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RESEARCH

Does Wildfire Open a Policy Window? Local Government and Community Adaptation After Fire in the United States

Miranda H. Mockrin[1] · Hillary K. Fishler[2] · Susan I. Stewart[3]

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Abstract

Becoming a fire adapted community that can coexist with wildfire is envisioned as a continuous, iterative process of adaptation, but it is unclear how communities may pursue adaptation. Experience with wildfire and other natural hazards suggests that disasters may open a "window of opportunity" leading to local government policy changes. We examined how destructive wildfire affected progress toward becoming fire adapted in eight locations in the United States. We found that community-level adaptation following destructive fires is most common where destructive wildfire is novel and there is already government capacity and investment in wildfire regulation and land use planning. External funding, staff capacity, and the presence of issue champions combined to bring about change after wildfire. Locations with long histories of destructive wildfire, extensive previous investment in formal wildfire regulation and mitigation, or little government and community capacity to manage wildfire saw fewer changes. Across diverse settings, communities consistently used the most common tools and actions for wildfire mitigation and planning. Nearly all sites reported changes in wildfire suppression, emergency response, and hazard planning documents. Expansion in voluntary education and outreach programs to increase defensible space was also common, occurring in half of our sites, but land use planning and regulations remained largely unchanged. Adaptation at the community and local governmental level therefore may not axiomatically follow from each wildfire incident, nor easily incorporate formal approaches to minimizing land use and development in hazardous environments, but in many sites wildfire was a focusing event that inspired reflection and adaptation.

Keywords Hazard · Fire adapted communities · Wildland–urban interface · Disaster · Recovery

Introduction

Wildfire management in the United States has become increasingly challenging and costly over the past two decades, as residential development in fire-prone vegetation has expanded, causing more ignitions and creating more infrastructure to protect during fire (Balch et al. 2017; Hammer et al. 2009). From 1999 to 2016, an average of 1449 residences were destroyed annually by wildland fire, despite billions spent on suppressing wildland fires (National Interagency Fire Center 2016). In the future, fire management is expected to become more difficult, as a result of a changing climate, the cumulative impacts of fire suppression, and ongoing wildland–urban interface (WUI) expansion (Flannigan et al. 2013; Moritz et al. 2014).

In response to the challenges of wildfire management, the National Cohesive Wildland Fire Management Strategy advocates the creation of fire adapted communities (FACs) that can coexist with wildfire through education, fuel treatments, planning and management of the built environment, and appropriate suppression and emergency response (Fire Adapted Communities Coalition 2014). In such communities, local governments, residents, and partners will collaborate on wildfire risk reduction actions, readjusting their efforts over time as resources, threats, and opportunities change (Fire Adapted Communities Coalition

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✉ Miranda H. Mockrin
mhmockrin@fs.fed.us

[1] USDA Forest Service, Northern Research Station, 5523 Research Park Drive Suite 350, Baltimore, MD 21228, USA

[2] Oregon State University, School of Public Policy, 300 Bexell Hall, 2251 SW Campus Way, Corvallis, OR 97331, USA

[3] Department of Forest and Wildlife Ecology, University of Wisconsin, 1630 Linden Dr, Madison, WI 53706, USA

2014). These multiple actors will pursue a range of actions to reduce wildfire risk, reflecting both the broad threat from wildfire, and the diffuse nature of wildfire and community management (FAC Learning Network 2016; Fire Adapted Communities Coalition 2014). For example, public land managers can thin vegetation or use prescribed burns to reduce the likelihood of wildfire spread onto private lands (Stephens et al. 2012; Winter et al. 2002). Homeowners can select fire-resistant materials for their homes and mitigate vegetation around their residences (i.e., create defensible space) to lower the risk of loss to wildfire (Cohen 2000; Mell et al. 2010). Local government also plays an important role through a variety of mechanisms. Residential mitigation (home materials or vegetation) can be encouraged via education and outreach programs or required by a variety of mechanisms, such as building codes, overlay zoning, and other ordinances or regulations (McCaffrey et al. 2011; Winter et al. 2009). Governments can also invest in appropriate fire suppression capabilities, create land use regulations to guide or restrict residential development to minimize wildfire risk, and incorporate wildfire risk into community planning (FAC Learning Network 2016; Fire Adapted Communities Coalition 2014). Much of the responsibility for adapting to fire falls on local governments and communities, because unlike other natural hazards (e.g., floods), there are no federal mandates to minimize or manage wildfire exposure (Burby 2001; Thomas and Leichenko 2011). Federal funding is provided to the states to distribute to local governments for suppression and prevention efforts, including community planning and preparation for wildfire (Steelman et al. 2004), but localities are ultimately responsible for their own fire-adaptedness.

However, given the range of potential actions and tools for wildfire risk reduction and the diversity of communities in the WUI (Paveglio et al. 2015a), it is unclear how communities will transition toward the FAC goal of living with fire on the landscape (Brenkert-Smith et al. 2017). One possibility is that destructive fires will trigger adaptive changes. The broader hazards literature demonstrates that hazard events can trigger periods of learning and adaptation, opening a "window of opportunity" for changes in policy and practice (Birkland 2006; Kingdon 1984; Solecki and Michaels 1994). There is some evidence of adaptive change after wildfire as well: for example, regulations about home mitigation (materials and vegetation) are often adopted after wildfires (Duerksen et al. 2011). However, wildfires, like other hazards, do not always lead to widespread change that reduces future exposure, and responses may even exacerbate future risk. Local governments may not revise land use planning to minimize hazard exposure; instead, recovery programs may stimulate rebuilding and new development in hazard prone areas (Mockrin et al. 2016; Pais and Elliott 2008; Platt et al. 2002). Residents may decline to take adaptive action, if they become fatalistic or inured to hazards (McGee et al. 2009; Mockrin et al. 2015) or if they are able to easily cope with wildfire impacts (Paveglio et al. 2016). Much of the past research on wildfire experience has focused on individual residents, rather than community-level and governmental response, despite the importance of these local responses and policies in the FAC framework (Fire Adapted Communities Coalition 2014; Labossière and McGee 2017). As currently envisioned, a FAC initiates changes iteratively in response to destructive fires and risks, using a broad range of tools and actions to diminish wildfire exposure (FAC Learning Network 2016; Fire Adapted Communities Coalition 2014). However, it is unclear how communities may respond to wildfires over time, and when in the process of adaptation communities will be open to formal or informal tools to reduce wildfire risk (Abrams et al. 2015; Paveglio et al. 2016).

In an effort to clarify these dynamics, we undertook a study of local government and community-level wildfire response following destructive fire in eight different sites across the United States (Table 1). We first assessed post-wildfire changes, including both formal and informal efforts to respond to wildfire at the community level, following Birkmann et al.'s (2010) framework, where formal responses are those undertaken by governmental organizations and informal responses are changes and actions where non-state actors are dominant participants and drivers of change (individuals, civic organizations, the private sector). We then examined the changes observed in light of two separate factors: a community's previous experience with destructive wildfire and past investment in wildfire-related regulations and planning. Based on previous research on policy windows, we expected that communities would be more likely to pursue change when destructive wildfire was a novel event (Birkland 2009). Formal regulation and planning is typically less common than informal efforts to diminish wildfire risk (Muller and Schulte 2011; Stidham et al. 2014) but it is unclear how these strategies have emerged over time, and might change with wildfire experience. We use our findings to reexamine the FAC concept, particularly the emphasis on iterative adaptation and use of a wide range of tools and actions.

This research expands upon previous wildfire social science that focused on post-fire community change in one or two locations (Abrams et al. 2015; Carroll et al. 2005; Paveglio and Edgeley 2017; Paveglio et al. 2016) or studied a narrow range of changes post fire across multiple locations (e.g., change in built environment and regulations (Mockrin et al. 2016) or acceptance of forest restoration by residents (Olsen and Shindler 2010)). This work also contributes to the broader policy scholarship on change after disaster by considering informal actions as well as formal

Table 1 Physical, social, and economic characteristics of sites and focal wildfires ($n = 8$)

Site	Jurisdictions	Fire year	Prev. fire experience[a]	Formal wildfire regs. and planning[a]	Fire ignition source	Landscape type[b]	Economy base[c]	Political orient.[d]	Urban typology[e]	Median income, 2010	% in poverty, 2010	Other hazards
Caughlin NV	Washoe County; Reno	2011	No	High	Electrical fire	High mountain plains	Services	Dem	Small metro, <1 million residents	$67,177	12%	Drought, Earthquake
Hwy 31 / WG SC	Horry County; North Myrtle Beach	2009	No	Med	Residential debris burning	Flat plains	Services	Rep	Small metro, <1 million residents	$51,691	15%	Hurricane, Flooding
Loco-Healdton OK	Stephens and Carter Counties	2009	Yes	Low	High winds, arcing power lines	Irregular plains	Mining	Rep	Non-metro (micropolitan, 1adjacent to small metro, 1 not)	$49,558	15%	Tornadoes, Flooding, Fracking Induced Earthquake, Drought
Monastery WA	Klickitat County	2011	No	Med	Tractor-trailer	Open low mountains	Manufacturing	Rep	Non-metro: Adjacent to small metro with town	$46,340	20%	Earthquake, Landslides
Monument AZ	Cochise County	2011	No	Med	Human ignition-disputed	High mountain plains	Federal/State Govt	Rep	Non-metro: Micropolitan adjacent to small metro	$52,513	16%	Drought, Flooding
Possum Kingdom TX	Palo Pinto County	2011	No	Low	Disputed	Hilly plains	Non-specialized	Rep	Non-metro: Micropolitan adjacent to large metro	$48,584	14%	Drought
Station CA	Los Angeles County	2009	Yes	High	Arson	High mountains	Services	Dem	Large metro, >1+ million residents	$60,879	15%	Earthquake Drought, Flooding, Mud and Debris Flows
Wallow AZ	Apache County[f]	2011	Yes	High	Unattended campfire	Considerable relief table	Federal/State Govt	Dem	Non-metro: Adjacent to small metro with town	$35,059	37%	Drought, Flooding

[a]Determined through interviews

[b]McGranahan, DA (1999) 'Natural amenities drive rural population change. Agricultural Economic Report No. 781.' US Department of Agriculture, Economic Research Service: Washington DC

[c]Economic Research Service, 2004 County Typology Codes. http://www.ers.usda.gov/data-products/county-typology-codes.aspx

[d]From 2012 presidential election

[e]Economic Research Service, 2003 Urban Typology Codes. http://www.ers.usda.gov/data-products/urban-influence-codes.aspx

[f]This was a large fire, but buildings were lost primarily in Apache County

policy responses, and by focusing on wildfire as a natural hazard, a policy arena and natural hazard which is less commonly included in the adaptation and policy literatures (Labossière and McGee 2017; Michaels et al. 2006). By examining change at the community and local governmental level, we highlight the role of local practitioners (Michaels et al. 2006), who are in many ways the key players in the pathways toward becoming fire adapted.

Literature Review

While the concept of FAC relies on homeowners and communities taking action in response to wildfire risks, the existing literature on disasters and policy change demonstrates that it is challenging to enact meaningful policy solutions to diminish exposure to natural hazards (Gerber 2007; Prater and Lindell 2000). Much of the public policy literature focuses on agenda setting, revealing the challenges of recognizing that a problem exists, and the difficulties in identifying appropriate solutions (Sabatier and Jenkins-Smith 1999). Focusing events, those sudden, uncommon events that lead to harm or expose the prospect for harm, may offer a unique opportunity to change the status quo (Birkland 1997; Kingdon 1984). Change that follows disaster may take many forms, including changes in policy, improved understanding of the social and natural forces that lead to disaster, or political learning, where actors learn how to best advocate for their interests (May 1992). Ideally, such event-based learning will result in meaningful policy change that mitigates the problem (Birkland 2009); in this case, reducing future exposure to wildfire risk. However, the policy change literature also shows that not all potential focusing events lead to reduced exposure to future hazards. For example, smaller incidents that do not overwhelm existing organizations and policies may be considered "routine" and may fail to lead to change. Additionally, groups may fail to identify appropriate policy tools after an event, or changes may be ineffective (e.g., inappropriate for the true nature of the hazard, but politically expedient) (Birkland 2009). In addition, policy windows are open for only a brief period, so that it may be difficult to identify and implement effective solutions before the opportunity for innovation has passed (Solecki and Michaels 1994). Research into policy response to natural disasters has focused primarily on U.S. federal policy, with limited studies of policy change at the subnational scale (Michaels et al. 2006), yet natural disasters and environmental issues, including wildfire mitigation, are often managed primarily at the local level. In addition, without broader mandates to minimize or manage wildfire exposure, informal efforts to encourage wildfire risk reduction and mitigation are often more common than similar formal efforts or policies (Muller and Schulte 2011; Stidham et al. 2014).

Much of the social science literature on wildfire risk and mitigation focuses on residents' risk perception and mitigation practices (McCaffrey et al. 2013). After wildfires, there is some evidence that residents re-examine risks and make changes to reduce future vulnerability. For example, residents may improve access for emergency vehicles, supply water for fire response, invest in fire-resistant materials, mitigate vegetation around homes, or relocate or decide not to rebuild after a home is lost (Brenkert-Smith et al. 2012; Champ and Brenkert-Smith 2015; Flint 2007; Mockrin et al. 2015; Mockrin et al. 2016). Some residents, however, do not increase mitigation effort after wildfire, in some cases concluding wildfire risk is reduced after fire removes vegetation, or experiencing denial about the likelihood of additional fires and/or fatalism about the efficacy of mitigation actions (Collins and Bolin 2009; McGee et al. 2009; Mockrin et al. 2015).

The role of community-level or policy changes post fire is less well known (Labossière and McGee 2017) although local governments and community-level actions play a vital role in mitigating wildfire risk, through a variety of tools and actions. Formal governmental action is perhaps most commonly conceived of as regulatory and planning efforts. Government regulations relevant for wildfire may include standards for egress and water supply, building codes, defensible space requirements, or zoning ordinances (Brzuszek et al. 2010; Buxton et al. 2011; Muller and Schulte 2011; Syphard et al. 2013b). Planning efforts at the jurisdictional level, including Community Wildfire Protection Plans (CWPPs) and multi-hazard mitigation plans or assessments, also offer an opportunity to prepare for wildfire incidents as a community (NFPA 2013). CWPPs were created under the Healthy Forest Restoration Act of 2003 as a way for communities to consider strategies and priorities for reducing wildfire risk on the landscape and around homes, and to improve local capacity to prepare for and respond to wildfires (Abrams et al. 2016). Completing a CWPP facilitates a community's access to state and federal mitigation funding under the National Fire Plan. The Federal Emergency Management Agency requires jurisdictions (typically counties or cities) to adopt all-hazard mitigation plans (HMPs) in order to be eligible for mitigation grants (Lyles et al. 2014).

In addition to planning and regulating the built environment, local communities and governments also manage suppression resources, control vegetation management on locally owned open space, and use education and outreach efforts to promote mitigation around homesites. These actions involve differing amounts of formal and informal involvement: because responsibilities for wildfire mitigation

are diffuse and tools to reduce risk are varied, government efforts often combine with actions by non-state actors including homeowners associations (HOAs), fire departments, and civic associations (Muller and Schulte 2011). For example, residents may decide to pursue Firewise certification, a voluntary program which allows residents to communally identify and implement measures to reduce wildfire risk at the neighborhood level (McGee 2011), through an HOA or civic organization, and/or with the support of local government or fire department employees. Vegetation management on public land is the responsibility of land management agencies, but often requires public input (e.g., if NEPA analysis is required before thinning on federal lands). Similarly, fire suppression/emergency response, planning, and regulations are managed by local governments, with public oversight and involvement.

Despite the variety of potential tools and actions available to communities, past research shows communities and local governments commonly pursue only a subset of these options in response to wildfire risk, typically education and voluntary efforts to promote mitigation around homes, increasing suppression and emergency response capacity, and conducting vegetation treatments on open space (Muller and Schulte 2011; Stidham et al. 2014). Similarly, CWPPs often emphasize forest conditions and landscape-level fuel modification, with less emphasis on changing resident behavior, construction materials, or land use planning (Abrams et al. 2016). Despite a long-standing interest in wildfire-related regulation and land-use planning to reduce hazard exposure (Plevel 1997; Syphard et al. 2013a), such efforts remain unpopular, particularly in rural areas (Muller and Schulte 2011; Winter and Fried 2000). Where they do exist, fire-related land-use regulations often focus on safety (e.g., egress and water access, restricting open burning during periods of high fire danger), as opposed to restricting development or requiring mitigation around the home (defensible space or use of fire-resistant building materials) (Harris et al. 2011; Muller and Schulte 2011; Winter and Fried 2000).

Research to date has rarely considered these tools and actions as part of a community level response to wildfire. It is unclear if wildfire is a reliable spur to community-level change and what form these changes may take. For example, the limited research on community-level action after wildfires typically finds that communities still focus on actions that are voluntary, informal, or tend to be broadly acceptable in the community, such as creating Firewise communities, improving emergency response, revising CWPPs, or developing novel outreach and education programs (Abrams et al. 2015; Jakes and Sturtevant 2013; Labossière and McGee 2017; McGee 2011; Paveglio and Edgeley 2017). We know little about how formal policy such as zoning, regulations, or ordinances relate to destructive wildfire events—although one study found they are typically implemented after direct experience with wildfire (Duerksen et al. 2011), it is unclear how often these regulations will be motivated by wildfire. Most puzzling is when wildfire destruction does not appear to result in action. For example, a survey of western counties found that proximity to sizeable fires had a weak relationship with county-level planning and mitigation efforts (with the exception of the state of California) (Muller and Schulte 2011), and only one of three Colorado jurisdictions chose to enhance regulations focused on homes (materials and defensible space) after destructive wildfire from 2010–2012 (Mockrin et al. 2016).

In summary, we focused on the time period after destructive wildfire as a unique opportunity when communities and local governments may adapt to wildfire hazards. Given the diversity of communities, settings, and potential wildfire management actions we considered a range of government and community-level actions and tools for wildfire preparation and mitigation (Muller and Schulte 2011), before and after wildfire. We grouped responses into six categories: Fire suppression/emergency response; Vegetation management on public lands or open space; Education/outreach (including programs to promote vegetation management on private lands); Firewise participation; Regulations; and Planning. Combined with an assessment of past experience with wildfire and investment in formal regulations and planning, we offer novel insights into post-fire community and government change in wildfire mitigation and risk reduction, over a range of settings.

Sites

We selected eight sites with a range of socioeconomic, environmental, and governance characteristics (Fig. 1, Table 1). We choose locations across the U.S., including two sites in the Southern Great Plains and one in the Southeastern U.S., to expand beyond the commonly studied Western U.S. (McCaffrey et al. 2013). We selected fires that occurred in 2009 and 2011 where at least 20 homes were destroyed by fire, relying on official fire reports (ICS-209) (National Wildfire Coordinating Group 2016) and an analysis of aerial imagery to identify buildings lost (Kramer et al. in review). We choose these years to allow time for any community-level changes to develop before interviews (no fires in 2010 met the damage criteria). In one case (Monastery Fire, WA), the number of homes reported lost was later determined to be less than 20, but respondents were still able to characterize the fire event and response, so we retained the site in our study. Below, we briefly describe each wildfire incident and community, in alphabetical order, and then refer to sites by a combination of the fire name and

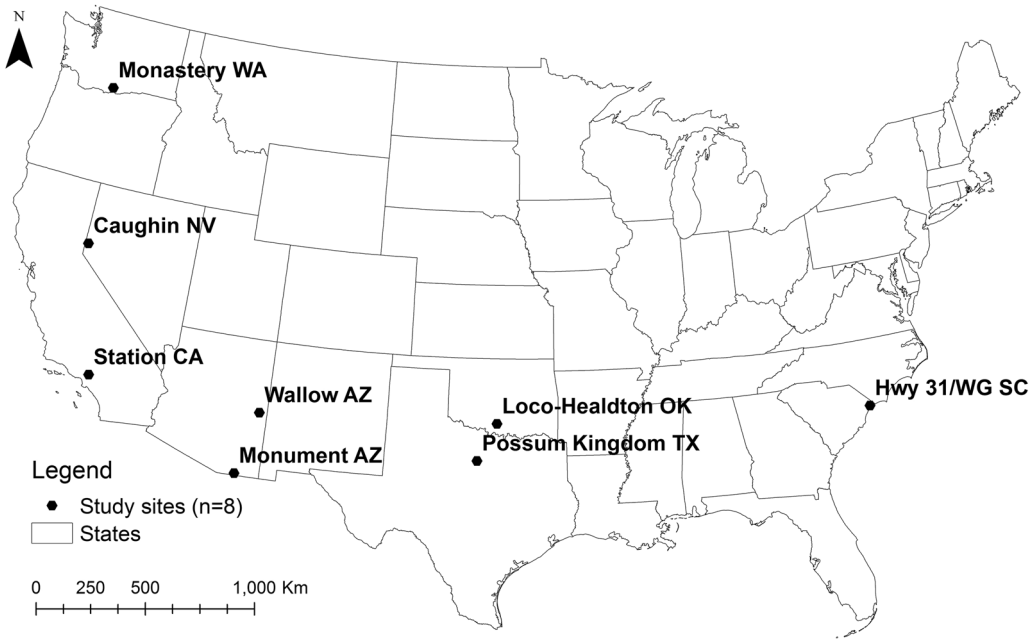

Fig. 1 Map of study sites across the United States (names are fire name and state abbreviation)

the state abbreviation. The wildfire suppression resources we mention are those departments that are present in the area and engaged in wildfire mitigation and management; actual fire responses to these incidents involved a mix of local and outside resources, including state and federal suppression resources, depending on the incident.

Caughlin Ranch, Nevada (NV)

The Caughlin Ranch fire began as an electric ignition on privately owned land in Washoe County, and burned into the city of Reno, destroying 42 homes in November 2011. Washoe County and Reno are growing in population, fueled by access to outdoor amenities and arrival of retirees. Recent development is primarily in subdivisions and planned unit developments (PUDs) around Reno's borders. This fire affected upper to middle income, single family, primary homes on the southwestern outskirts of Reno where residential development abuts county-owned canyons that are not developable because of the terrain. The county has active wildland firefighting teams, while the city fire department concentrates on structure protection. Although there was a long history of WUI fires in the state and Lake Tahoe area, this fire was notable for spreading into Reno, and for occurring in November.

Hwy 31/WG, South Carolina (SC)

The Highway 31 (Hwy 31) fire began with residential debris burning in Horry County and moved into the city of North Myrtle Beach, destroying 76 homes in April 2009. This fire affected middle income, single family homes in a large PUD with golf courses. Respondents discussed this fire along with the 2013 Windsor Green (WG) fire that destroyed over 100 homes in six condo buildings in Horry County, so we included both fire incidents and jurisdictions in our study. Both fires affected primarily full-time residents. Unincorporated Horry County has grown rapidly in recent decades, with development of large subdivisions and PUDs, driven by access to the beach and popularity with retirees. North Myrtle Beach is mostly developed but can grow via annexation. The county has an active wildland firefighting team, while the city fire department concentrates on structure protection. This area has a long history of wildfires, but previous fires affected open space or timber plantations, before housing development expanded into wildlands. These fires were seen as notable given the number of homes lost, and the speed with which they progressed.

Loco-Healdton, Oklahoma (OK)

The Loco-Healdton fire occurred in April 2009, as a result of malfunctioning power lines, and burned structures in ranch and agricultural lands in Stephens County, and some area in Carter County. Approximately 20 homes were lost, all owned by full-time residents, including modest manufactured homes and trailers, as well as custom homes. The economy in these counties is dominated by energy production and ranching, and land is primarily privately owned and unincorporated. Housing growth or expansion is not a

concern in this area. This part of Oklahoma has a long history of volatile, wind-driven grass fires, and 2009 was a year with substantial wildfire activity across the state, including multiple fires on the day that the Loco-Healdton fire began. Rural volunteer fire departments are responsible for much of the area, with help from Oklahoma Forestry Services wildland fire suppression team when needed. Despite the prevalence of wildland fire, most rural fire departments are trained primarily in structural firefighting.

Monastery, Washington (WA)

The Monastery fire started as result of a tractor-trailer malfunction in unincorporated Klickitat County, destroying 12 homes and numerous outbuildings in September 2011. Most homes in this area are modest primary residences or second homes with a few upscale second or retirement homes mixed in, on 5–20 acre parcels. Homes lost in the fire included five permanent residences, all trailers, and seven secondary homes. Modest parcel subdivision and housing growth have occurred in recent decades, with migrants drawn by natural amenities, but the area's economy remains limited. Most land in this area is privately owned, and is a mixture of grassland and forest. The county is served by multiple volunteer fire districts. Substandard housing and roads make wildland and structural firefighting challenging. Wildfire is a common occurrence in this area, but past fires had been contained or had occurred in ranch lands.

Monument, Arizona (AZ)

The Monument fire occurred in June 2011 (unknown origin), and burned extensively on the Coronado National Monument before spreading to the Coronado National Forest and privately owned land in Cochise County, burning 62 homes, all primary residences. Homes in the fire area and nearby are a mix of custom built and modular homes on 1–4 acre parcels. Housing in the canyons outside the National Forest has expanded over the past several decades. Fort Huachuca in Sierra Vista drives much of the area's economy and attracts military retirees. The fire area is served by professional fire departments, and federal firefighters are also active in the area. This fire was bigger and more destructive than previous wildfires, which had been contained on federal land.

Possum Kingdom, Texas (TX)

The Possum Kingdom Complex fire (unknown origin) burned 254 homes and outbuildings in the Possum Kingdom Lake resort community in Palo Pinto County, Texas in April 2009. While the county is rural, the man-made lake's 300-mile shoreline is ringed with second homes owned by residents of Dallas-Fort Worth. Homes range from older, modest homes on unpaved roads to upscale, large homes constructed on multiple parcels, in recently developed, gated and paved subdivisions. The Brazos River Authority, a state agency, originally leased lakefront land for development and managed its vegetation. Growth in this area has increased greatly since the development of a local water supply in the early 1990s, and in 2010 residents were able to purchase parcels, so that the area transitioned from state to private ownership. Fire protection is provided by the local volunteer fire department. This complex of fires was considered unusual in the number of homes burned and size of the incident.

Station, California (CA)

The Station fire started in the Angeles National Forest as the result of arson and burned into unincorporated Los Angeles County in August 2009, destroying 89 homes. Approximately two-thirds of the homes lost were along the southern border of the forest, with 32 lost in a forest inholding (Stonyvale/Vogel Flats). Homes were older, modest houses clustered on small parcels, divided between privately-owned homes and Forest Service-owned recreation cabins. Wildfire management is provided by the Angeles National Forest, and structure protection by Los Angeles County Fire Department, which is also active in wildfire mitigation and outreach. The county and this area along the southern border of the Angeles National Forest have had extensive WUI fires in the past, but the Station fire was notable for its size (at over 160,000 acres it was the largest fire in LA County in decades), and attracted controversy about the Forest Service suppression response.

Wallow, Arizona (AZ)

The Wallow Fire started in May 2011 as an unattended campfire on the Apache-Sitgreaves National Forest and grew to over 500,000 acres (the largest fire in Arizona history), destroying 32 homes, primarily in the unincorporated community of Greer in Apache County. Communities in the southern portion of Apache County are small towns with modest, full-time residences in the lower elevation areas. Summer, vacation, and retiree-owned homes on individual parcels are in heavily wooded slopes above the towns. Housing growth has been modest but steady in this area, with residents drawn by the climate and large federal landholdings (more than 85% of Apache County is in public ownership). Each community has their own fire district, staffed by volunteers, in addition to federal wildfire management resources. This was the largest and most destructive wildfire to occur in this area but many in

the community had hosted evacuees from the 2002 Rodeo-Chediski fire, which burned 30 miles to the west.

Methods

We used a mixed-methods case study design and collected background information from media sources, reviewed government documents, and then interviewed local officials and community leaders. For both interviews and document review, we chose jurisdictions where most homes were lost (typically counties, although in two cases where fires spanned city and county boundaries, we surveyed both locations) (Table 1). For each jurisdiction, we used interviews to examine the novelty of destructive wildfire, including questions about wildfire history, damages, and resident risk perception and mitigation actions, as the novelty of destructive wildfire can also be reflected in resident risk perception and mitigation actions, before and after fire. We used document reviews to assess formal (governmental) investment in wildfire-related regulations and planning prior to focal wildfire events. We compiled a list of wildfire-related regulations and planning actions recommended in guides for communities (Fire Adapted Communities Coalition 2014; NFPA 2013). Two members of the research team (either authors or a master's level research assistant) reviewed community planning and regulatory documents and independently noted the presence or absence of each item before the wildfire event, and the lead author then rectified any disagreement between observers (Supplemental Table). During interviews we confirmed the document review results by asking if each regulation/plan existed and how it related to wildfire risk and management. Interviews with government employees and community leaders allowed us to gather information about informal changes, all potential changes made or considered after wildfire, and broader community perception of these potential changes. The scope of our project precluded numerous interviews with residents but our interviews with informants were sufficient to provide multiple, overlapping views of communities, wildfire management, and response to fire events. Our 80 interviewees included county and city government staff (planners, emergency managers), fire chiefs, state and federal government employees (foresters, natural resource managers, fire managers), university extension agents, real estate agents, and other community leaders who were actively involved with wildfire recovery and mitigation (e.g., head of a civic association, point person for a neighborhood).

Interviews took place between December 2014 and November 2015 (on average 5 years after fires), with 6–12 informants per site, and 3–7 days spent per site. We identified central informants, typically fire department or government staff, through fire documents, web searches, or newspaper articles about the fire. These key informants then suggested others we should speak with. Interviews were typically 1–2 h, conducted individually or in small groups (maximum of four) when more than one person from the same organization was interested in participating (e.g., multiple members of a planning department). We used the same set of open-ended, semi-structured questions for all interviews, expanding upon questions developed by Mockrin et al. (2015). For our first fieldwork visit, all three authors conducted interviews together, revising interview questions as needed. Subsequent visits were conducted by one or two investigators. Interviews were conducted in person if possible, with several interviews held over the phone. After professional transcription, we used open coding to organize concepts into initial categories, followed by focused coding to organize material into themes (Corbin et al. 2015), working in QSR Nvivo 11 software (QSR 2014). Authors worked together to generate initial themes, and Mockrin then conducted coding for the analysis presented here, to examine community- and government-level changes post fire as well as wildfire history, mitigation practices, and changing risk perception over time.

Results

Before Fire: Wildfire History, Formal Management, and Resident Mitigation Practices

Just over half of our sites ($n = 5$, Hwy 31/WG SC, Possum Kingdom TX, Caughlin Ranch NV, Monument AZ, Monastery WA) had not previously experienced a wildfire that burned homes. Either residential development had expanded to put new homes at risk, or the wildfire was larger or more extreme than previous fires. Risk perceptions varied; informants reported that some residents were aware of wildfire risk and others either unaware or unconcerned about it.

In contrast, informants in three sites described a long history of destructive WUI fires (Wallow AZ, Loco-Healdton OK, and Station CA) (Table 1). Informants here thought residents were aware of the danger wildfire posed to homes and the community, although in Wallow AZ some thought seasonal home owners were less aware of wildfire risk.

Communities had undertaken a range of formal wildfire regulations and planning efforts prior to focal wildfire events. Of the 31 actions we considered, jurisdictions had completed on average 55% (range 13–90%) (Supplemental Table). All locations had regulations related to open burning, and many had HMPs that addressed wildfire (80% of sites had HMPs or similar; all plans included wildfire)

(Supplemental Table). Based on total scores, we classified jurisdictions into low ($n = 2$), medium (3), or high (3) levels of pre-fire formal wildfire management and planning (Table 1). Sites in the Great Plains (Loco-Healdton OK and Possum Kingdom TX) had the lowest use of formal wildfire regulations and planning (for example, neither jurisdiction had a building code) (Supplemental Table). In contrast, Station CA and Wallow AZ had relatively high levels of formal regulation and planning before focal fires. The three locations with past experience with destructive wildfire therefore had either the lowest (Loco Healdton OK) or highest investment in formal wildfire management and planning (Wallow AZ and Station CA). Locations where destructive WUI fire was a novel occurrence had low (Possum Kingdom TX) to moderate (all other sites) investment in formal wildfire management and planning before fires (Table 1).

None of our sites, regardless of past wildfire experience or relevant regulations, were described as places where mitigation around homes (structural materials or vegetation) was pervasive before fire. In the Hwy 31/WG SC and Possum Kingdom TX sites, participants characterized mitigation as limited, and there were no regulations requiring mitigation. In the rest of the sites, participants described home site mitigation (materials and vegetation) as variable.

> "[Housing] was a mixed bag. Some of the newer houses have class-A rated tile or concrete roofs or composition roofs but we also had some pretty large houses that were constructed in the '70s with wood siding and shake roofs. They're a nightmare"—Caughlin Ranch NV.

> "Some people, that I would say, given the amount of risk and the close proximity to forest vegetation, I would say it was shockingly little how little [vegetation mitigation] they'd actually done"—Wallow AZ.

Only the Station CA site had formal requirements for home mitigation before the wildfire, with baseline standards required by the state, and expanded upon by the County because of their long history of wildfires. All new construction in mapped fire hazard areas must have defensible space and use fire-resistant materials. Los Angeles County can compel homeowners to maintain defensible space, by using County staff to mitigate vegetation on private property, then recouping costs via property taxes (County of Los Angeles 2016). However, county officials indicated they seldom pursued this path because it was seen as confrontational and could pose financial hardships for homeowners. Similar to other sites, mitigation in the area was mixed, with varying housing age, materials, and defensible space maintenance. Prior to the Caughlin Ranch NV fire, there were WUI regulations in place for only select areas in Washoe County and the City of Reno, outside the fire area.

After Fire: Community-Level Response and Adaptation

If wildfire is a novel event, it seems reasonable that local experts and government would also report changed perception of wildfire risks. Indeed, in the majority of locations, all five where destructive fire was novel (Hwy 31/WG SC, Possum Kingdom TX, Caughlin Ranch NV, Monument AZ, Monastery WA), and one (Wallow AZ) where it was not, informants thought wildfire events had led to greater understanding of wildfire risks and danger, although not all residents were uniformly concerned about wildfire.

> "I think the fires that we've had, Caughlin Ranch certainly one of those, has raised the awareness that the fire threat is real. We live in an area where fire is a natural occurrence. I think people are gaining in their understanding of that"—Caughlin Ranch NV.

> "I think people are aware of fire now. People still mention it. We just had…10 little fire starts along the highway in the last couple of days. Of course, it's all front page news and people say, yeah, you got to remember the Monument Fire"—Monument AZ.

After focal wildfires, informants thought risk and awareness of wildfire in Station CA and Loco-Healdton OK, two places with long history of WUI wildfires, remained high.

At the community level, we then noted the proportion of study sites reporting any change in each category of wildfire management and mitigation (Fig. 2). Changes in emergency response and/or suppression capabilities were most common (all sites), followed by revision of planning documents (seven out of eight sites). Changes in fire education and outreach, as well as establishment of Firewise neighborhoods, were less common but occurred in half our sites, while changes in regulations and public land vegetation management were least common (Fig. 2). Understanding these changes requires considering previous actions taken, their magnitude or efficacy, and the current status of programs and management interventions. We therefore discuss individual categories in more detail below, in light of the novelty of destructive wildfire and past investment in formal wildfire regulation and planning.

Suppression/emergency response capabilities

For this category, we discuss only the changes each location reported after the wildfire, but we recognize that each study

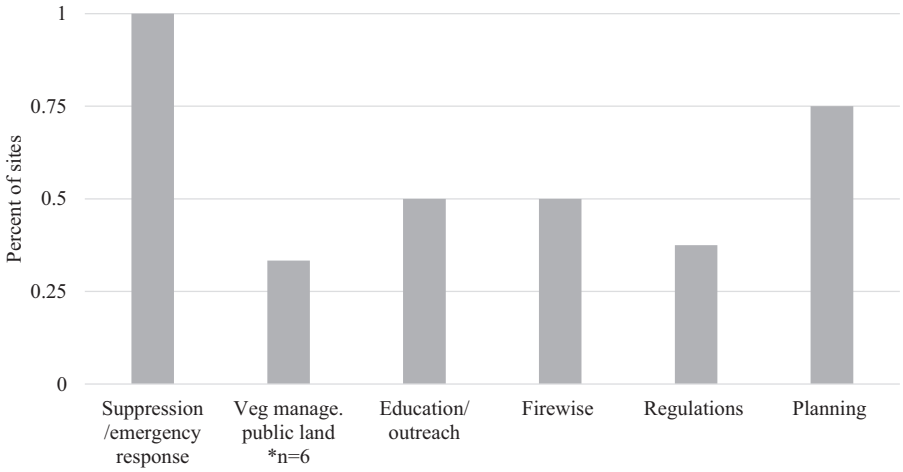

Fig. 2 Percent of study sites ($n = 8$) reporting community-level changes in each category of wildfire mitigation and risk reduction

site has different resources and administrative structures (Table 2). After the focal wildfires, all study sites made changes in suppression and response (e.g., enhancing fire department resources, communications, and training), using a diversity of mechanisms (Table 2). These changes were therefore universal, regardless of the novelty of destructive wildfire or past investment in formal wildfire regulation and planning. Changes were often carried out directly by local government or fire departments. In instances when suppression responses had been controversial with local communities, governments and fire departments devoted substantial time and energy responding to the fallout from these efforts. Perhaps the highest profile example in our study was the 2009 Station Fire; the Station CA site was unique in that the fire incident was subject to formal, national-level review by the Government Accountability Office, culminating in several changes in federal firefighting strategies in the region (Government Accountability Office 2011). However, across all sites, informants could readily link changes to experiences during wildfires:

> "We exercise [setting up the emergency operations center] every year. It took us several hours to get up and operational for Wallow. We can be up and running in 15 minutes now"—Wallow AZ.

> "We have eleven volunteer departments and one pay department…they all train together a lot more now; they have a monthly get-together once a month where all the departments come together and whether it's to talk about something or [do] hands-on training, [they're] trying to get a lot more unified"—Possum Kingdom TX.

Half of our study sites also reported neighborhood-level improvements to enhance water supply or egress (Table 2). Only in the Station CA site were neighborhood-level changes required by formal regulation, which was controversial. Here, the long history of destructive fires had resulted in pre-existing regulations which required homeowners who were rebuilding to enhance water supply through an expensive communal pipe:

> "Finally, we were in a meeting with a meeting with these county guys and I was like, you do not get it. You're talking about seventeen families, if everyone moves back and I can tell you, they're dropping like flies. Now how are we going to finance three quarters of a million dollars in pipe and labor on these properties [to provide required water supply]? You want to kill this community? You require the pipe. You require the water."—Station CA (residents were eventually able to negotiate individual storage tanks rather than a communal pipe).

Neighborhood-level changes occurred through informal means in the other sites: housing developments made improvements as part of becoming Firewise (Hwy 31/WG SC), a fire department encouraged homeowners to improve roads (Monastery WA), and the water authority installed unofficial hydrants (Possum Kingdom TX; unofficial because water pressure does not meet state standards) (Table 2). These improvements were modest and non-controversial among residents. In each of these locations, destructive fire was a novel occurrence, and previous investment in wildfire regulation and planning was low to moderate. However, the four study sites that did not change neighborhood-level resources had varying prior experience with wildfire (in some places it was novel, in others it was not), and a range of previous formal investment in wildfire management, from low to high (Table 2).

Vegetation management on public lands

Vegetation management on public lands was relevant for only six study sites: the Loco-Healdton OK and Monastery

Table 2 Suppression and emergency response changes after wildfires

Site	Fire department type[a]	Previous destructive fire experience?	Formal wildfire regulation and planning	Neighborhood-level changes	Community-level changes
Caughlin Ranch NV	Career	No	Mod		R911 enhanced
Hwy 31/WG SC	Career	No	Mod	Egress and water supply (HOAs added exits and hydrants as pursued Firewise)	Firefighter radio communications, equipment, training; R911 enhanced; new public safety director
Loco-Healdton OK	Volunteer	Yes	Low		Firefighter training via public safety tax in one county
Monastery WA	Volunteer	No	Mod	Egress (fire dept. asked those rebuilding to improve egress)	Support across fire departments; Enhanced radio communications; R911 added; County trainings for ICS and evacuation
Monument AZ	Career	No	Mod		R911 added; new emergency management personnel
Possum Kingdom TX	Volunteer	No	Low	Water supply (local authority installed unofficial hydrants)	Firefighter equipment and training; R911 in progress
Station CA	Career	Yes	High	Egress and water supply (egress improved by LA County; All rebuilt homes had water on-site, per County requirement)	Changes in Forest Service suppression, via GAO report.
Wallow AZ	Career and Volunteer	Yes	High		New group created to share burn ban information; New emergency operations center protocol

[a]Volunteer used here for those departments that rely primarily on volunteers (may also have some paid staff)

WA sites did not have public land. For the four sites with substantial amounts of public land (federal for Monument AZ, Wallow AZ, and Station CA; county for Caughlin Ranch NV), respondents reported no meaningful change in approach as a result of wildfires. In each location public land managers had previously been engaged in vegetation mitigation work, and continued efforts after the focal wildfires (Table 3). These four sites were evenly divided between those were destructive wildfire was novel and past investment in regulations and planning was moderate (Caughlin Ranch NV, Monument AZ) and those with long histories of wildfire and higher investment in regulations and planning (Station CA, Wallow AZ). Managers in each of these locations revised treatment plans after fire activity, but participants did not consider the fires turning points in their vegetation management.

> "Well the Forest Service actually always does thinning projects up there… Absolutely. And they've always done burns up on [Fort Huachuca] too"—Monument AZ.

> "What's unique about this area is, we had the White Mountain Partnership…for 10 years…almost immediately following the Rodeo-Chedeski fire. Once that contract ended we went right into the Four Forest Restoration Initiative which is a bigger stewardship program that covers four National Forests…So we've had a lot of thinning and a quite a number of success stories."—Wallow AZ.

The Station CA site was unique in that the Angeles NF created a program to allow homeowners adjacent to the forest extend defensible space mitigation onto public land, as necessary to comply with county regulations (Angeles National Forest 2014). This site had a long history of destructive wildfire and extensive investment in wildfire regulations and planning at the county level, although this process happened through federal regulation (as recommended by the GAO review of the wildfire incident).

The remaining two sites had different patterns of public land ownership and housing development, and each reported some change in vegetation management. In both locations destructive wildfire was novel and there was low to moderate previous investment in wildfire regulation and planning (Table 3). Possum Kingdom TX has minimal public land, in a state park; managers had done vegetation mitigation before the fire, but saw a reduced need for treatment after wildfire. However, the local water authority began thinning around their infrastructure post fire. In the Hwy 31/WG SC site housing developments abut open spaces (typically wetlands protected from development), and contain communal open space. Post fire, vegetation

Table 3 Vegetation treatment, education, Firewise programs, and wildfire-related planning and regulations, before and after wildfire, for each site (n = 8). For each category any changes after fire are noted with a +sign and in bold

						Planning and regulations				
Name	Previous destructive wildfire?	Previous wildfire reg and planning	Public land vegetation: Before +**After**	Education/ outreach: Before +**After**	Firewise: Before +**After**	Burning regulations: Before +**After**	Building code: Before +**After**	WUI regs: Before +**After**	CWPP[a]: Before +**After**	Other planning: Before +**After**
Caughlin Ranch NV	No	Mod	Active	Active	None	Yes	Yes	Yes[b] +**IWUI county only**		HMP, CP[c] +**Revising HMP**
Hwy 31/WG SC	No	Mod	Limited +**Expanded**	Limited +**Expanded**	2–4 +**20**	Yes +**City banned; county strengthened**	Yes	+**Overlay city**		HMP +**Revising HMP, CP**
Loco-Healdton OK	Yes	Low	NA	Limited	None	Yes				HMP (1 county)
Monastery WA	No	Mod	NA	Limited +**Expanded**	1[d] +**1**[d]	Yes	Yes			Emer. ops plan +**Revising emer. ops plan**
Monument AZ	No	Mod	Active	Limited +**Expanded**	None +**1**[d]	Yes	Yes (county,1 fire dept) +**1 more fire dept.**		+**New CWPP**	HMP +**Revising HMP**
Possum Kingdom TX	No	Low	Active +**Public infrast.**	Limited	None	Yes				Emer. ops plan +**Revising emer. ops plan**
Station CA	Yes	High	Active +**Resident thinning**	Active	None	Yes	Yes	Yes[e]	Fire Plan[e]	HMP, CP +**Revising HMP, CP**
Wallow AZ	Yes	High	Active	Limited +**Expanded**	None +**1**[d]	Yes	Yes		Yes +**Revising CWPP**	HMP, CP +**Revising HMP**

[a]Caughlin Ranch NV and Monastery WA had older assessment documents or CWPPs, but not current ones. LA has county-wide fire plan similar to a CWPP

[b]Present in both city and county in limited areas

[c]Comprehensive Plan that mentions wildland fire

[d]In close proximity to fire, not necessarily within fire perimeter

[e]As required by the state of CA

management increased on both, though it was challenging for HOAs to obtain the governmental approval (Army Corps of Engineers permits) to treat wetlands areas outside developments.

Education/outreach and Firewise participation

After wildfire, the sites with the most change in education and outreach after wildfire, including Firewise participation, were all locations with moderate to high levels of previous investment in formal wildfire regulation and planning (Monument AZ, Wallow AZ, Monastery WA, Hwy 31/WG SC), and three of the four were also locations where destructive fire was novel (Table 3). In each of these four locations, outreach had been limited before focal wildfires; after the fires new programs were created to encourage vegetation mitigation through expert advice, free labor from inmates, or cost-shares. New funding and staffing supported expansion in three of these instances: two gained state employees and in one location the county obtained a grant. In each of these sites, interviewees thought residents were actively participating in these programs, demonstrating increased concern about wildfire risk. However, respondents also indicated that concern about wildfire diminished with time from wildfires, and that there were also residents who were not pursuing mitigation options.

> "Even now so many years after the fire, and after the two biggest fires in the nation, we're still dealing with people that aren't going to cut trees, aren't going to take Firewise information in and use it." –Wallow AZ.

> "If we don't have a wildfire for four or five years we don't have wildfires. I mean, if it hasn't happened to you, you haven't seen it happen, you haven't been here when it happened, it doesn't happen…I thought I moved to paradise, I didn't think bad things happened here."—Hwy 31/WG SC.

After fires, Firewise programs were also expanded in the same four study sites with enhanced education and outreach (Table 3) (before the focal fires two of the study sites had Firewise communities, Hwy 31/WG SC and Monastery WA, but Monument AZ and Wallow AZ did not). In two of these locations, new state government employees who helped expand outreach also expanded Firewise communities (Hwy 31/WG SC and Monastery WA), while in the other two locations the endeavors were separate, as a result of fire department (Wallow AZ) and non-profit staff (The Nature Conservancy in Monument AZ). While for the most part the increase in Firewise certified communities was modest (e.g., from no communities to one), these could still be significant changes for these locations. For example, in Monument AZ, the only canyon that was undamaged in the fire pursued Firewise certification.

> "[that] canyon is my worst nightmare. That's one I always worry about because it's a very steep, very, very steep canyon and you have canopies that just run over across the road. It's one of those bad situations… so we actually are doing the fuels reduction grant there [and it's now a] Firewise community up in that area"-Monument AZ].

The Hwy 31/WG SC site had by far the greatest expansion in Firewise: before fires two to four subdivisions were pursuing Firewise, but an estimated 20 were pursuing or had obtained Firewise certification at the time of our interviews, motivated by wildfire experience. However, of the two communities damaged in fires, only one had become Firewise (the condos damaged by WG); the PUD/golf course development affected by Hwy 31 had considered but not yet pursued Firewise. Across study sites, decisions to pursue Firewise were not without controversy.

> "Even within those Firewise communities there's a lot of division….you've got the Firewise committee that is a group of residents that formed outside of the HOA Board and so they're doing things that maybe the Board's not okay with…it's a power trip type thing"—Hwy 31/WG SC.

> "There are some homeowners that hold out. I mean even with [that] canyon we've got free money [for fuels treatments] and they don't want to do it. They're like no, we don't even want you on our property"—Monument AZ.

We saw the least change in wildfire education and outreach efforts in the two locations that already had, and continued, extensive education[1] (Caughlin Ranch NV, Station CA) and the two locations that lacked active education previously (Loco-Healdton OK and Possum Kingdom TX). Before the focal wildfires, both Caughlin Ranch NV, which was close to the headquarters for Nevada's Living with Fire program, and Station CA, where both LA County Fire and Angeles NF staff were engaged in education, had invested substantial effort in education and outreach. These locations had moderate to high previous investment in wildfire related regulations and planning,

[1] In California, communities may pursue the similar California Fire Safe Council program, but none were located near the housing losses in the Station CA site. Nevada's Fire Safe Council program folded before the Caughlin Ranch NV event, and neither Firewise nor Fire Safe Councils were expanded afterwards, although the fire departments were encouraging Firewise participation in Washoe County.

respectively (destructive fire was novel in Caughlin Ranch NV but not in Station CA). After these fires, officials used the experiences from the fires to re-engage with communities and adjust their messages. For example, Caughlin Ranch NV educators emphasized that wildland fires could occur at any time of year. In contrast, Loco-Healdton OK and Possum Kingdom TX lacked active education before focal fires, and did not gain new efforts after the fires. However, OK state employees did note that state-wide education efforts focused on prevention had expanded since the mid-2000s). These two sites had the lowest pre-fire investment in formal wildfire regulation or planning, with a long history of destructive wildfire in Loco-Healdton OK but not Possum Kingdom TX.

Wildfire-related regulations and planning

Before focal fires, all locations had some wildfire-related regulations and plans (Table 3, Supplemental Table). Among regulations, all locations had the ability to manage or ban burning, and nearly all had building codes (exceptions: Loco-Healdton OK and Possum Kingdom TX). These regulations often tier to state and federal standards (e.g., burning is managed by local and state authorities to comply with the federal Clean Air Act; states may have requirements for building codes). HMPs are also often coordinated by states, and in some cases required. The other two efforts considered, community-level CWPPs and wildfire regulations related to homes (materials or defensible space), were less common (Table 3).

Post fire, we saw changes in regulations in three study sites, all in locations with moderate investment in formal wildfire regulations before fires and where destructive WUI fires were novel. The Hwy 31 fire (2009) in SC was started by open burning, and both local jurisdictions changed burning regulations post fire (the city banned it, while the county strengthened management). The ban in the city was readily accepted, as open burning was relatively rare here.

> "Q: How did the community feel about [the change in burning regulations]? A: Well that was kind of a no brainer. That was one very uncontroversial ordinance. It went right through."—Hwy 31/WG SC.

The city of North Myrtle Beach also revised their Planned Development District regulations to create an overlay zone in the one area of undeveloped land remaining, and require Firewise design principles. In the Monument AZ site, one fire department adopted a more recent version of the international fire code than required by the state, which they characterized as a first step toward improving buildings. The informant described a process of convincing the board to enact the code, and said it would then be an ongoing process of community education and board approval to move toward code enforcement:

> "We don't do enforcement right now. What we're doing is, we adopted it, and…we're using it as an educational piece for everybody. If enforcement ever happens, at that point [people will need to comply to get a building permit from us]. Right now, we're not at that level yet"—Monument AZ.

The state of Nevada began the process of adopting International WUI codes after the 2009 Angora fire (Nevada Division of Forestry 2010), and Washoe County adopted 2012 International WUI codes in 2013 (however, Reno did not adopt the full codes).

However, there were no formal changes in regulations related to wildfire in the other five sites, which included both places where destructive WUI fires were novel, and places with long history of wildfires, as well as sites with a range of investment in wildfire-related regulations pre-fire (Table 3). In the one location that already had extensive regulations (Station CA), LA County fire was continuing to revise regulations, but there were no changes as result of this fire. In many of the study sites without WUI regulations for homes (all low to moderate investment in regulations and planning), there were concerns about the acceptance of defensible space regulations, although destructive wildfire was novel in each setting:

> "I don't think that the lake community is receptive to regulation because they had very onerous regulations, you know, very recently [when land was leased from Brazos River Authority]. I mean, it's in our recent memories, and that's one of the attractions, moving out here, is the lack of rules"—Possum Kingdom TX.

> "I don't think that you could [have regulations about home mitigation], I really don't. Because Arizona is an all free rights state. Unless you live in a strong homeowners association to where you sign off on all those deed restrictions, I don't think it's going to happen here…Even within these homeowners associations; I mean they have to take people to court all the time"—Monument AZ.

> "The building code stuff has been discussed. This is a pretty conservative community and they don't want government intrusion. That's a sticking point because commissioners respect that. So those building codes have not been adopted in Klickitat County. I don't know if they will be."—Monastery WA.

The Hwy 31/WG SC site also had moderate past investment in wildfire-related regulation and planning, and

destructive wildfire was novel, but they had some different concerns. Here, local officials were interested in potential regulations, and recognized that some residents would support such an effort, but were concerned about the challenges of crafting wildfire regulations given the diversity of land use, the extent of existing residential development, and regulations that already existed (for stormwater management and wetlands preservation) (Hwy 31/WG SC).

> "I think it's difficult when you, at a county level when you try to regulate things and we have such a diverse county. Agricultural to very urban and everything in between"—Hwy 31/WG SC.

> "I think it's in the back of everyone's mind that zoning should have been done differently from the beginning but it's not and we're dealing with it… there's some chatter [about changes] but it's just chatter right now"—Hwy 31/WG SC.

Post-fire changes in planning documents were far more common than changes in regulations: all sites except for Loco-Healdton OK incorporated recent wildfire experiences in HMPs or emergency operations plans, though changes were often minimal (e.g., mention of the focal event among a list of past hazard events) (Table 3, Supplemental Table). Three locations made more substantial changes in planning documents, all locations with moderate investment in planning pre-fire (in two locations destructive wildfire was novel, in one it was not). In Hwy 31/WG SC, Horry County inserted wildfire concerns in their comprehensive plan, as an attempt to raise the profile of wildfire threats and encourage future action (Supplemental Table). The Wallow AZ site was the only location to have a CWPP before fire, and it was being revised post fire. In the Monument AZ site, the county obtained grant funding to create a CWPP, focused primarily on fuels mitigation. Plan participants expressed pride about creating a first-ever county-wide CWPP, although they also noted the aspirational nature of the document (funds are required to do the treatments, for example).

Discussion

As wildfires become more common and more destructive across the U.S., the responsibility for adapting to this threat remains dispersed, falling primarily to governments and informal institutions at the local or community level, making it challenging to track and understand adaptation. The broader hazards and wildfire-specific literatures suggest that the time after wildfire may be a window of opportunity for adaptation, and indeed, we did find evidence of community and government-level change in each of our study sites. However, across diverse settings, we found that destructive fires did not change the tools and actions typically used for wildfire mitigation and planning, and that local and state governments alike declined to take larger action on land use planning or building standards in response to these wildfires.

Across diverse sites, the most common response to wildfire experience was to invest in suppression and emergency response. All locations, from those with limited to extensive previous experience with destructive wildfire, and with a range of past investment in formal wildfire management and regulation, identified opportunities for improvement in suppression or emergency response after focal wildfires. Our findings concur with studies demonstrating that improvements in suppression are a common tactic in response to wildfire threats, and typically garner community support (Jakes and Sturtevant 2013; McCaffrey et al. 2013). For example, in our study residents in rural Oklahoma (Loco-Healdton OK) passed a public safety tax to improve firefighter resources. Wildfire suppression management is often controversial with communities after losses (Carroll et al. 2005; Paveglio et al. 2015b), which may also drive the subsequent emphasis on improving response. At the national level as well, improving fire suppression remains a key area of policy emphasis and attention (Steelman and Burke 2007). We also found consistent investment in vegetation mitigation on public lands, another commonly used tool to reduce wildfire risk (Jakes and Sturtevant 2013). Lastly, planning efforts (especially updates to HMPs) were also common in our study sites, because of external mandates which require communities to create and maintain HMPs.

Conversely, wildfire-related regulations were rare in our study, even after fire, demonstrating that opposition commonly found to these regulations (McCaffrey et al. 2013; Muller and Schulte 2011) persists after wildfire. The changes we did see in regulations were carefully considered to meet with public approval: banning outdoor burning—a safety-related, and typically well-accepted regulation (Muller and Schulte 2011)—in a city where residents did not typically burn debris; enacting development regulations where little land remains undeveloped; or implementing stricter building codes but not requiring compliance. Although Muller and Schulte (2011) found that regulations related to emergency response and suppression (e.g., egress or water supply) were among the most palatable of wildfire-related regulations, in our study we mostly saw communities make such improvements through informal means, rather than enacting regulations that would shape future development.

None of our study sites elected to enact or strengthen WUI regulations focused on homes (vegetation, building

materials). Although Duerksen et al. (2011) found that such regulations were often enacted after a wildfire event, we conclude that this experience may be necessary but is not sufficient to lead to adoption. In our study, both locations that have such regulations (Caughlin Ranch NV and Station CA) gained them after a focal wildfire led to state-level action (2009's Angora Fire in NV, 1991's Oakland Hills fire in CA) (Nevada Division of Forestry 2010; Plevel 1997). Even then regulations may be controversial, as demonstrated by the city of Reno adopting less stringent standards than surrounding Washoe County. In addition, repeated wildfires do not always spur state-level action. For example, Colorado considered, but declined to expand the state's role in wildfire-related regulations after a series of destructive wildfires from 2009–2013 (Mockrin et al. 2016).

The changes we saw in intermediate frequency, including neighborhood-level improvements in suppression and emergency response, expansions in Firewise participation and education, and changes in regulations and planning (beyond updating HMPs), provided the greatest insight into the role of wildfire history and pre-fire investment in formal regulation and planning. As anticipated, adaptation was more likely when destructive wildfire was novel, and varied with past investment in formal wildfire regulation and planning. We found that locations with moderate investment in formal wildfire management and planning showed the greatest changes, as they either already had or gained the capacity and staff resources to respond to wildfires, and take advantage of the heightened awareness of risk or policy window immediately following an incident. Research from wildfire and hazards literature also demonstrates the importance of local government capacity, external resources, and issue champions (Labossière and McGee 2017; Michaels et al. 2006; Prokopy et al. 2014). However, the changes we saw were not uniform across settings—that is, not all locations with similar characteristics and fire histories pursued the same changes. Other factors, including social capital, histories of land use development, local culture, partnerships and collaborations, relationships between and among jurisdictions, among others, also influenced the paths that locations took post fire.

Our study also revealed where wildfires resulted in little to no change. Among locations, we saw less change associated with several different characteristics, which may occur in combination: communities where there was a long history of destructive wildfire (Station CA, Loco-Healdton OK), those with a history of limited capacity and investment in formal wildfire-related mitigation through regulations and planning (Loco-Healdton OK, Possum Kingdom TX), and settings where extensive past investment in formal regulation and mitigation were considered sufficient. For locations with long histories of wildfire, although we chose fires that destroyed homes as focal events, they may not have met Birkland's (1997) criteria that focusing events must be uncommon and reveal novel potential for harm. For example, the Station fire was one of many wildfires to affect Los Angeles County, and the changes that followed occurred primarily within the Forest Service (not the county), as a result of national-level review, motivated by controversy around suppression (Government Accountability Office 2011).

For places like Los Angeles County that have experienced repeated wildfire over time, and have extensive investments already in regulations, planning, and risk reduction programs, it is unclear if and how cumulative hazard experience results in change over time. Existing investments were not infallible: informants characterized mitigation around homes pre-fire as uneven, and local officials did not fully enforce or implement vegetation mitigation standards, but they also were not altering standards, enforcement, or outreach as a result of experience with this wildfire. Similarly, across sites vegetation mitigation on public lands was generally considered sufficient in our study, and continued after wildfire (we note that we did not assess the extent, type, and efficacy of treatments).

We also saw little change in Loco-Healdton OK, which had a long history of wildfires, but far less formal investment in wildfire regulation and planning. Here, informants considered fire a routine event, despite the potential for harm. The experience in Oklahoma demonstrates that repeated wildfires may not always increase regulatory pressure from local, state, or federal authorities. In both locations communities may be considered fire adapted in that they have accepted the inevitability of losses to wildfire.

Even when fire is novel, locations without governmental capacity and experience with formal wildfire regulation and planning, as in the case of Possum Kingdom TX, may not respond by adopting the tools and actions expected of FACs. This was the most destructive fire in our study in terms of number of homes lost, but community-wide responses were modest (mostly enhanced suppression). In this setting, wildfire was still seen as an isolated incident by some community leaders, and many residents were wealthy, which may have diminished the perceived need to reduce future exposure. Similarly, Paveglio et al. (2016) found that the magnitude of damage was important; adaptation was lacking in a location where the community could readily rebuild with existing resources.

Combined, these experiences raise questions about the pathway to FAC for communities where wildfire events are common and/or interest in adaptation and capacity for using formal tools and actions is low. Although the FACs concept currently envisions an iterative cycle of assessment and adaption (FAC Learning Network 2016; Fire Adapted Communities Coalition 2014), the broader policy literature and this study show that the stimulus to change may be

diminished when locations have experienced destructive wildfires repeatedly. In addition, although FAC typically emphasizes a wide range of formal and informal tools and actions that local governments and communities can take, we did find that destructive wildfire motivates governments to adopt novel formal regulations or planning approaches to reduce risk. In many instances, practitioners were focused on immediate concerns such as restoring housing and repairing relationships with the public after controversies over suppression. In this way optimism about post-wildfire windows of opportunity may be too high if we expect communities to routinely enact land use planning that restricts development extent or alters home characteristics after fires. We acknowledge that such formal regulations and planning are only one tool to reduce future wildfire exposure but they do play a unique and critical role: without such policies even the most ferocious wildfire event may result in relatively little change in the built environment, if rebuilding is robust and homeowners do not take independent, voluntary measures to reduce the risk of wildfire (at present, homeowners insurance is typically still widely available, and does not restrict rebuilding practices) (Mockrin et al. 2015; Mockrin et al. 2016).

Such voluntary and individual level response to wildfire risk is an important component of adaptation, and one that fell outside the scope of our study. There is much we still do not yet understand about how residents and communities together transition from being at risk from fire to being adapted to fire (Paveglio and Edgeley 2017). Communities are made up of individual residents who respond in widely varied ways to wildfire experience (Edgeley and Paveglio 2017; McGee et al. 2009; Mockrin et al. 2015). Future research could explore the variation in individual responses to wildfire events, and how those might be linked to broader community-level efforts. Finally, in future studies, it will be important to assess the potential efficacy and impacts of such post-wildfire adaptation. In this study we primarily considered the presence of different tools and actions to reduce wildfire risk, but did not examine how these actions may result in altered vulnerability to or resilience from wildfire. For example, the presence of a CWPP or HMP alone may not result in meaningful risk reduction, especially where governmental resources are limited (Frazier et al. 2013; Jakes and Sturtevant 2013).

Ultimately, a better understanding of post-hazard mitigation and action across scales, including residents, communities, and states, will be required to more fully understand response to hazard events and the development of FACs. While the time post wildfire is not always an opportunity for change, or the only opportunity for change, in many settings the idea of a wildfire as a focusing event did resonate with the experiences and perspectives of local practitioners. Although the hazards literature emphasizes that post-event heightened salience of risk events may be short, and our informants thought residents' risk perception declined over time, we agree with Michaels et al. (2006) that these events have long histories in local government and organizations. In many cases, focal wildfire events were still inspiring adaptation and change from government and community leaders, years later.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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