbers are most important: 1) the non-compliance rate (i.e., respondents who stated they received a mandatory evacuation order but did not evacuate) and 2) the shadow evacuation rate (i.e., respondents who stated they did not receive a mandatory evacuation order but still evacuated). We found the non-compliance rate to range from 3.2% to 13.0% across the three fires. These low non-compliance rates indicate that individuals were highly motivated to evacuate and heeded evacuation orders. In some of these cases, the environmental cues of the fire coupled with the order may have influenced individuals to leave.

We also calculated the shadow evacuation rate, which is typically used for analyzing hurricane evacuations. For hurricanes, officials issue evacuation orders before landfall with clear geographical boundaries based on storm risk. However, some individuals decide to leave despite not being issued a mandatory evacuation order. While some vulnerable individuals should probably still evacuate, most citizens in non-mandatory zones are safe to ride out the storm. Higher shadow evacuation rates lead to more congestion on the roadways, dilute emergency and transportation resources, and decrease sheltering availability. For wildfires, the direct implications of high and variable shadow evacuation rates (ranging from 29.1% to 75.0% for the three fires) are unclear. One possible explanation is that officials

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were often unable to issue mandatory evacuation orders before residents needed to evacuate. Another explanation is that residents may have found the environmental cues of the fire to be very high risk, leading them to evacuate without an order. Future research is needed to separate the impacts of poor messaging and environmental cues on shadow evacuations for wildfires.

Table 11: Bivariate Cross Tabulations for Evacuation Decision and Mandatory Order

2017 Northern California Wildfires *(n=79)*		**Evacuation Decision** Yes	No
Received Mandatory Evacuation Order	Yes	87.5%	**12.5%**
	No	**29.1%**	70.9%
	Total	46.8%	53.2%

2017 Southern California Wildfires *(n=226)*		**Evacuation Decision** Yes	No
Received Mandatory Evacuation Order	Yes	87.0%	**13.0%**
	No	**62.5%**	37.5%
	Total	77.4%	22.6%

2018 Carr Wildfire *(n=284)*		**Evacuation Decision** Yes	No
Received Mandatory Evacuation Order	Yes	96.8%	**3.2%**
	No	**75.0%**	25.0%
	Total	89.4%	10.6%

Messaging and Communication

We asked respondents a number of questions related to evacuation orders as seen in Table 12. We first found that a high proportion of the respondents from the 2017 Southern California Wildfires and 2018 Carr Wildfire received a mandatory evacuation order. A high proportion from the 2017 Southern California Wildfires also received a voluntary evacuation order (note that multiple selection was allowed). For the message media type, most respondents across the three fires said they received mandatory orders through text message, personal interaction with public officials, or a secondary source (i.e., neighbor, friend, extended family). Reverse 911 was a popular source for the 2017 Southern California Wildfires and the 2018 Carr Wildfire, while social media and internet websites saw higher rates for the 2017 Southern California Wildfires. Respondents also received mandatory evacuation orders through alert subscription services heavily for the 2017 Northern and Southern California Wildfires. For voluntary evacuation orders, respondents tended to receive the order through text message, television, social media, internet websites, and secondary sources.

A significant number of respondents from each wildfire also sought additional information for mandatory evacuation orders (ranging from 29.8% to 50.0%) and voluntary evacuation orders (ranging from 62.2% to 66.7%). This indicates that information across sources needs to be consistent. Clarity of messaging (extremely clear) was also fairly high across wildfires but lowest for the 2017 Southern California Wildfires. Voluntary evacuation orders were always less clear than mandatory evacuation orders. Level of trust of the source (very high) also followed a similar pattern in that trust was greater for those who received a

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mandatory evacuation order. In addition, the level of trust of the sources (very high) was strong across disasters. For reentry information, only a subset of respondents received information through an official source (22.0% to 33.3%). This number jumps for news sources (35.3% to 64.6%), indicating that the dissemination of reentry plans may be best through the news. Some individuals did not receive any information before returning (8.5% to 23.5%), which suggests key gaps in the communication of reentry plans.

Table 12: Communication and Messaging of Evacuation Orders

	2017 Northern California Wildfires		2017 Southern California Wildfires		2018 Carr Wildfire	
Sample Size (all respondents)	*n=79*		*n=226*		*n=284*	
Received by Order Type	Mandatory	Voluntary	Mandatory	Voluntary	Mandatory	Voluntary
Received the order	30.4%	34.2%	61.1%	54.4%	66.2%	26.1%
Did not receive the order	69.6%	65.8%	38.9%	45.6%	33.8%	73.9%
Sample Size (received order)	*n=24*	*n=27*	*n=138*	*n=123*	*n=188*	*n=74*
Messaging by Order Type						
Message	Mandatory	Voluntary	Mandatory	Voluntary	Mandatory	Voluntary
Reverse 911 call	8.3%	0.0%	34.1%	22.8%	38.8%	18.9%
Text message	29.2%	33.3%	50.0%	52.0%	37.2%	29.7%
Television announcement	12.5%	14.8%	21.0%	26.8%	19.7%	33.8%
Radio announcement	4.2%	3.7%	6.5%	9.8%	6.9%	8.1%
Flyer	0.0%	0.0%	0.7%	0.8%	0.5%	0.0%
Personal interaction with a public official	41.7%	22.2%	32.6%	8.9%	30.3%	16.2%
Social media (Facebook, Instagram, Twitter, etc.)	16.7%	37.0%	34.1%	35.0%	14.9%	25.7%
Alert from a subscribed service	41.7%	55.6%	32.6%	35.0%	11.7%	6.8%
Internet website (news, emergency management/government page)	8.3%	29.6%	37.7%	38.2%	13.3%	21.6%
Smartphone application	0.0%	11.1%	8.7%	14.6%	11.7%	8.1%
Someone told you (neighbor, friend, extended family)	37.5%	51.9%	26.8%	22.8%	36.2%	33.8%
Billboard or road message board	0.0%	0.0%	0.7%	2.4%	0.0%	0.0%
Other	12.5%	14.8%	15.2%	7.3%	10.1%	6.8%

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Sought Additional Information						
Answer	Mandatory	Voluntary	Mandatory	Voluntary	Mandatory	Voluntary
Yes	41.7%	66.7%	50.0%	62.6%	29.8%	62.2%
No	58.3%	29.6%	49.3%	35.0%	69.7%	37.8%
No answer	0.0%	3.7%	0.7%	2.4%	0.5%	0.0%
Clarity of Messaging						
Level	Mandatory	Voluntary	Mandatory	Voluntary	Mandatory	Voluntary
Extremely clear	79.2%	37.0%	58.7%	44.7%	70.7%	41.9%
Somewhat clear	12.5%	40.7%	26.8%	36.6%	16.0%	31.1%
Neither clear nor unclear	0.0%	7.4%	2.9%	4.9%	4.8%	9.5%
Somewhat unclear	8.3%	7.4%	9.4%	9.8%	4.3%	6.8%
Extremely unclear	0.0%	3.7%	1.4%	1.6%	4.3%	10.8%
No answer	0.0%	3.7%	0.7%	2.4%	0.0%	0.0%
Trust of Source(s)						
Level	Mandatory	Voluntary	Mandatory	Voluntary	Mandatory	Voluntary
Very high	87.5%	70.4%	77.5%	63.4%	83.5%	50.0%
Somewhat high	12.5%	22.2%	18.1%	26.0%	10.1%	28.4%
Neither high nor low	0.0%	3.7%	0.7%	6.5%	4.3%	16.2%
Somewhat low	0.0%	0.0%	2.2%	1.6%	1.1%	5.4%
Very low	0.0%	0.0%	0.7%	0.0%	0.5%	0.0%
No answer	0.0%	3.7%	0.7%	2.4%	0.5%	0.0%
Sample Size (returnees)	*n=34*		*n=162*		*n=246*	
Received Information to Return						
Official source	26.5%		33.3%		22.0%	
News source	35.3%		48.8%		64.6%	
Secondary source	35.3%		28.4%		31.3%	
Did not receive information	23.5%		19.8%		8.5%	

Departure Day

Departure day for wildfire evacuations is highly dependent on the characteristics of the wildfire. Unlike hurricanes that generally have a set landfall date, wildfires spread at different rates, making the choice of departure date more difficult to analyze. Indeed, it is difficult to classify evacuees as “late” or “early” evacuees in a wildfire context without knowing the precise impact of the fire on a residence. However, we still provide the statistics on departure day for all three wildfires in Table 13, since this information indicates days of peak congestion on roadways. We find that peak congestion for the 2017 Northern California Wildfires occurred on Sunday, October 8 and Monday, October 9, which falls in line with the timeline in our case study. Yet, some people also evacuated on October 10, as the wildfire still threatened areas and smoke became a major health issue. The evacuations for the 2017 Southern California Wildfires

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were more variable. While the Creek Fire moved rapidly leading to earlier evacuations, the Thomas Fire was more prolonged (after rapid spreading at the start), allowing officials time to issue evacuation orders more methodically. For the 2018 Carr Wildfire, a significant number of people (78.3%) left on Thursday, July 26 when the fire threatened the city of Redding. With such high evacuation rates on a single day, officials need to be prepared for spikes in congestion on roadways. Some wildfires move too quickly to plan transportation response. However, given that some wildfires do not threaten major population centers until later (such as for the Carr Wildfire), proactive evacuation messaging and transportation response may be necessary to reduce peak congestion.

Table 13: Departure Day of Survey Respondents

2017 Northern California Wildfires		2017 Southern California Wildfires		2018 Carr Wildfire	
Sunday, Oct. 8	21.6%	Monday, Dec. 4	32.6%	Monday, July 23	2.4%
Monday, Oct. 9	64.9%	Tuesday, Dec. 5	28.6%	Tuesday, July 24	2.0%
Tuesday, Oct. 10	8.1%	Wednesday, Dec. 6	5.1%	Wednesday, July 25	8.3%
Wednesday, Oct. 11	0.0%	Thursday, Dec. 7	4.0%	Thursday, July 26	78.3%
Thursday, Oct. 12	2.7%	Friday, Dec. 8	4.6%	Friday, July 27	5.9%
Friday, Oct. 13	0.0%	Saturday, Dec. 9	3.4%	Saturday, July 28	0.8%
Saturday, Oct. 14	2.7%	Sunday, Dec. 10	8.0%	Sunday, July 29	0.0%
After Saturday, Oct. 14	0.0%	After Sunday, Dec. 10	13.7%	After Sunday, July 29	2.4%

Departure Time of Day

Similar to departure day, departure time of day is highly dependent on the wildfire (Table 10). For example, some wildfires spark at night and are fueled by stronger nighttime winds. We find that departure time of day was concentrated in the early morning (12:00 a.m. to 5:59 a.m.) for the 2017 Northern California Wildfires, which is consistent with the fire timeline. Time of day was more spread out for the 2017 Southern California Wildfires. The highest concentration of evacuees for the 2018 Carr Wildfire was during the evening (6:00 p.m. to 11:59 p.m.). This is also a logical finding with the fire timeline, as the fire reached the Redding city limits in the afternoon of July 26. While these results are unsurprising, they do confirm that the evacuees from the survey followed behavioral patterns consistent with the wildfire events. In addition, the results indicate that agencies need to be prepared for evacuations at any hour of the day.

Transportation Mode

For transportation mode, we found that most respondents used a personal vehicle or two personal vehicles to evacuate (Table 10). A high number of individuals also used three or more personal vehicles to evacuate (ranging from 8.6% to 16.5%). These values may be due to larger households. Other evacuees may have wanted to protect their vehicles from the fire, packed their vehicles with additional possessions, or wanted additional flexibility in traveling while away from home. Despite these benefits for evacuees, low occupancy levels in evacuating vehicles pose a significant issue: roadways are not being utilized efficiently. The resulting congestion increases travel times for all evacuees, raising risk levels from the wildfire and decreasing the ease of evacuating. At the same time, these evacuating vehicles do have spare

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capacity. We found that between 54.1% and 68.5% of evacuating households had at least two or more spare seats available over all their evacuating vehicles (i.e., seats not taken by people, luggage, or pets). This spare capacity could be used to help evacuate carless individuals or others with mobility challenges.

Route

In the survey, respondents were asked what primary route they took from five options: highways, major roads, local roads, rural roads, and no majority type. A primary route is defined as the road type that a respondent took more than 50% of the time. Respondents generally favored routing on highways for their primary route (Table 10). However, respondents also decided to use major roads and a mixture of roads (no majority type) for the 2017 Northern California Wildfires and the 2018 Carr Wildfire. While this is partially influenced by only one major highway running through both wildfire impact areas, some evacuees may have been more comfortable driving on other roads or had better knowledge of non-highway routes. Between just 7.5% and 18.9% of respondents used GPS during the evacuation and followed the GPS route, even though 78.2% or more had GPS navigation available to them. Unlike hurricanes, where GPS is used substantially (Wong et al., 2018a), wildfires appear to require less GPS use. One possible explanation is that wildfire evacuations tend to be shorter and more localized. Since evacuees do not need to travel distances, they may have a greater knowledge of road and route options. Regardless, the rise of GPS navigation tools inside the vehicle and on smartphone applications (e.g., Google Maps, Apple Maps, Waze) could allow some evacuees to route around evacuation traffic. One potential side effect is that without proper knowledge of the hazard, these GPS tools could send evacuees toward the fire.

Sheltering

Most respondents stayed with friends or family for the wildfires as seen in Table 10. This result indicates a preference towards free housing with amenities and social connections. Some respondents also stayed at hotels (13.4% to 22.9%), while only a few (2.4% to 5.4%) stayed at public shelters. Even though public shelter use was relatively low, shelters are often used as a last resort for evacuees without family or friends in the area and for those who cannot pay for an extended hotel stay. Two interesting results were that between 4.0% and 8.1% used a portable vehicle such as an RV or camper, and between 0.4% and 2.7% used a peer-to-peer service such as Airbnb. The portable vehicle sheltering option indicates that evacuees may need safe locations with enough amenities to park their vehicles. Access to power and dumping stations would also be beneficial. Peer-to-peer services are a new phenomenon that could offer alternative sheltering (and transportation) resources for evacuees (Wong et al., 2018b). These options – whether through the free Airbnb Open Homes Program (which encourages hosts to provide their home for free to evacuees) or as a standard rental – could grow with increasing service coverage. Finally, from 41.7% to 48.4% of evacuees had to shelter in more than one location. This indicates that evacuees had additional transportation and housing challenges, which made the evacuation process more difficult. While it may be necessary to keep evacuees from returning home for safety reasons, agencies should consider building reentry plans to allow evacuees to return more quickly.

Destination

Unlike hurricanes, in which the size of the storm requires evacuees to travel long distances, wildfires often have localized impacts. As shown in Table 10, between 66.1% and 70.3% of evacuees stayed within their county of residence. These short-distance evacuations likely helped alleviate congestion, especially for those who had to travel further away to find shelter. As seen in Table 14, most respondents evacuated to

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a nearby county if they decided to leave the county of their residence. Some respondents traveled long distances to Sacramento County for the 2018 Carr Wildfire. This is most likely because Sacramento is the closest large metropolitan area to Redding. We also note that the 2017 Southern California Wildfires included several fires separated by over 50 miles, leading to the wide geographic distribution of counties. Consequently, we also provide the county of destination for the Thomas and Creek Fires in Table 15. While the sample size is small for the Creek Fire, all respondents remained in Los Angeles County. With short-distance evacuations across wildfires, impacted communities must be prepared for highly localized transportation and sheltering needs.

Table 14: Destination by County of Survey Respondents

2017 Northern California Wildfires		2017 Southern California Wildfires		2018 Carr Wildfire	
n=37		n=175		n=254	
Napa	35.1%	Ventura	37.1%	Shasta	66.5%
Sonoma	35.1%	Santa Barbara	25.7%	Tehama	5.9%
Marin	8.1%	Los Angeles	18.9%	Sacramento	4.7%
All counties under 3 respondents each	21.6%	San Luis Obispo	5.7%	Siskiyou	3.1%
		Monterey	2.9%	Butte	2.8%
		All counties under 5 respondents each	9.7%	All counties under 5 respondents each	16.9%

Table 15: Destination by County for Two 2017 Southern California Wildfires*

Destination County	Thomas Fire (Ventura and Santa Barbara Counties)	Creek Fire (Los Angeles County)
Sample Size (Evacuees)	n=152	n=21
Ventura	42.8%	0.0%
Santa Barbara	29.6%	0.0%
Los Angeles	7.2%	100.0%
San Luis Obispo	6.6%	0.0%
Monterey	3.3%	0.0%
All counties under 5 respondents each	10.5%	0.0%

* Two evacuees from the Skirball Fire are not included in this table

Reentry Date

Reentry date is highly dependent on the wildfire event. Long-lasting fires lead to both additional evacuations and later reentry dates. As seen in Figures 1 through 3, some respondents across all wildfires began returning to their residence quickly, most likely because the residence was no longer under threat. We find steady return rates for the 2017 Southern California Wildfires and the 2018 Carr Wildfire, with a maximum peak of 11.7% and 12.2% respectively on a single date. These results indicate that congestion related to reentry may not be a key concern for transportation response. We found that it took some respondents a considerable amount of time to return from the 2017 Southern California Wildfires as seen in Figure 2 with the jump for reentry after December 17. This may be a result of three factors: 1) the long-burning Thomas Fire; 2) additional evacuation orders for mudslides immediately following the Thomas Fire; and/or 3) a slow process for allowing residents to return home.

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Figure 1: Reentry Date for the 2017 Northern California Wildfires

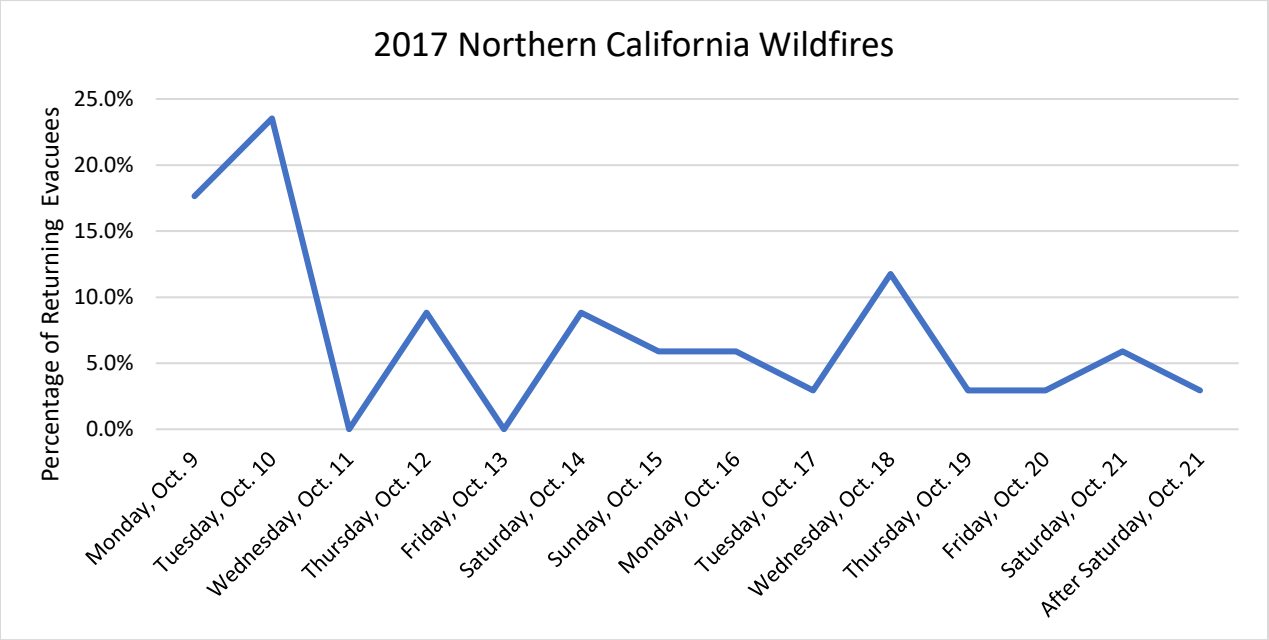

Figure 2: Reentry Date for the 2017 Southern California Wildfires

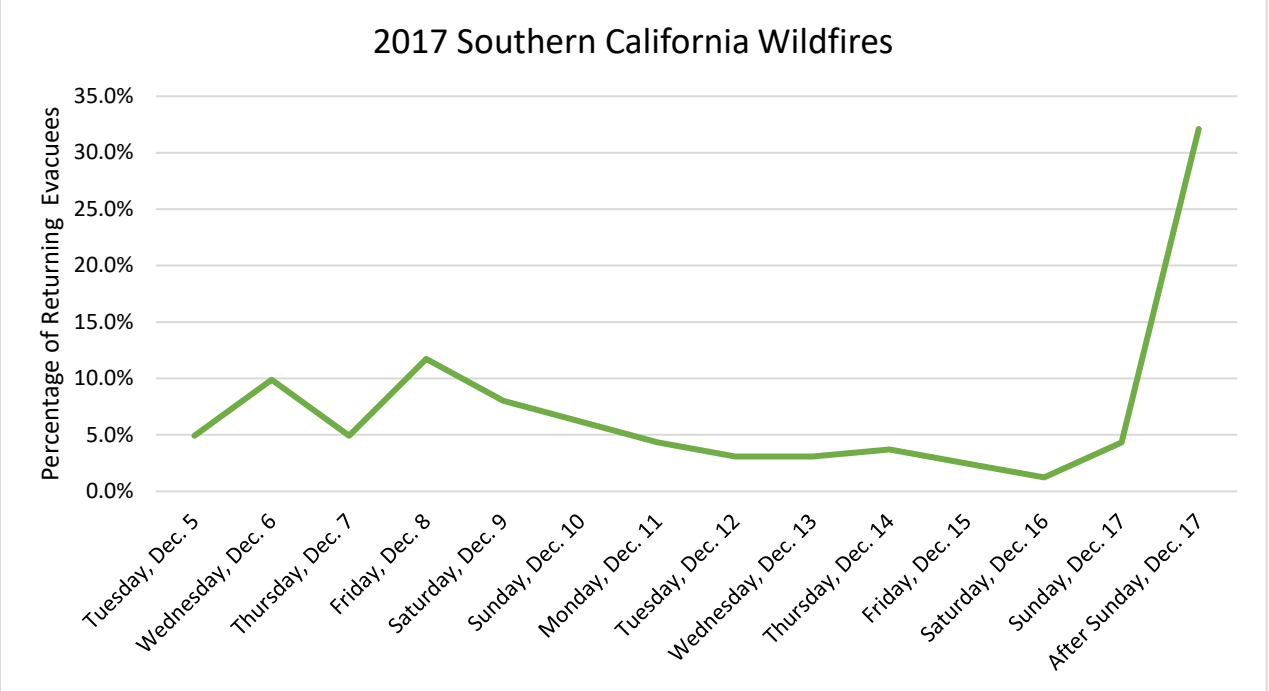

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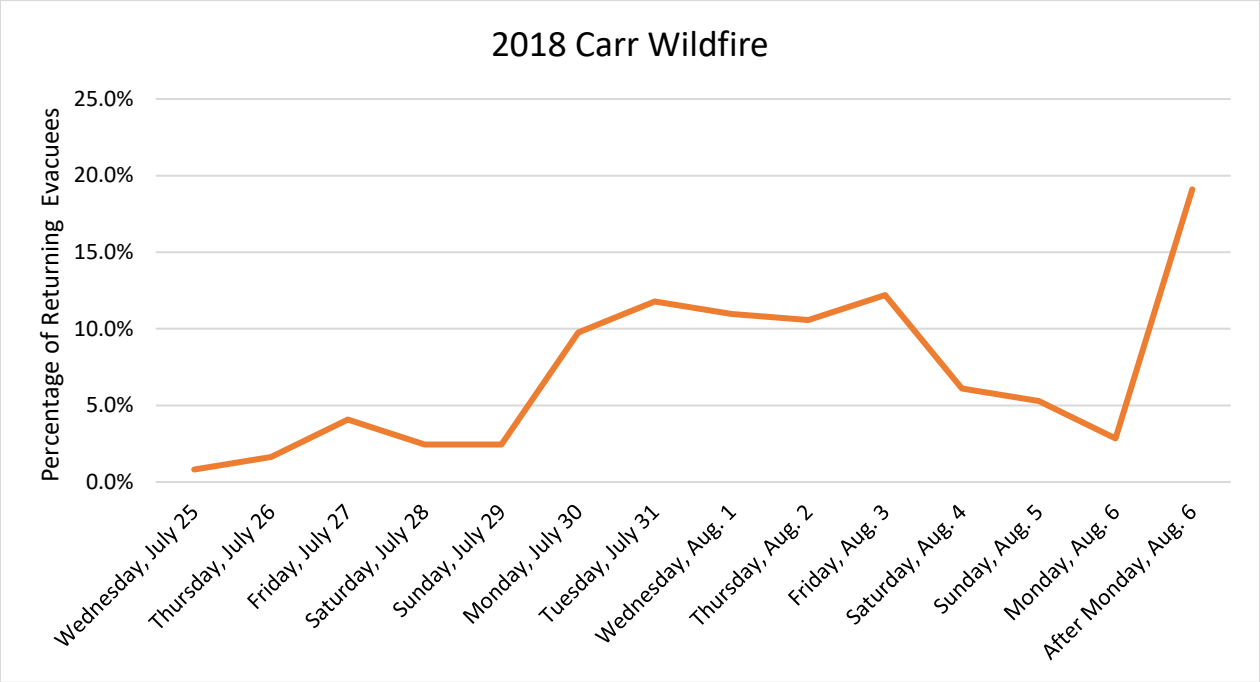
Figure 3: Reentry Date for the 2018 Carr Wildfire



Other Evacuation Characteristics

We also analyzed several other key evacuation characteristics that could assist practitioners in improving evacuation planning.

Length of Evacuation

Figure 4 displays the length of evacuation by each wildfire. The length of evacuation is the time between an evacuee leaving their residence and arriving at their final destination. We find that the majority of respondents took under two hours to evacuate. However, we also note that an evacuation taking even a few minutes longer could have dire consequences in fast-moving wildfires. Given evacuees have limited time to evacuate, improving traffic flow to decrease the length of evacuations is critical. At the same time, we also found some individuals spent 10 hours or more evacuating, which may result from long-distance evacuations and high levels of congestion.

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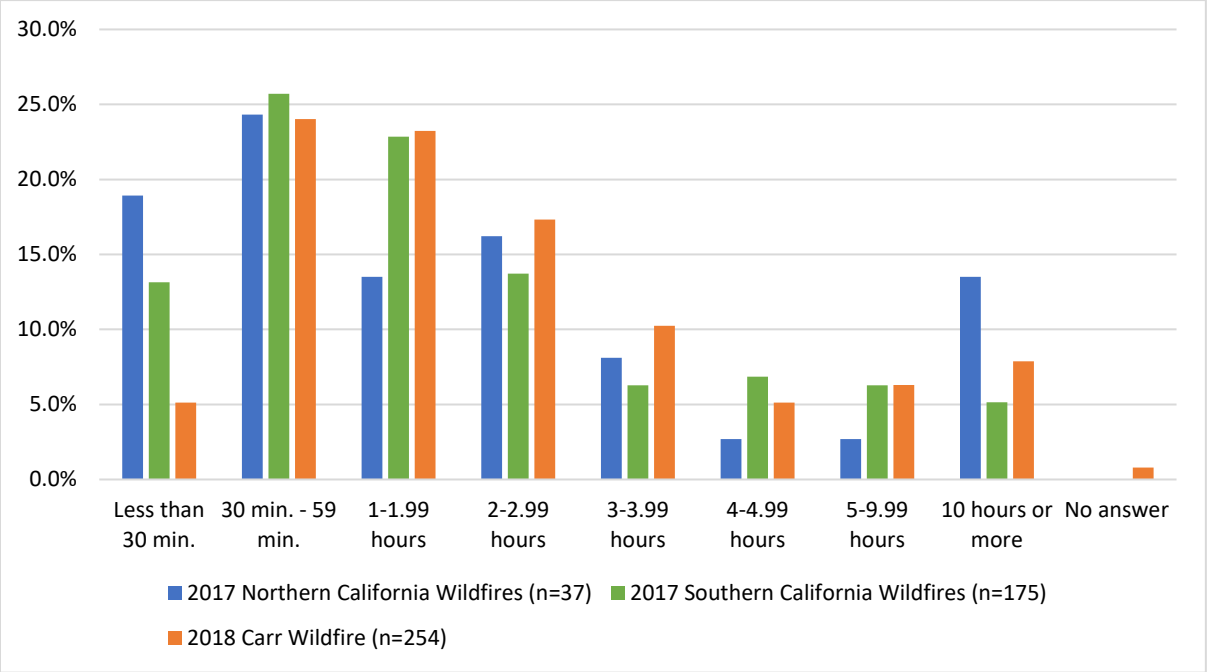
Figure 4: Length of Evacuation by Wildfire



Length of Stay and Workdays Missed

We find in Figures 5 and 6 that while many people stayed at their final destination between one and eight days, a high proportion of respondents reported that they did not miss any days of work. Still, we find that a considerable number of people had to miss multiple days of work, which can be detrimental for households. This is especially problematic for individuals who hold hourly positions and do not receive vacation or paid-time-off benefits. By missing even a few days of work, some households living paycheck to paycheck would be unable to pay bills. At the same time, long stays away from home can also be costly, especially if respondents stay at a hotel or motel. Other resources, such as food and water, may also cost substantially more when respondents are away. These are important considerations for agencies, especially during the recovery process. Moreover, concerns about work requirements or workdays missed often decrease the likelihood of evacuating. Indeed, 23.5% of non-evacuees from the 2017 Southern California Wildfires stated that work requirements were a reason they decided not to evacuate (Table 20).

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Figure 5: Length of Stay at Final Evacuation Destination

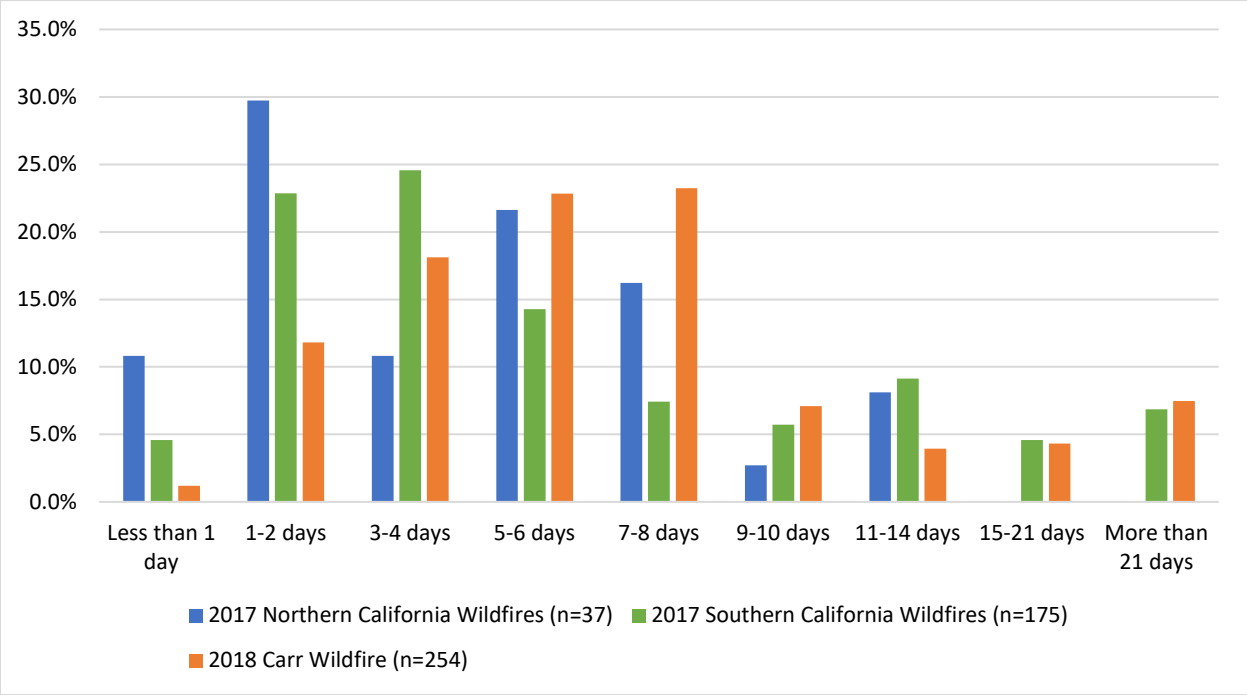
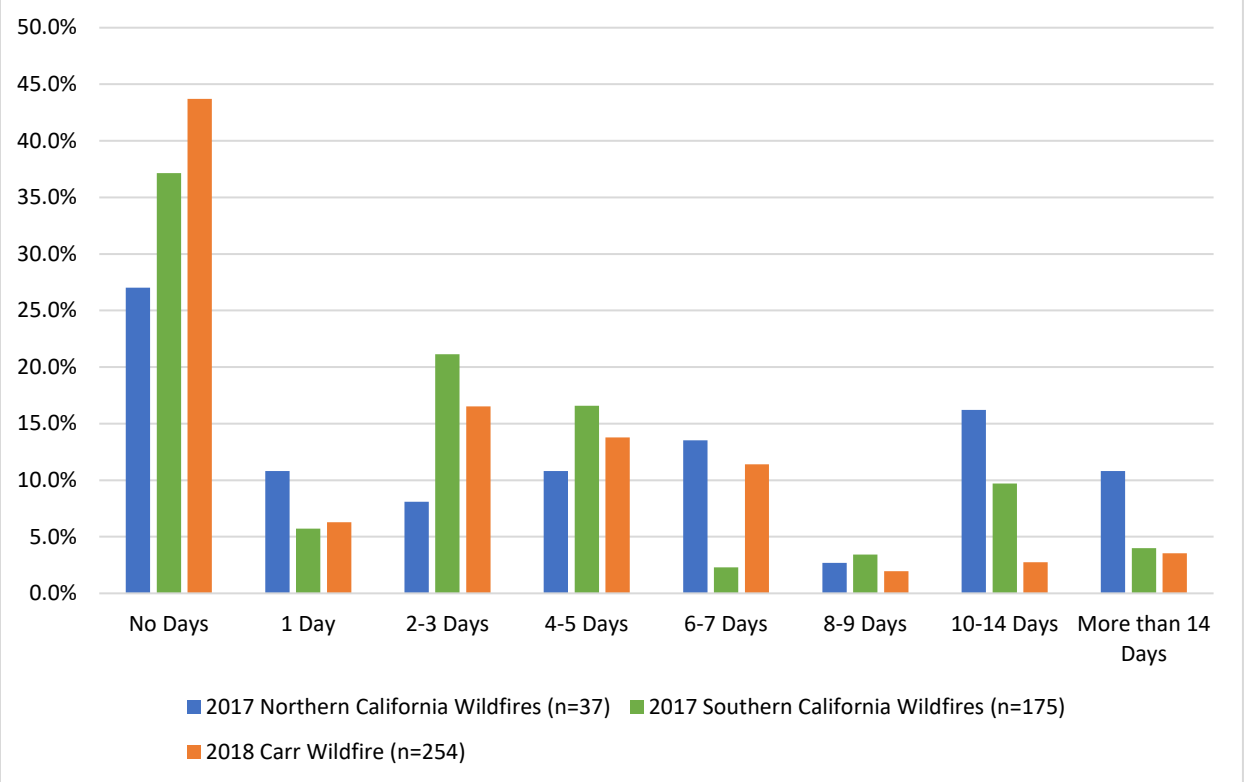


Figure 6: Number of Missed Workdays



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Number of Trips Before Evacuating

Before evacuating, some households make additional trips to collect household members or find supplies. This trip-making prior to evacuating is sometimes necessary and must be factored into the transportation response. Indeed, not all vehicles on the roadway may be evacuating. The majority of survey respondents took either no trips or one trip before evacuating as seen in Table 16. However, some respondents reported that they made multiple trips before evacuating, which could severely impact other vehicles attempting to evacuate. While we do not know the purposes of the additional trips, we note here that increasing trip chaining (making multiple stops along a single trip from the point of origin to the destination) could decrease the number of overall trips and decrease congestion.

Table 16: Number of Trips before Evacuation

Number of Trips before Evacuation	2017 Northern California Wildfires	2017 Southern California Wildfires	2018 Carr Wildfire
Sample Size	n=37	n=175	n=254
0	40.5%	20.0%	25.6%
1	24.3%	45.1%	48.0%
2	16.2%	15.4%	12.2%
3	5.4%	6.9%	7.9%
4	5.4%	4.0%	2.0%
5 or more	8.1%	8.6%	4.3%

Towing Items

Some evacuees tow additional items while they evacuate, including boats and trailers. In other cases, some evacuees drive a recreational vehicle and tow their personal vehicle. Since these towing arrangements take up additional space on roadways, they may impact calculations for traffic congestion and lead to less vehicle throughput during evacuations. In Table 17, we find that a high number of respondents for the 2018 Carr Wildfire (20.5%) towed a large item during the evacuation. Agencies should consider methods to decrease the number of towed items or encourage these vehicles to evacuate earlier, if possible.

Table 17: Towed Large Item During Evacuation

Towed Large Item During Evacuation	2017 Northern California Wildfires	2017 Southern California Wildfires	2018 Carr Wildfire
Sample Size	n=37	n=175	n=254
Yes	10.8%	6.3%	20.5%
No	89.2%	93.1%	79.5%
No answer	0.0%	0.6%	0.0%

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Worries and Likelihood Belief of Events

We asked respondents several questions related to their worries that events would occur on a Likert scale from extremely worried to not at all worried. These questions encouraged respondents to think back to the time before they decided to evacuate or not from the wildfires. We asked a similar set of questions regarding respondents' belief that an event would occur on a Likert scale from extremely likely to extremely unlikely. In Tables 18 and 19, we present only the percentage of respondents who were extremely worried or believed that an event would be extremely likely to occur.

We find that respondents were extremely worried about the severity of the wildfire and the speed of the wildfire. We also find that about a quarter of respondents across wildfires were extremely worried about traffic. A sizable number of respondents were also extremely worried about finding resources such as housing, gasoline, and food, indicating the perception of resource shortages. Other respondents were extremely worried about the cost of transportation and the cost of housing (to a stronger degree), which suggests that some respondents did not have the means to pay for an evacuation. For likelihood belief, many respondents believed that it would be extremely likely that their residence would lose utilities (i.e., power and water), burn down, and/or have structural damage. Looting concerns were especially high for the 2018 Carr Wildfire, while concerns over a lack of first responders were especially high for the 2017 Northern California Wildfires. A significant number of respondents also believed that they would be extremely likely to have work requirements, which might encourage citizens to stay at home or try to return early.

Table 18: Worry About Certain Events Before Evacuating (Extremely Worried)

	2017 Northern California Wildfires	2017 Southern California Wildfires	2018 Carr Wildfire
Sample Size	n=79	n=226	n=284
Severity of the Wildfires	55.7%	59.3%	51.1%
Speed of Wildfires	63.3%	66.4%	57.0%
Evacuation Process	30.4%	44.2%	25.0%
Traffic	21.5%	25.7%	26.4%
Finding Housing	10.1%	15.5%	11.6%
Finding Gasoline	11.4%	11.5%	9.5%
Finding Food	7.6%	9.7%	4.6%
Cost of Transportation	1.3%	7.1%	4.6%
Cost of Housing	8.9%	15.9%	7.0%

Table 19: Belief of the Probability About Certain Events Before Evacuating (Extremely Likely)

	2017 Northern California Wildfires	2017 Southern California Wildfires	2018 Carr Wildfire
Sample Size	n=79	n=226	n=284
Residence Burns Down	26.6%	31.0%	32.0%
Injury/Death	5.1%	10.2%	9.2%

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Utility Loss	41.8%	58.8%	57.0%
Structural Damage	29.1%	34.1%	35.2%
Belongings Damaged	30.4%	38.5%	36.6%
Belongings Stolen	10.1%	11.9%	23.9%
First Responders Not Available	29.1%	16.4%	16.5%
Require Rescuing	6.3%	10.2%	5.6%
Work Requirement	22.8%	18.1%	18.7%

Non-Evacuees

While the focus of this research is to understand the decisions of evacuees, we also asked non-evacuees about the reasons they did not evacuate. The primary reasons for not evacuating included not receiving any evacuation orders, not wanting to leave, and wanting to protect property (Table 20). Traffic congestion also played a role in non-evacuee decision-making. Some individuals decided not to evacuate because they did not want to sit in traffic (4.8% to 7.8%). Improving transportation response to decrease congestion can serve a dual role: 1) improving the evacuation for individuals already evacuating and 2) encouraging at-risk non-evacuees to also evacuate. We also note that some people may not have the ability or the resources to evacuate. We find this to be the case in our surveys, with between 3.3% and 5.9% of respondents indicating they did not have the money to evacuate. Other respondents did not have the opportunity to shelter with friends or family, while others did not have transportation to get to a safe location.

Table 20: Reasons to Not Evacuate for Non-Evacuees

Reasons to Not Evacuate *Multiple selection allowed*	**2017 Northern California Wildfires**	**2017 Southern California Wildfires**	**2018 Carr Wildfire**
Sample Size (non-evacuees)	n=42	n=51	n=30
Did not receive any orders	71.4%	47.1%	30.0%
Did not want to leave	31.0%	39.2%	26.7%
Wanted to protect property	16.7%	29.4%	36.7%
Some requirement to go to work during wildfire	9.5%	23.5%	0.0%
Was not sure where pets could be taken	7.1%	7.8%	10.0%
Believed the wildfires would not be bad	4.8%	21.6%	0.0%
Did not want to sit in traffic	4.8%	7.8%	6.7%
Did not have the money to evacuate	4.8%	5.9%	3.3%
Did not want to go to public shelter	2.4%	15.7%	0.0%
No transportation to get to shelter	2.4%	2.0%	0.0%
No friends or family to shelter with	0.0%	9.8%	3.3%
Tried to but ended up going back home due to traffic	0.0%	2.0%	3.3%
Tried to but was turned away at shelter	0.0%	0.0%	0.0%

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Government Response

Finally, we asked respondents their opinion of the effectiveness of government response in five main areas: communication, road management, evacuating carless populations, shelter management, and overall evacuation management. We did not specify the type of agency. Across wildfires in Figures 7 through 9, respondents did not find most government response to be extremely effective or very effective. The highest performing areas across the wildfires were shelter management and overall evacuation management. Respondents found the government response of evacuating carless populations to be fairly poor with 21.5% to 33.5% stating that the response was not effective at all. Communication also received poor marks, especially for the 2017 Northern California Wildfires and the 2018 Carr Wildfire. Road management tended to receive responses in the middle of the scale, indicating some success during the evacuation but also room for improvement. Takeaways and recommendations from these opinions and other descriptive statistic results will be highlighted in a later section.

Figure 7: Opinion of Government Effectiveness – 2017 Northern California Wildfires (n=79)

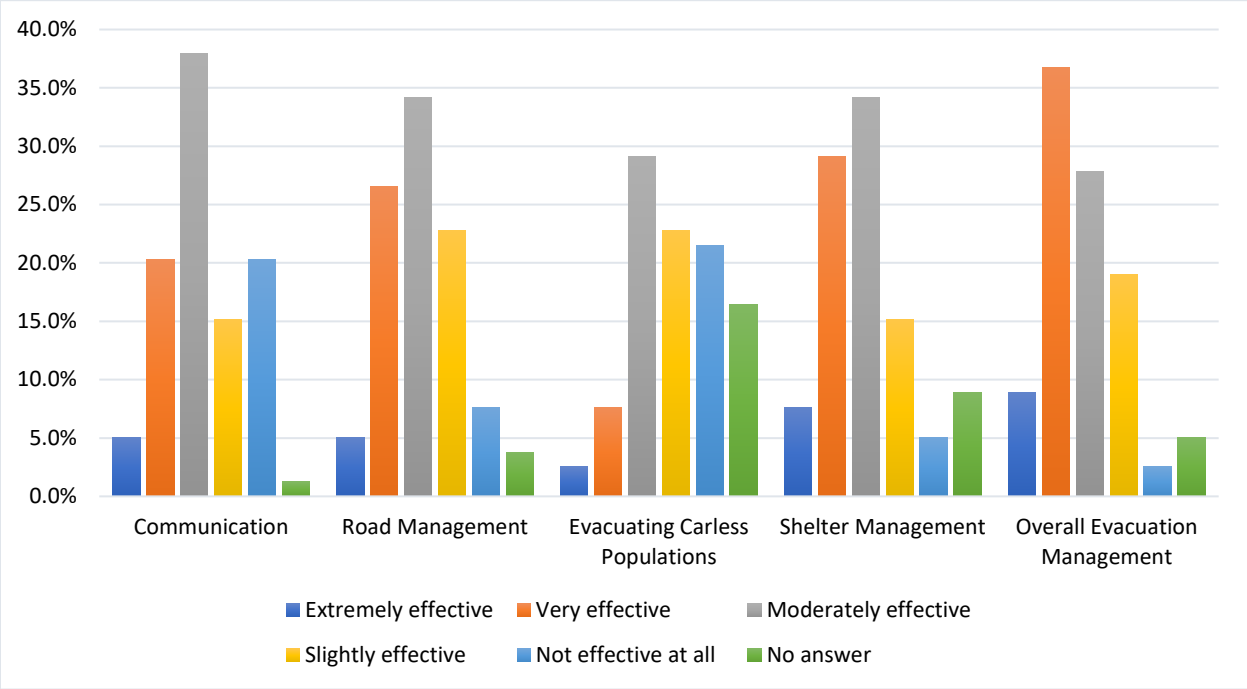

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Figure 8: Opinion of Government Effectiveness – 2017 Southern California Wildfires (n=226)

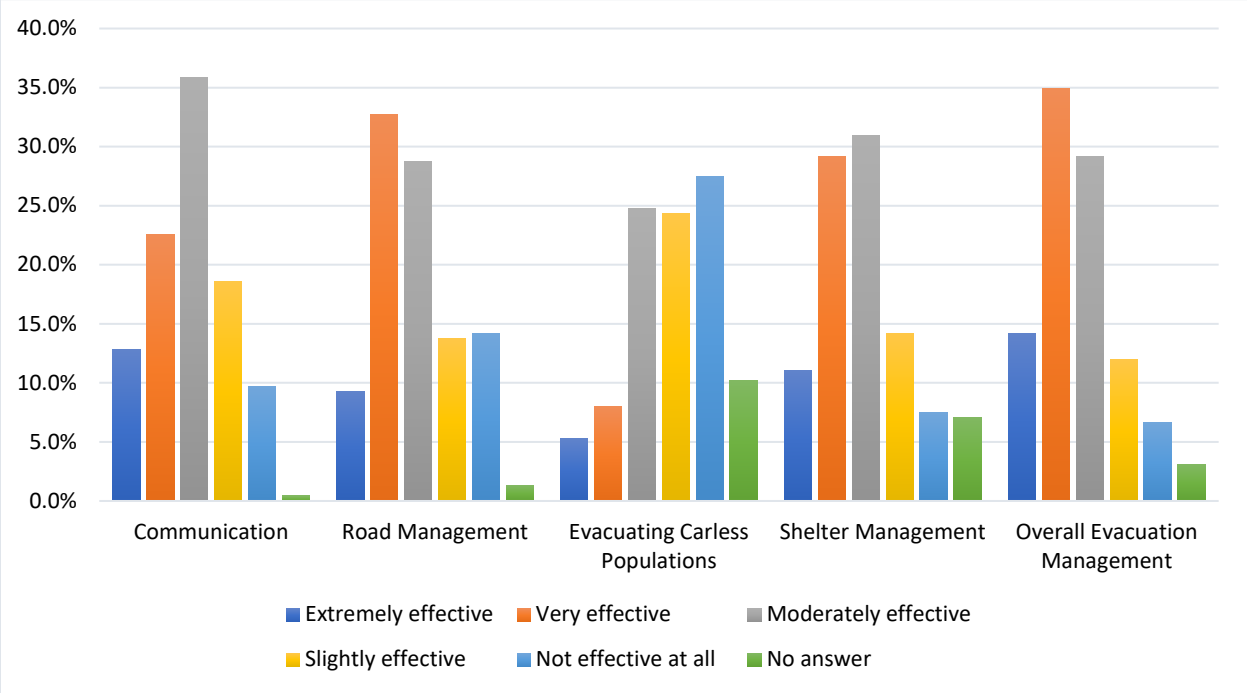
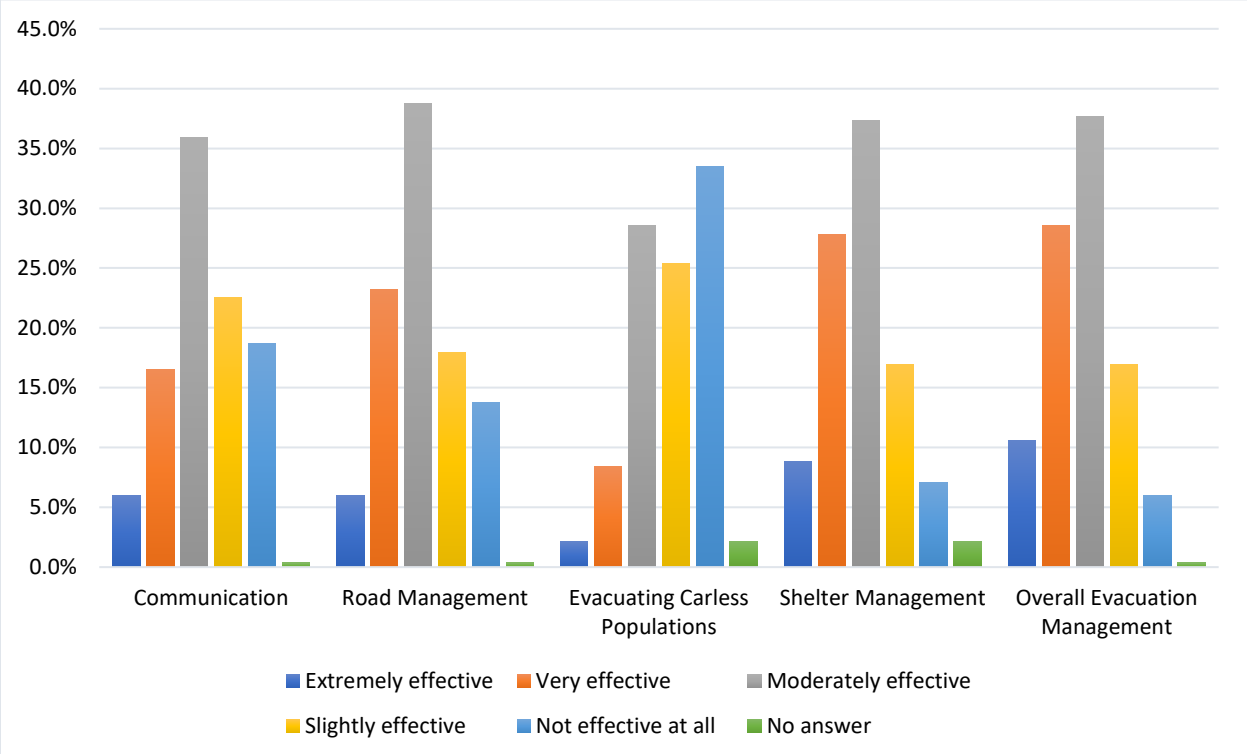


Figure 9: Opinion of Government Effectiveness – 2018 Carr Wildfire (n=284)



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Recommendations

To consolidate results and provide practice-ready strategies for practitioners, we present several recommendations for wildfire evacuations. Additional recommendations for wildfire logistics management and building a shared resource evacuation strategy can be found in Wong and Shaheen (2019a, 2019b) and Wong et al. (2020a). We use the following abbreviations in the recommendations section: SoCal (2017 December Southern California Wildfires) and Carr (2018 Carr Wildfire).

Evacuation Orders and Communication

1. Agencies should leverage mandatory evacuation orders, improve evacuation order communication, and rapidly distribute orders to increase compliance. Evacuation orders should contain additional information (e.g., available shelters, current road closures, safety tips, reminders to help others) to improve the evacuation.

    Evidence: Individuals impacted by both the Southern California and Carr Wildfires who received a mandatory evacuation order were more likely to evacuate.

2. Evacuation orders, especially when both voluntary and mandatory orders are issued, need to have clear geographical boundaries and departure times to reduce shadow evacuations. Orders also need to be distributed rapidly.

    Evidence: 62.5% (SoCal) and 75.0% (Carr) of respondents who stated they did not receive a mandatory evacuation order, still decided to evacuate (i.e., shadow evacuation).

3. All communication with the public should be quickly distributed and consistent across platforms. Agencies should maintain a high media presence and attempt to control rumors to improve communication flow. Agencies should also consider alternative low-tech communication methods including door-to-door notifications, radios, static sirens, and mobile sirens (via emergency vehicles or drones) to prepare for power outages.

    Evidence: 50.0% (SoCal) and 29.8% (Carr) of respondents who received a mandatory evacuation order sought additional information. Moreover, six (SoCal) and four (Carr) different platforms each reached at least 30% of respondents who received a mandatory order. From the case studies, communication systems that required power (i.e., cell towers, landlines) sometimes failed during the wildfires.

4. Voluntary orders should be used sparingly in disasters, and language should be geared towards preparation to reduce mobilization time. However, agencies should also consider access and functional needs populations when issuing voluntary orders, as some of these populations may require additional assistance or need to depart earlier due to their vulnerability.

    Evidence: Only 44.7% (SoCal) and 41.9% (Carr) of respondents who received a voluntary evacuation order found the message to be extremely clear. Moreover, very high trust levels of the messaging source were lower for voluntary evacuation orders than for mandatory orders for both the SoCal (-14.1%) and Carr (-33.5%) fires.

5. Agencies should consider alternatives to build an opt-out system (as opposed to a current opt-in system) for emergency alerts or develop a marketing campaign to encourage signups.

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Evidence: For multiple wildfire case studies, agencies were unable to reach a significant number of residents in the jurisdictions via emergency alert systems. While the WEA system overcomes opt-in challenges, agencies often hesitate to use it due to geographic control issues and messaging limitations.

6. To decrease defending behavior, agencies should develop information and education campaigns about the risks of defending and the impacts it has on firefighting ability. Agencies could consider workshops, public forums, and school-based programs to encourage safe behavior for wildfires.

   Evidence: 29.4% (SoCal) and 36.7% (Carr) of non-evacuees stated a reason for not evacuating was wanting to protect their property. Reports from several wildfire case studies indicated substantial defending behavior that hampered firefighters and first responders.

7. Agencies should notify the public beforehand via preparedness plans on the intended methods of communication. Agencies should also pre-develop content in other languages and have translators available during disaster response and recovery to assist non-English speakers.

   Evidence: In some wildfire cases, residents did not know about certain communication methods that could have been useful sources of information regarding the evacuation and wildfire. Moreover, content in other languages was communicated long after English content or not even created.

Departure Timing

8. Agencies should develop a phased evacuation plan that subdivides high-risk areas into zones for different timed releases to reduce congestion. This plan should be empirically driven and clearly communicated to the public well in advance. Agencies may also need to distribute preparedness information and encourage residents to pack vehicles beforehand to more effectively control departure times.

   Evidence: While most California wildfires occurred rapidly, several wildfires did not require mass evacuations until several days after ignition. 78.3% of Carr evacuees departed three days after ignition. In cases when wildfires spark further away from the WUI or spread less rapidly, agencies need transportation plans to reduce congestion on the roadways via a phased plan.

9. Agencies need to be prepared for evacuations that occur at any time of day, including more chaotic nighttime evacuations. Given the high variability of when wildfires occur, agencies need to be able to ramp up resources, staff, and communication very quickly at any time of day.

   Evidence: From the wildfire case studies and descriptive statistics, departure time of day was highly dependent on the wildfire and characteristics of the event.

10. Agencies should be prepared for high spikes in evacuations that could occur at any point during the wildfire. Some response strategies might include staffing intersections quickly, rapidly changing signal timing, removing stalled or parked vehicles, reversing all lanes to move away from the fire, and/or encouraging carpooling.

    Evidence: A significant number of evacuees left on a single day (78.3% for Carr), which led to significant congestion according to the case study. Agencies need a toolkit of rapid deployment

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options to handle this rapid increase in evacuees, particularly given the evolving nature of wildfires.

Transportation Mode and Route

11. Transportation response and evacuation models need to account for multi-vehicle households when designing capacity-increasing measures. Agencies should also consider leveraging potential spare capacity in extra vehicles to help carless households.

    Evidence: 40.6% (SoCal) and 45.3% (Carr) of evacuees used two vehicles for their evacuation. Moreover, 8.6% (SoCal) and 16.5% (Carr) of evacuees used three or more vehicles.

12. Agencies, including state agencies, should deploy congestion reduction measures closer to the impact area of the fire, in high-risk neighborhoods, and along major arterial roads. In cases where highways are close to the impact area, resources should also be deployed to increase highway capacity.

    Evidence: 37.7% (SoCal) and 61.8% (Carr) of evacuees did not use highways as their primary route while evacuating. 62.3% of SoCal evacuees used highways as a primary route, which reflects high usage of Highway 101 for the Thomas Fire.

13. Agencies should consider working with app-based navigation companies (e.g., Waze, Google Maps, Apple Maps) and in-vehicle navigation systems to restrict travel on dangerous and blocked roads.

    Evidence: Although only 18.3% (SoCal) and 7.5% (Carr) of evacuees used a GPS system and followed the GPS route during the wildfires, 78.2% or more of respondents had access to GPS navigation.

14. Transit agencies should be ready to deploy drivers and buses to assist evacuees, particularly those in denser areas and health care facilities. Transit also has an added benefit of reducing congestion on roadways due to high occupancy.

    Evidence: From the case studies, transit vehicles were highly effective in evacuating vulnerable populations.

Destination and Sheltering

15. Transportation, sheltering, and relief resources should be concentrated within the county of impact.

    Evidence: Approximately two-thirds of evacuees (SoCal and Carr) evacuated within county, indicating the preference to remain close to the disaster area and travel shorter distances. Adjacent counties were also popular among evacuees.

16. Agencies should increase accommodation capacity by working with the ARC, other NGOs, CBOs (e.g., churches), private companies (e.g., Airbnb), and private citizens.

    Evidence: Across most wildfire case studies, public shelters filled rapidly, and 15.7% of non-evacuees (SoCal) cited not wanting to go to a public shelter as a reason to forgo evacuating. Moreover, 9.8% (SoCal) and 3.3% (Carr) of non-evacuees did not evacuate because they could not shelter with friends or family.

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17. Agencies should ensure that public shelters have resources (e.g., ADA accessible facilities, medical supplies, trained staff) for access and functional needs populations and space for pets. Shelters should be pre-designated if pets are allowed.

    Evidence: Reports from some wildfire case studies indicated a lack of resources for access and functional needs populations and restrictions on pets. 7.8% (SoCal) and 10.0% (Carr) of non-evacuees did not know where they could take their pets.

18. Shelters should be placed outside of primary fire risk areas to avoid shelter evacuations, which cause additional congestion and safety issues.

    Evidence: Wildfire case studies revealed several instances in which established shelters were under threat of fire damage or had to be evacuated due to oncoming fire.

Reentry

19. Agencies should develop clear reentry plans that are communicated to the public prior to the wildfire. Different forms of communication (e.g., text messages, Internet, flyers) should be used to increase outreach.

    Evidence: Wildfire case studies found that while resources were available for recovery and reentry, agencies lacked formalized plans, which increased general confusion.

20. Reentry plans need a communication element to transmit procedures for returning to evacuees. Similar to evacuation orders, reentry information should be communicated consistently across multiple platforms.

    Evidence: 8.5% (Carr) and 19.8% (SoCal) of evacuees did not receive any information on how to return. Just 22.0% (Carr) and 33.3% (SoCal) of evacuees received information directly from an official source.

21. Agencies likely do not need special transportation response for reentry, but rather a continued recovery and relief effort. This effort may involve ensuring that public transit continues to operate, encouraging carpooling, and creating a clear reentry process.

    Evidence: Unlike evacuations, travel did not spike for reentry, with a maximum peak of 11.7% (SoCal) and 12.2% (Carr) returning on a single day.

Other Evacuation Characteristics

22. Agencies should work with employers to reduce work requirements for evacuees and increase flexible schedules (e.g., telecommuting) to increase evacuation rates.

    Evidence: 23.5% of SoCal non-evacuees stated that work requirements were a reason they decided not to evacuate. Moreover, 56.3% (Carr) and 62.9% (SoCal) of evacuees missed at least one day of work due to the wildfires.

23. Agencies should consider methods to decrease the number of towed items (i.e., restricting boats) in order to decrease congestion.

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Evidence: 6.3% (SoCal) and 20.5% (Carr) of evacuees towed an item during the evacuation. While some of these items could serve as housing (i.e., an RV), other items increase congestion without serving a transportation or sheltering purpose.

24. Residents should be reminded to chain trips together as much as possible prior to evacuating and create preparedness plans for their family that reduce overall travel.

Evidence: 74.4% (Carr) and 80.0% (SoCal) of evacuees took at least one trip prior to evacuating, suggesting trips to gather supplies and family members. While these trips are sometimes necessary, agencies should consider options that decrease pre-evacuation trip-making, which could impact the evacuation of other people and increase overall congestion.

Conclusion

In this report, we conducted a case study analysis of 11 major wildfires in California between 2017 and 2019 and presented results from three surveys of individuals impacted by California wildfires. The case studies found that approximately 1.1 million people were ordered to evacuate, 1.47 million acres were burned, and 30,000 structures were destroyed across the 11 major wildfires. The case studies revealed several strong similarities related to: human involvement in starting and spreading the fires; windy and dry conditions that exacerbated fire spread; varied and usually ineffective communication methods; considerable congestion due to personal vehicles; rapid filling of shelters; and a lack of formalized reentry plans. Despite these similarities, each wildfire context led to unique responses and events, which suggests that transportation responses need to be tailored to specific communities, densities, topologies, and wildfire characteristics.

Through the survey of individuals impacted by the 2017 October Northern California Wildfires, the 2017 December Southern California Wildfires, and the 2018 Carr Wildfire, we found a number of similarities. Non-compliance rates were relatively low, particularly compared to hurricanes (Wong et al., 2018a), and shadow evacuation rates were moderately to significantly high. About two-thirds of evacuees across the surveys stated they stayed within county for the evacuation. The distribution of transportation mode was also similar across wildfires, with strong use of personal vehicles and significant multi-vehicle evacuations. Accommodation type for sheltering was also consistent across wildfires, while GPS usage, pre-evacuation trip-making, length of evacuation, and missed workdays were fairly similar. For key differences, departure day, departure time of day, and reentry day were highly dependent on the wildfire characteristics, while route choice mirrored geography and road networks. Communication methods also varied between wildfires, indicating differing agency preferences. Opinion of government response across the wildfires was also varied. However, overall evacuation management received the highest effectiveness levels, and evacuation of carless populations received the lowest effectiveness levels. Differences between wildfire survey results indicate that community-specific transportation responses for evacuations will be necessary to plan and employ.

This report suggests that a considerable amount of work is still necessary to build evacuation plans and effectively respond during wildfires. While agencies have continued to improve over the last three years, the impact of ongoing climate change, increased development in high-risk areas, new policies (e.g., public safety power shutoff events), and evolving risks will only magnify the need for wildfire research and evacuation preparedness. Future work should begin to address wide gaps in knowledge, including wildfire evacuation behavior, wildfire impact on vulnerable populations, wildfires in rural communities, cascading threats involving wildfires, and wildfire recovery processes.

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Appendix

Table A1: Individual and Household Characteristics of Survey Respondents

	2017 Northern California Wildfires	2017 Southern California Wildfires	2018 Carr Wildfire
Sample Size (All Respondents)	*n=79*	*n=226*	*n=284*
Individual Characteristics			
Gender			
Male	22.8%	26.1%	30.3%
Female	77.2%	73.9%	69.7%
Age			
18-24	2.5%	2.7%	2.8%
25-34	15.2%	17.7%	12.7%
35-44	12.7%	15.0%	19.0%
45-54	21.5%	19.0%	22.9%
55-64	26.6%	26.5%	19.7%
65+	21.5%	19.0%	22.9%
Race			
Asian	2.5%	2.7%	1.1%
Black or African-American	0.0%	0.4%	0.0%
Mixed	6.3%	7.5%	3.5%
Native American/Alaska Native	1.3%	0.4%	1.4%
Pacific Islander	1.3%	0.9%	0.0%
White	83.5%	81.4%	90.8%
Other	1.3%	4.0%	0.0%
Prefer not to answer	3.8%	2.7%	3.2%
Ethnicity			
Hispanic	5.1%	11.1%	5.3%
Not Hispanic	82.3%	76.1%	87.3%
Prefer not to answer/No answer	12.7%	12.8%	7.4%
Education			
No high school degree	0.0%	0.0%	0.7%
High school graduate	5.1%	0.9%	4.9%
Some college	12.7%	15.9%	23.2%
2-year degree	7.6%	5.8%	12.0%
4-year degree	32.9%	41.2%	27.8%
Graduate or professional degree	29.1%	28.3%	27.5%
Doctorate	10.1%	8.0%	3.9%
Prefer not to answer	2.5%	0.0%	0.0%
Employment			
Employed full time	49.4%	57.1%	47.9%

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Employed part time	13.9%	11.9%	10.9%
Unemployed looking for work	5.1%	2.2%	2.8%
Unemployed not looking for work	5.1%	2.7%	4.2%
Retired	21.5%	22.1%	26.1%
Student	0.0%	2.2%	1.8%
Disabled	2.5%	1.3%	2.8%
Prefer not to answer	2.5%	0.4%	3.5%
Primary Mode of Transportation			
Drive alone using a car, SUV, pickup, or van	81.0%	87.6%	92.6%
Carpool/vanpool	0.0%	2.2%	1.4%
Rail (e.g., light/heavy, subway/metro, trolley)	0.0%	0.9%	0.0%
Bus	1.3%	1.8%	0.0%
Motorcycle/scooter	0.0%	0.9%	0.4%
Bicycle	1.3%	0.9%	0.7%
Walk	3.8%	0.4%	0.0%
Shuttle service	0.0%	0.0%	0.4%
Work from home	7.6%	1.8%	1.4%
Other	5.1%	0.9%	2.8%
Prefer not to answer/No answer	0.0%	2.7%	0.4%
Decision Making Role			
Sole decision maker	24.1%	25.2%	18.3%
Primary decision maker with input from another household member	12.7%	19.9%	19.4%
Share equally in making decisions with another household member(s)	58.2%	51.3%	57.4%
Provide input into decisions, but not the primary decision maker	5.1%	2.2%	3.2%
Another person is the sole decision maker	0.0%	0.4%	1.4%
Prefer not to answer	0.0%	0.9%	0.4%
Previous Evacuee			
Yes	20.3%	35.3%	31.0%
No	79.7%	64.7%	69.0%
Previous Wildfire Experience			
Yes	77.2%	93.4%	89.1%
No	22.8%	6.6%	10.9%
Mobile Phone Access and Type			
Do not own a mobile phone	1.3%	2.7%	3.2%
Own a typical mobile phone (non-smartphone)	7.6%	5.3%	3.9%
Own a smartphone	91.1%	92.0%	93.0%
Access to Internet at Home			
Yes	100.0%	98.7%	97.2%
No	0.0%	1.3%	2.8%

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In-Vehicle or Smartphone Navigation			
Yes	87.3%	79.6%	78.2%
No	12.7%	20.4%	21.8%
Household Characteristics			
Displacement after Wildfire			
Same Residence	93.7%	88.9%	87.0%
Displaced	6.3%	10.6%	13.0%
No answer	0.0%	0.4%	0.0%
Length of Residence			
Less than 6 months	5.8%	5.8%	3.2%
6 to 11 months	4.9%	4.9%	5.3%
1 to 2 years	12.4%	12.4%	13.7%
3 to 4 years	14.6%	14.6%	9.5%
5 to 6 years	7.1%	7.1%	7.7%
7 to 8 years	5.3%	5.3%	5.3%
9 to 10 years	4.9%	4.9%	6.0%
More than 10 years	45.1%	45.1%	49.3%
Residence Structure			
Site build (single home)	79.7%	73.9%	91.2%
Site build (apartment)	12.7%	19.5%	4.2%
Mobile/manufactured home	6.3%	6.2%	4.6%
Prefer not to answer	1.3%	0.4%	0.0%
Homeownership			
Yes	78.5%	67.3%	81.3%
No	21.5%	29.6%	17.3%
Prefer not to answer	0.0%	3.1%	1.4%
Live in Cal Fire High Risk Area			
Yes	10.1%	38.1%	37.7%
No	48.1%	28.8%	35.2%
Do not know	41.8%	33.2%	27.1%
Household Characteristics			
Household with Person with a Disability	19.0%	14.2%	18.7%
Household with Children	27.8%	25.2%	35.2%
Household with Older Adults	29.1%	28.3%	31.3%
Households with Pets	75.9%	63.7%	81.7%
Household Income			
Less than $10,000	1.3%	0.4%	0.7%
$10,000 - $14,999	1.3%	1.3%	3.9%
$15,000 - $24,999	1.3%	2.2%	2.8%
$25,000 - $34,999	0.0%	2.2%	5.6%

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$35,000 - $49,999	8.9%	6.2%	9.5%
$50,000 - $74,999	19.0%	14.6%	17.6%
$75,000 - $99,999	7.6%	11.5%	14.8%
$100,000 - $149,999	21.5%	21.2%	19.7%
$150,000 - $199,999	8.9%	13.3%	5.6%
$200,000 or more	19.0%	14.2%	8.1%
Prefer not to answer	11.4%	12.8%	11.6%

Table A2: County of Residence of Survey Respondents

2017 Northern California Wildfires		2017 Southern California Wildfires		2018 Carr Wildfire	
n=79		*n=226*		*n=284*	
Sonoma	64.6%	Ventura	43.8%	Shasta	94.0%
Napa	24.1%	Santa Barbara	41.6%	Other California	2.5%
Solano	11.4%	Los Angeles	13.3%	Non-California	3.5%
		Other California	1.3%		

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