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Articles

Catching Fire? Social Interactions, Beliefs, and Wildfire Risk Mitigation Behaviors

KATHERINE DICKINSON

Research Applications Laboratory, National Center for Atmospheric Research, Boulder, Colorado, USA, and Institute of Behavioral Science and Center for Science and Technology Policy Research, University of Colorado, Boulder, Colorado, USA

HANNAH BRENKERT-SMITH

Institute of Behavioral Science, University of Colorado, Boulder, Colorado, USA

PATRICIA CHAMP

U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, USA

NICHOLAS FLORES

Institute of Behavioral Science, University of Colorado, Boulder, Colorado, USA

Social interactions are widely recognized as a potential influence on risk-related behaviors. We present a mediation model in which social interactions (classified as formal/informal and generic/fire-specific) are associated with beliefs about wildfire risk and mitigation options, which in turn shape wildfire mitigation behaviors. We test this model using survey data from fire-prone areas of Colorado. In several cases, our results are consistent with the mediation hypotheses for mitigation actions specifically targeting vegetative fuel reduction. Perceived wildfire probability partially mediates the relationship between several interaction types and vegetative mitigation behaviors, while perceptions of aesthetic barriers and lack of information play a mediating role in the case of fire-specific formal interactions. Our results suggest that social interactions may allow mitigation and prevention behaviors to "catch fire" within a community, and that wildfire education programs could leverage these interactions to enhance programmatic benefits.

Keywords natural hazards, risk mitigation, social interactions, wildfire

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Address correspondence to Katherine Dickinson, Research Applications Laboratory, National Center for Atmospheric Research, PO Box 3000, Boulder, CO 80307-0300, USA. E-mail: katied@ucar.edu

Like so many other environmental challenges, current wildfire risk is a product of both natural processes and human behaviors. While wildfire itself has been an integral part of many of Earth's ecosystems since well before the dawn of humanity, a combination of factors has contributed to the increasing risk and impacts of fire on human communities. Fire suppression policies and drought increase fuel loads and enhance the probability that fires will occur and spread, while in-migration and private land development at the wildland's edge, the wildland–urban interface (WUI), augment the values at stake when a fire does occur. Together, these factors increase the potential for devastating, costly wildfires. Indeed, in the past 10 years, areas throughout the United States have incurred increased economic and social costs due to wildfire. In this time period billions of dollars have been spent on fire suppression while millions of acres and thousands of structures have burned. The western United States has been particularly hard hit—in 2012, for example, 67,315 wildland fires resulted in more than 9.2 million acres burned. In Colorado alone, 1,498 fires burned more than 246,000 acres, resulting in 648 structures lost and 6 deaths (National Interagency Fire Center 2012). Climate-change-related increases in temperature and decreases in precipitation are predicted to exacerbate this already worsening situation, particularly across the American West (Westerling et al. 2006).

Measures to confront this environmental challenge occur at multiple scales: For example, federal policies govern fire management on federal lands, while state agencies and local-level fire protection districts are tasked with fuel management, fire prevention, and suppression within their jurisdictions. The task of reducing fuels on private lands, however, falls largely on the shoulders of private homeowners, whose behaviors play a central role in shaping potential wildfire impacts on WUI communities. Homeowners' actions to alter structural characteristics of the home and vegetation in its immediate surroundings influence home "ignitability" during wildfire events (Cohen 2000).

Given the importance of homeowners' mitigation behaviors in shaping wildfire risk and impacts, understanding the full range of factors related to these behaviors is essential for developing wildfire education programs and policy. The focus of this article is on one set of factors related to homeowners' beliefs about wildfire and mitigation behaviors: social interactions. We examine the ways in which homeowners' social connections and engagement with neighbors and other social reference groups are connected to perceptions of wildfire risk and responses to that risk. Our focus on social interactions is informed by case-study research on wildfire mitigation and other hazards-related behaviors that highlights the importance of social influences (Lindell and Perry 2000; Tierney 2001; McGee and Russell 2003; Agrawal and Monroe 2006; Jakes 2007; Brenkert-Smith 2010).

The article proceeds as follows. First, we develop a conceptual model in which social interactions of various types are linked to wildfire mitigation behaviors via a mediating set of wildfire-related beliefs. We apply this mediation model to an empirical analysis of data from a survey of WUI homeowners in Colorado. Finally, we use these results along with a review of relevant theoretical and empirical literature to generate hypotheses about the possible mechanisms underlying patterns of results observed in these data. Further exploration of these hypotheses could inform efforts to harness the power of social interactions and encourage mitigation behaviors to "catch fire" and spread within communities at risk.

Conceptual Framework and Empirical Model

The way people come to understand wildfire risk as a "problem" to be addressed is shaped, in part, by the claims made about the risk at hand (Stallings 1995). Through a variety of interactions related to these claims-making efforts, people form ideas about the hazard and how to respond to it (Spector and Kitsuse 1987). Thus, our basic proposition is that social interactions shape beliefs about wildfire risk and options for mitigating that risk, and that these beliefs, in turn, are related to the mitigation behaviors that individuals choose to undertake.

Social Interactions

Several members of homeowners' social environments in fire-prone areas are involved in the processes of constructing meaning around the problem of wildfire risk. These members include representatives of agencies tasked with fire management who seek to engage residents in their goals, as well as local entities, neighborhood groups, and neighbors. Social interactions can occur in formal, organized settings (e.g., community meetings) or informal contexts (e.g., conversations between neighbors) (McCaffrey 2004; Prell et al. 2010). Furthermore, some types of social interactions among WUI homeowners revolve specifically around wildfire (e.g., attending a community wildfire meeting), while others may be more general (e.g., attending a homeowners' association meeting) (Brenkert-Smith et al. 2013). As discussed further in the following, these different types of interactions can shape beliefs about wildfire and mitigation behaviors through several possible pathways.[1]

Beliefs

Relevant beliefs that may influence mitigation behaviors include beliefs about wildfire risk and options for mitigating that risk. In the former category, wildfire risk perceptions include the probability of a fire and the consequences of wildfire for one's own house and property, as well as for the broader community (McCaffrey 2002; 2004; Martin, Martin, and Kent 2009; Brenkert-Smith et al. 2013). Beliefs about mitigation options include perceived benefits and costs, broadly defined, of taking action. Benefits include perceived efficacy of mitigation actions in reducing the impacts of wildfire. The hazards literature indicates that response efficacy (whether actions actually reduce risk) (Tierney 2001; Hall and Slothower 2009; Absher and Vaske 2011) and self-efficacy (whether one can successfully implement action) are important factors influencing protective action (Lindell and Whitney 2000). Costs include the time, money, and effort required to mitigate, as well as the cost of obtaining the requisite information to complete mitigation actions. Less tangible factors shaping homeowners' choices may include perceived loss of aesthetic value from cutting trees, or social rewards (or penalties) resulting from taking mitigation action.

Behaviors

In the wildfire context, relevant behaviors that homeowners can undertake to reduce home ignitability include two broad categories of mitigation actions: reducing vegetative fuels around the home (trimming trees, raking leaves, etc.) and changing structural features of the home (e.g., using fire-resistant roofing or siding materials). Several studies have empirically measured WUI residents' mitigation behaviors and their determinants, though the specific list of actions measured varies across studies (e.g., McGee 2005; Collins 2008; Martin, Martin, and Kent 2009).

The literature on wildfire mitigation and other hazards-related behaviors identifies several mechanisms through which social interactions can influence wildfire-related beliefs, thus altering mitigation behaviors. First, formal and informal interactions provide opportunities for information transmission (McCaffrey 2004; McCaffrey et al. 2011). For example, an individual might get information from a neighbor about weather conditions favoring fire, or that individual may learn about "fire science" in a book club or other social group. Social interactions can also help people learn about mitigation options; for example, seeing examples of mitigation on neighbors' property can provide concrete information about its benefits and costs, including diminished or enhanced aesthetic value from reducing vegetation. Second, social interactions influence how individuals interpret and process risk-related information and form risk perceptions through a process Kasperson et al. (1988) called the social amplification of risk. Studies in a variety of contexts, from environmental pollutants (Pidgeon, Kasperson, and Slovic 2003) to health decisions (Petts and Niemeyer 2004), have documented how social interactions can serve to amplify or attenuate perceptions of and beliefs about risks. Third, in addition to shaping how individuals perceive an exogenous source of risk, fuel conditions on neighboring properties can also endogenously affect the objective risk level itself. This process has been called risk interdependency, interdependent security (Kunreuther and Heal 2003), or risk externalities (Shafran 2008). A fourth pathway through which social groups can shape beliefs about fire risk and mitigation options involves social norms, which include a wide array of different processes through which individuals assign value to different actions and test the "appropriateness" of their actions within their social environment (Turner et al. 1980; Fishbein and Ajzen 2010). Fifth, social capital, or the degree of connectedness between members of a community (Putnam 2000), can shape wildfire-related beliefs and behaviors in a number of ways. For example, attachment to home and community has been found to correlate with wildfire mitigation actions (Kyle et al. 2010). Social capital may also serve as a resource to reduce individual mitigation costs (Agrawal and Monroe 2006; Jakes 2007), as in the case of neighborhood "work days" where households come together to complete mitigation actions on each other's property (Brenkert-Smith 2010).

In light of these different processes that may be at play, we hypothesize that the relationships among social interactions, beliefs, and wildfire mitigation behaviors can be understood as a case of mediation (Baron and Kenny 1986; MacKinnon, Fairchild, and Fritz 2007). That is, different types of social interactions ($\boldsymbol{S}_i$), our independent variables, shape the dependent variables of mitigation behaviors ($\boldsymbol{M}_i$), via the former's effect on mediating variables, fire-related beliefs ($\boldsymbol{B}_i$). This model is depicted in Figure 1, and empirically, this model implies three regression equations:

$$\boldsymbol{B}_i = f(\boldsymbol{S}_i, \varepsilon_i) \tag{1}$$

$$\boldsymbol{M}_i = f(\boldsymbol{S}_i, \varepsilon_i) \tag{2}$$

$$\boldsymbol{M}_i = f(\boldsymbol{S}_i, \boldsymbol{B}_i, \varepsilon_i) \tag{3}$$

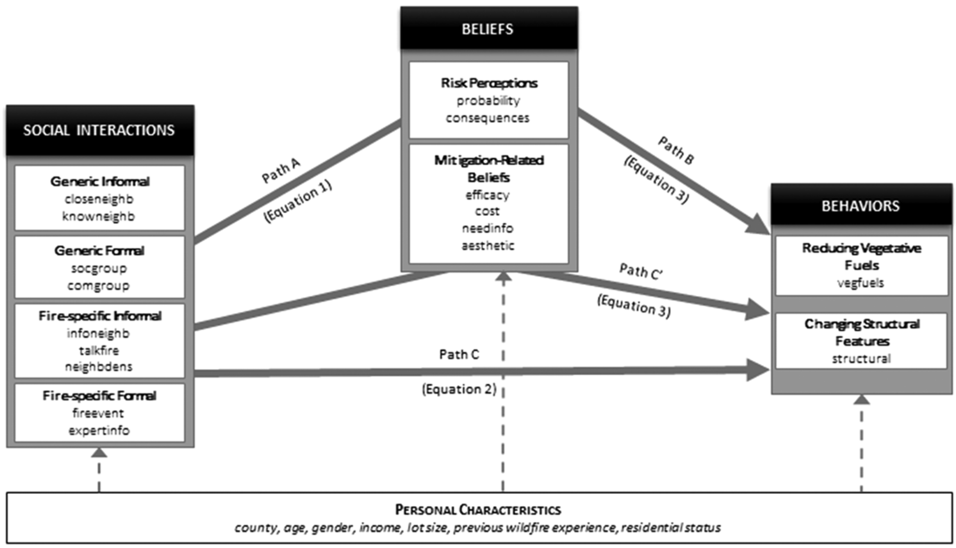

Figure 1. Mediation model linking social interactions with wildfire-related beliefs and mitigation behaviors.

The first equation looks at the relationship between social interactions and the mediating belief variables. The second looks at the relationship between social interactions and mitigation behaviors, and the third posits the same relationship controlling for the effect of the mediating variables, beliefs. The mediation model implies the following specific hypotheses:

H1: There are statistically significant relationships between social interactions and wildfire-related beliefs (Eq. 1, Path A in Figure 1).
H2: There are statistically significant relationships between social interactions and mitigation behaviors (Eq. 2, Path C in Figure 1).
H3: There are statistically significant relationships between beliefs and mitigation behaviors controlling for social interactions (Eq. 3, Path B in Figure 1).
H4: The magnitude of relationships between social interactions and mitigation behaviors in Eq. 2 (i.e., when beliefs are included) is smaller than the relationships observed in Eq. 1 (i.e., Path C' coefficients are smaller than Path C coefficients in Figure 1).

If all of these hypotheses hold, wildfire-related beliefs may be said to mediate the relationship between social interactions and wildfire mitigation behaviors.

Methods

Data

We use data from a 2007 study of homeowners' wildfire mitigation behaviors in the Front Range area of Colorado to examine the relationships described above. Boulder and Larimer counties rank as the top two counties at risk of wildfire in Colorado, based on the number of square miles of developed land within the WUI (Gude, Rasker, and Noort 2008). The target population for the 2007 survey included all privately owned residential properties in the WUI areas of the two counties. Using geographic information systems (GIS) and geo-coded data from the county assessors' offices, all of the parcels in the WUI were mapped, and a random sample of 3500 parcels with dwellings was selected. In the summer of 2007, a letter of invitation was mailed to these 3500 households; recipients had the choice of completing a Web-based survey or a paper survey. Nonrespondents were sent reminder mailings approximately 1 and 2 weeks after the initial mailing.

Overall, 2053 letters were successfully delivered and we received 747 responses, for a 36% response rate. Any response rate less than 100% gives rise to the possibility of nonresponse bias. It is often suggested that low response rates are more likely to be associated with nonresponse bias; however, results of a meta-analysis (Groves and Peytcheva 2008) did not find response rates to be a good predictor of nonresponse bias. While a nonresponse check was not performed for this study, we do note that compared to 2000 U.S. Census data for the counties, the survey respondents were more educated and had higher incomes than the overall populations of these counties. However, our survey sample frame only covered the areas within each county classified as WUI, and these areas may differ in key ways from than the counties as a whole (e.g., less urban, more second homes). Thus, we would not expect our sample characteristics to exactly match the Census data even with a perfect response rate.[2] Given these considerations, we limit our analysis and interpretation of results to relationships observed within this specific sample and do not attempt to generalize our findings to these counties or broader populations.

The resulting dataset includes a set of measures that we use to estimate Eqs. 1, 2, and 3. These variables are detailed in Table 1, and summarized in the following.

Social Interactions

The dataset includes a wide variety of variables measuring different types of social interactions. We categorize these interactions along two dimensions, generic vs. fire-specific and formal vs. informal, giving rise to four groups of social interactions measures. The *generic informal* interactions that are measured include living in close proximity to other households and reporting interacting with neighbors on a regular basis. Measures of *generic formal* interactions include participation in social and community groups. *Fire-specific informal* interaction measures include receiving wildfire-related information from friends, family, or neighbors, talking with neighbors about wildfire, and observing that vegetation on neighboring properties is dense. Finally, the *fire-specific formal* interactions include attending a wildfire-related event and receiving information about wildfire from wildfire experts.

Beliefs

Wildfire-related beliefs are measured with several variables (Table 1). First, we measure wildfire risk perceptions using a probability index and a consequence index (Brenkert-Smith et al. 2013). Second, several variables measure beliefs about mitigation options. We measure the perceived efficacy of mitigation, the perceived costs (time, money, and effort) involved in mitigating, the belief that additional information would be required to undertake mitigation, and the perceived aesthetic impacts of mitigation on one's property.[3]

Table 1. Description of variables used in the analysis

Variable	Description	*D*-Stats *N*	Range	Mean
Social interaction variables:				
Generic informal				
Closeneighb	Closest neighbor is less than 100 ft away	720	0–1	0.28
Knowneighb	Interact with neighbors at least monthly	701	0–1	0.76
Generic Formal				
Socgroup	Participate in social groups at least monthly	702	0–1	0.47
Comgroup	Participate in community groups at least monthly	700	0–1	0.17
Fire-specific informal				
Infoneighb	Received wildfire information from neighbors, friends, or family members	728	0–1	0.38
Talkfire	Ever talked to neighbor about fire	668	0–1	0.76
Neighbdens	Vegetation on neighboring properties is "dense" or "very dense"	699	0–1	0.32
Fire-Specific Formal				
Fireevent	Participated in wildfire-related event	728	0–1	0.43
Expertinfo	Received wildfire information from at least one of the following expert sources: local fire department; county wildfire specialist; Colorado State Forest Service; U.S. Forest Service	728	0–1	0.70
Belief variables				
The following indices were created by averaging the 5-point Likert-scale responses to multiple survey items that are listed for each index. The resulting indices are normalized to a 0–1 scale.				
Risk perceptions				
Probability	*Agree (0)/Disagree (1) with:* (1) a wildfire is unlikely to happen within the time period you expect to live here; (2) your property is not at risk of wildfire	696	0–1	0.74
Consequence	*Likelihood (0 = Not Likely, 1 = Very Likely)* of following impacts if fire occurs on property: (1) there would be some smoke damage to your home; (2) there would be some physical damage to your home; (3) your home would be destroyed; (4) your trees and landscape would burn	685	0–1	0.66
Mitigation Beliefs				
Efficacy	*Agree (0)/Disagree (1) with:* Actions to reduce the risk of loss due to wildfire are not effective.	699	0–1	0.23
Cost	*Amount of consideration (0 = None, 1 = Strong)* given to each of the following when deciding whether to take action to reduce the risk of loss due to wildfire on property: (1) financial expense/cost of taken action; (2) time it takes to implement actions; (3) physical difficulty of doing the work *Agree (0)/Disagree (1) with:* (1) you do not have the time to implement wildfire risk reduction actions (reverse coded); (2) you do not have the money for wildfire risk reduction actions (reverse coded)	684	0–1	0.41

(*Continued*)

Table 1. Continued

Variable	Description	*D*-Stats *N*	Range	Mean
Needinfo	*Amount of consideration (0 = None, 1 = Strong)* given to the following when deciding whether to take action to reduce the risk of loss due to wildfire on property: lack of specific information about how to reduce risk	690	0–1	0.28
Aesthetic	*Agree (0)/Disagree (1) with:* You live here for the trees and will not remove any of them to reduce fire risk (reverse coded)	701	0–1	0.24
Behavior variables:				
The behavioral variables are counts of the following self-reported mitigation actions:				
Structural	(1) Installed fire resistant roof; (2) Installed fire resistant siding on house or other buildings; (3) Installed screening over roof vents	728	0–3	0.91
Vegfuels	(1) Pruned limbs within a 30-foot perimeter of house; (2) pruned limbs within area 30–100 feet from house; (3) removed dead/overhanging branches within a 30-foot perimeter of house; (4) removed dead/overhanging branches within area 30–100 feet from house; (5) thinned trees and shrubs within a 30-foot perimeter of house; (6) thinned trees and shrubs within area 30–100 feet from house; (7) cleared leaves and pine needles from roof and/or yard to reduce wildfire risk; (8) mowed long grasses around home to reduce wildfire risk	728	0–8	4.5
Covariates:				
Version	Web = 1; mail = 0	728	0–1	0.69
County	Larimer = 1; Boulder = 0	728		0.44
Age	Respondent's age in years	677	15–87	56
Gender	Female = 1; male = 0	693		0.46
Income	Respondent's income (imputed for missing values)	671	25–200	95650
Lotsize	Lot size in acres	693	.25–750	10.6
Evacuated	Evacuated or prepared to evacuate = 1; otherwise = 0	718	0–1	0.38
Fire10	Wildfire within ten miles of property = 1; otherwise = 0	718	0–1	0.74
Parttime	Live in residence part-time = 1; otherwise = 0	721	0–1	0.07

Wildfire Mitigation Behaviors

Turning to the behavioral outcomes, the survey included a detailed section assessing actions the homeowners had taken to reduce wildfire risk on their properties. In particular, respondents were asked to indicate whether or not they had engaged in 12 risk reduction actions that are consistent with local recommendations outlined by the county wildfire programs in both counties. For these analyses, we aggregated these 12 indicators into 2 behavioral outcome variables: structural mitigation, and vegetative fuels mitigation (Table 1). We separated structural and vegetative mitigation because different types of mitigation may be associated with different motivations or be related to different obstacles, and the social interactions we examine may affect structural and vegetative mitigation in different ways.

Covariates

Finally, we also include several other covariates that have been shown to be related to mitigation choices (Table 1). These include the survey format (Web vs. mail), county, age, gender, income, lot size, prior evacuation and fire experience, and part versus full time residence.

Estimation

Using the variables in Table 1, we empirically estimate Eqs. 1, 2, and 3. For Eq. 1, we estimate regression models for each of the six belief variables. Because each of these belief indices is scaled between 0 and 1 (see Table 1), we use a fractional logit model for these regressions, with social interaction variables and the full set of covariates included as explanatory variables. For Eqs. 2 and 3, there are two mitigation-dependent variables: structural and vegetative fuels. Because these outcomes are ordered categorical variables (i.e., counts of the number of actions taken in each category), and because we did not want to impose the assumption that all actions had equal weight or importance, we estimated ordered logistic models. The right-hand side variables in Eq. 2 are the social interaction measures and the full set of covariates listed in Table 1. Equation 3 includes all of these variables and also adds the six belief indices.

Results

Table 2 shows results for Eq. 1, which corresponds to Path A in Figure 1. Table 3 presents results for Eqs. 2 and 3 (Paths B, C, and C′).

We find evidence supporting our first hypothesis (H1): Several types of social interactions are related to wildfire-related beliefs (Table 2). In particular, wildfire risk perceptions are significantly associated with all four types of social interactions. Perceived probability of wildfire is positively associated with generic formal interactions (participation in community groups), fire-specific informal interactions (receiving information from friends and neighbors, talking with neighbors about fire, and observing dense vegetation on neighbors' properties), and fire-specific formal interactions (receiving information from wildfire experts). Perceived consequences of wildfire are positively associated with generic informal interactions (proximity to neighbors) and fire-specific informal interactions (receiving information from friends and neighbors and observing dense vegetation on neighbors' properties). Fewer significant relationships are observed between social interactions and beliefs about wildfire mitigation. There are weak positive associations between the two fire-specific formal interactions and perceived efficacy of mitigation, while some fire-specific formal and informal interactions are associated with lower perceived barriers to mitigation. Specifically, perceived cost barriers are lower among those who have talked with neighbors about fire, while

Table 2. Beliefs as a function of social interaction factors (Eq. 1, Path A)

	Risk perceptions		Mitigation beliefs			
Variables	Probability	Consequence	Efficacy	Cost	Needinfo	Aesthetic
Generic informal						
Closeneighb	−0.088	0.23	−0.053	0.098	0.13	0.055
	(0.099)	(0.10)**	(0.11)	(0.091)	(0.12)	(0.11)
Knowneighb	−0.040	−0.17	0.0089	−0.043	−0.21	−0.12
	(0.11)	(0.11)	(0.11)	(0.096)	(0.13)	(0.12)
Generic formal						
Socgroup	0.058	0.15	−0.13	−0.090	−0.15	0.0098
	(0.095)	(0.099)	(0.10)	(0.088)	(0.12)	(0.11)
Comgroup	0.24	−0.098	0.043	−0.086	0.17	−0.11
	(0.12)**	(0.12)	(0.13)	(0.11)	(0.15)	(0.13)
Fire-specific informal						
Infoneighb	0.24	0.22	0.14	−0.051	0.056	0.077
	(0.089)***	(0.092)**	(0.099)	(0.082)	(0.11)	(0.10)
Talkfire	0.43	0.0068	0.12	−0.25	−0.25	−0.20
	(0.10)***	(0.11)	(0.12)	(0.098)**	(0.14)*	(0.12)
Neighbdens	0.32	0.32	−0.084	0.13	0.062	−0.037
	(0.090)***	(0.093)***	(0.099)	(0.082)	(0.11)	(0.10)
Fire-specific formal						
Fireevent	0.15	0.046	0.20	0.011	−0.11	−0.26
	(0.094)	(0.098)	(0.10)*	(0.087)	(0.12)	(0.11)**
Expertinfo	0.26	0.068	0.19	0.038	−0.48	−0.40
	(0.10)**	(0.11)	(0.11)*	(0.095)	(0.13)***	(0.12)***
Observations	536	536	536	536	536	536
Akaike's information criterion (AIC)	−509.0	−234.6	−562.5	−201.9	−661.8	−542.9
Schwarz's Bayesian information criterion (BIC)	−423.2	−149.0	−476.7	−116.2	−576.1	−457.2

Note. Coefficients are from fractional logit regressions. Robust standard errors in parentheses; significance: $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$. All covariates listed in Table 1 were also included in these regressions. Significant relationships (at 5% level) are as follows: (1) Respondents who took the survey via the Web (vs. mail) (*version*) negatively associated with *needinfo*; (2) women (*gender*) have higher perceived *probability, consequence,* and *efficacy*; (3) individuals with higher *income* have lower perceived *costs*; (4) previous evacuation (*evacuated*) associated with higher perceived *probability*; (5) prior wildfire within 10 miles of property associated with lower perceived *costs*; and (6) part-time (*pt*) residents have lower perceived *efficacy*.

perceived information barriers are negatively associated with *talkfire* and *expertinfo*. These latter two variables are also negatively associated with perceived aesthetic impacts of mitigation.

Our second hypothesis (H2) was that significant relationships would be observed between social interactions and wildfire mitigation behaviors (Path C). We find some support for this hypothesis in the case of both structural and vegetative mitigation (Table 3). Structural mitigation is negatively associated with proximity to neighbors and receiving information from neighbors and friends, and positively related to receiving information from experts. Meanwhile, vegetative mitigation is related to three of the four types of interactions: A negative relationship is observed in the case of generic informal interactions (proximity to neighbors), while fire-specific informal (*talkfire* and *neighbdens*) and formal (*fireevent* and *expertinfo*) interactions are all positively associated with vegetative mitigation.

Table 3. Mitigation behaviors as a function of social interaction factors and beliefs (Eqs. 2 and 3, Paths B and C)

Variables	Structural		Vegfuels	
	Eq. 2, Path C	Eq. 3, Paths B and C'	Eq. 2, Path C	Eq. 3, Paths B and C'
Social interactions				
Generic informal				
closeneighb	−0.37	−0.33	−0.66	−0.66
	(0.20)*	(0.20)	(0.19)***	(0.18)***
knowneighb	−0.29	−0.30	−0.14	−0.15
	(0.20)	(0.20)	(0.20)	(0.20)
Generic formal				
socgroup	−0.30	−0.30	0.046	−0.061
	(0.19)	(0.20)	(0.19)	(0.19)
comgroup	0.077	0.042	0.24	0.13
	(0.25)	(0.25)	(0.22)	(0.21)
Fire-specific informal				
infoneighb	−0.45	−0.44	0.21	0.21
	(0.19)**	(0.20)**	(0.17)	(0.18)
talkfire	0.34	0.28	0.67	0.40
	(0.22)	(0.23)	(0.21)***	(0.21)*
neighbdens	0.23	0.24	0.49	0.37
	(0.18)	(0.19)	(0.17)***	(0.17)**
Fire-specific formal				
fireevent	0.20	0.17	0.58	0.47
	(0.20)	(0.20)	(0.19)***	(0.18)**
expertinfo	0.71	0.68	0.67	0.40
	(0.20)***	(0.22)***	(0.21)***	(0.22)*
Beliefs				
Risk perceptions				
probability		0.40		2.29
		(0.51)		(0.49)***
consequence		−0.47		0.35
		(0.41)		(0.40)
Mitigation beliefs				
efficacy		−0.013		−0.98
		(0.50)		(0.44)**
cost		−0.21		−0.48
		(0.45)		(0.45)
needinfo		0.11		−0.59
		(0.31)		(0.30)*
aesthetic		−0.44		−1.70
		(0.49)		(0.40)***
Observations	536	536	536	536
Akaike's information criterion (AIC)	1289	1297	2190	2145
Schwarz's Bayesian information criterion (BIC)	1379	1413	2302	2282

Note. Coefficients are from ordered logistic regressions. Robust standard errors are in parentheses. Sample is restricted to parcels more than 0.25 acres in size (so all households do have property >30 ft from their house and could engage in all of the mitigation actions listed); significance: $^{***}p < .01$, .01, $^{**}p < .05$, $^{*}p < .1$. All covariates listed in Table 1 were also included in these regressions. Significant relationships are as follows: (1) Older age associated with higher levels of structural mitigation; (2) women report completing more structural mitigation; and (3) prior evacuation positively related to vegetative mitigation.

The third hypothesis (H3) posits that wildfire-related beliefs will be significantly associated with mitigation behaviors (Path B). We find no support for this hypothesis in the case of structural mitigation: None of the belief measure coefficients in Table 3 are significant in the structural mitigation model. However, this hypothesis does hold in the case of vegetative mitigation. A large and significant positive relationship is observed between perceived probability of wildfire and level of mitigation of vegetative fuels. There is a surprising negative relationship between the belief that mitigation is effective and observed vegetative mitigation actions.[4] We also observe negative relationships between vegetative mitigation and beliefs that more information is needed in order to be able to mitigate, and mitigation has negative aesthetic impacts.

Finally, H4 states that observed relationships between social interactions and mitigation behaviors should be smaller in magnitude when controlling for the hypothesized mediating variables, beliefs. Once again, we find some support for this hypothesis in the case of vegetative mitigation, but not for structural mitigation. In the latter case, the differences between Path C and C' coefficients are quite small; for example, the coefficient on *infoneighb* is -0.45 ($p < 0.05$) in Eq. 2 and -0.44 ($p < 0.05$) in Eq. 3 (Table 3). However, including beliefs does result in smaller Path C' coefficients in the case of the fire-specific social interactions and vegetative mitigation. For example, in the case of the *talkfire* variable, the coefficient is reduced from 0.64 ($p < 0.001$) in Equation 2 to 0.36 ($p < 0.1$) in Equation 3. Meanwhile, proximity to neighbors is negatively related to vegetative mitigation, and this relationship is largely unchanged when beliefs are added to the equation.

To specifically identify which relationships are consistent with our mediation model, we computed Sobel test statistics for all cases (i.e., social interaction–belief–mitigation combinations) in which all four of the preceding hypotheses were supported. All such cases involve vegetative mitigation (since H2 was rejected for structural mitigation), and the specific cases tested are identified as the shaded cells in Table 4. Defining A and s_A as the coefficient and its standard error from Eq. 1, and B and s_B as the coefficient and standard error from Eq. 3, the Sobel test statistic is computed as

$$z = \frac{A^{*}B}{\sqrt{B^{2*}s_A^2 + A^2 + s_B^2}}$$

Resulting test statistics and their significance levels are shown in Table 4. We find evidence that beliefs about the probability of a fire mediate the social interaction–behavior relationship for generic formal, fire-specific informal, and fire-specific formal interactions. More specifically, all of these interactions are associated with increases in perceived probability (Path A), which in turn is associated with increased vegetative mitigation (Path B). The overall mediation effect is a product of these two relationships, and is thus positive. In addition, perceived information barriers mediate the relationship between expert information sources and vegetative mitigation behaviors. In this case, receiving information from experts decreases perceived lack of information (Path A), and lack of information is negatively associated with vegetative mitigation (Path B). Multiplying these relationships together once again produces a positive mediation effect. Finally, beliefs

Table 4. Sobel tests: Mediation of social interactions' relationship with vegetative mitigation by beliefs

	Risk perceptions		Mitigation beliefs			
Variables	Probability	Consequence	Efficacy	Costs	Needinfo	Aesthetic
Generic informal						
Closeneighb						
Knowneighb						
Generic formal						
Socgroup						
Comgroup	**1.84***					
Fire-specific informal						
Infoneighb	**2.34****					
Talkfire	**3.16*****				1.55	
Neighbdens	**2.83*****					
Fire-specific formal						
Fireevent			−1.49			**2.07****
Expertinfo	**2.27****		−1.36		**1.74***	**2.62*****

Note. Sobel tests statistics with *p*-values in parentheses. Significance: $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$. Tests were run for all cases in which a significant relationship between the social interaction variable and the belief variable was observed in Table 2 (Path A in Figure 1), and a significant relationship between the belief measure and vegetative fuels was observed in Table 3 (Path B in Figure 1). A significant statistic (boldfaced) indicates that the relationship between the social interaction factor (row variable) and vegetative mitigation is significantly mediated by the belief index (column variable).

about aesthetic impacts of mitigation mediate the relationship between fire-specific formal interactions and vegetative mitigation. As described earlier, the Path A and Path B coefficients in these cases are both negative, leading once again to a positive mediation effect. Significant mediation relationships were not observed for perceived efficacy or costs.

Discussion

Our initial proposition was that wildfire-related beliefs mediate the relationship between social interactions and wildfire mitigation behaviors. Our results support this hypothesis for certain relationships. In particular, our strongest evidence points to a positive relationship between fire-specific social interactions and heightened perception of wildfire probability, which is in turn positively linked to vegetative mitigation. Interestingly, Martin, Martin, and Kent (2009) also found that wildfire risk perceptions acted as a mediating variable linking mitigation behaviors with a different set of explanatory variables, including subjective knowledge about fire and attitudes about mitigation. Meanwhile, we find no evidence that the mediation relationship holds for structural mitigation. A few significant relationships are observed between social interactions and structural mitigation actions (e.g., proximity to neighbors); however, these relationships do not appear to be operating through wildfire-related beliefs.

While these patterns of results are interesting, the next step is to consider the possible mechanisms or pathways underlying observed results. Why and how do social interactions shape wildfire-related beliefs and mitigation behaviors? Our review of the literature identified five potential pathways that could be relevant in this case: information transmission, social amplification of risk, risk interdependency, social norms, and social capital. We review our results in light of these possible pathways.

For vegetative mitigation, our results could be consistent with several potential processes. First, the strong relationship we observe between fire-specific interactions and perceived wildfire probability could be the result of information transmission, as well as social amplification of risk. That is, through interactions such as talking with neighbors about fire and attending wildfire-related events, homeowners in fire-prone areas may be learning about wildfire risk and assigning value to that risk in a way that makes them more concerned about the problem. This finding is consistent with other wildfire studies highlighting the importance of social networks as information sources (McCaffrey 2004; McCaffrey et al. 2011). In addition, we replicate our result from prior work (Brenkert-Smith et al. 2013; using the same data set) that individuals who engaged in fire-specific social interactions (e.g., talking with neighbors about fire or attending fire-related events) tended to think that wildfire was more likely to occur, and extend this finding to show that these individuals are also more likely to undertake vegetative mitigation actions.

In addition, our finding that perceived density of vegetation on neighboring properties is associated with heightened wildfire risk perceptions provides possible evidence for risk interdependency. The direction of the estimated relationships in our case is somewhat at odds with the pattern observed by Shafran (2008), in which homeowners were observed to have more defensible space when neighbors had more defensible space (i.e., sparser vegetation). In our case, we find that perceived risk is higher when neighbors have denser vegetation, and that higher risk perceptions are associated with higher mitigation.

Furthermore, the observed relationship between fire-specific formal interactions and (reduced) perception of aesthetic impacts from mitigation points in the direction of social norms. That is, it is possible that attending fire-related meetings may serve to shape members' opinions about whether mitigation is acceptable or desirable, thus overcoming one potential barrier to vegetative mitigation actions. This is consistent with findings regarding the role of social interactions in making mitigation normative (Sturtevant and McCaffrey 2006) and the influence of neighbors' approval or disapproval on likelihood of implementing risk reduction actions found by Monroe, Nelson, and Payton (2006).

Equally interesting is examining the patterns that we do not observe. First, while the social capital pathway might suggest that people with closer ties to friends and neighbors (i.e., people who engage in more generic social interactions) could have greater access to social resources to assist with mitigation and thus lower perceived costs (as in Brenkert-Smith 2010), we do not find strong evidence in this direction.

More notably, all of our evidence for social interactions–beliefs–behaviors linkages applies exclusively to vegetative mitigation. This implies that the decision-making process guiding structural mitigation actions is distinct, and not as closely tied to social processes. In contrast, some individual covariates included in the models were significantly associated with structural mitigation, including age and gender. We have also observed that wildfire education programs place more emphasis and provide more resources for vegetative mitigation than structural mitigation, perhaps providing more fodder for social effects in the former case compared to the latter. Whatever the explanation for this distinction, our results highlight the importance in clearly defining mitigation outcomes, and of examining possible differences between factors influencing different actions. Testing whether the pattern we observe in this context holds more generally across different WUI areas, and further examining possible reasons for this distinction, would be a fruitful direction for further study.

Finally, as with all observational studies, the nature of the data collected in this survey necessarily limits the extent to which causality can be determined. While we find strong evidence that different types of social interactions are related to wildfire-related beliefs and mitigation behaviors, we are not able to assert causal linkages. For some of the relationships we identify, it is likely that causality runs in both directions. One example involves the relationships between risk beliefs and fire-specific interactions. While talking about fire with neighbors may serve to increase perceived probability of a given hazard (the social amplification hypothesis), it is also likely that individuals who are more concerned about a hazard will actively seek out information from a variety of sources, including social sources (see Risk Information Seeking and Processing [RISP] theory, e.g., in Griffin, Dunwoody, and Neuwirth 1999). One can make a similar case in the context of our risk interdependency results: On the one hand, perceiving that neighbors have not mitigated may increase perceived fire risk; on the other hand, people with high risk perceptions may pay more attention to neighbors' (in)activity and thus be more likely to report that some neighbors are not doing their part. In still other cases, unobserved variables may be driving multiple observed outcomes. For example, local wildfire outreach programs may shape both hazard-related beliefs (Brenkert-Smith et al. 2013) and mitigation behaviors. As these examples illustrate, a key challenge with observational data is that a single pattern (e.g., more social interaction being correlated with more mitigation) has multiple potential explanations. This "identification problem" has been discussed extensively in the econometrics literature (Manski 1993; Moffitt 2001; Soetevent 2006), among other places.[5]

Ultimately, we believe that a combination of experimental and observational approaches, and both quantitative and qualitative methodologies, will be necessary to gain a richer and more complete understanding of the ways in which social interactions relate to hazard beliefs and mitigation actions. This kind of information, in turn, can assist hazard managers as they grapple with the task of reducing hazard exposure for different populations. The wildfire management community is actively seeking effective approaches to encourage the growing WUI population to take more action to reduce risk. The effort here to better understand the social processes related to risk reduction behavior can shed light on possible solutions in this particular context, and many lessons and methods will be applicable to other hazards as well. The results demonstrate that there are multiple, complex, and interacting relationships between social interactions, hazard-related beliefs, and mitigation outcomes. However, clarifying the mechanisms underlying these patterns requires additional exploration.

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Notes

1. It is also the case that social interactions within households (e.g., between spouses) can play an important role in shaping wildfire-related beliefs and mitigation actions. For the purposes of this article, we are focused on interactions between households.
2. This lack of correspondence between our sample and the census areas also precludes application of survey weights.
3. Unfortunately, our survey did not include good measures of the perceived social rewards or penalties of mitigation, such as whether individuals think that neighbors would approve of mitigation actions. These types of measures would be a useful addition to future surveys.
4. In other analyses we ran where the efficacy variable is included without the other belief measures, the relationship with vegetative mitigation is positive and not significant.
5. Experimental and quasi-experimental approaches offer one potential solution to some of the challenges involved in identifying causal social effects. Laboratory experiments in this vein include Meyer's (2008) use of computer-based visual games to examine households' protective decisions in the face of earthquakes and hurricanes. Relevant field experiments include the use of "social comparisons" messages that focus attention on how an individual's behavior stacks up against that of her peers (e.g., Ferraro and Price 2013).

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