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Trying Not to Get Burned: Understanding Homeowners' Wildfire Risk–Mitigation Behaviors

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Abstract Three causes have been identified for the spiraling cost of wildfire suppression in the United States: climate change, fuel accumulation from past wildfire suppression, and development in fire-prone areas. Because little is likely to be performed to halt the effects of climate on wildfire risk, and because fuel-management budgets cannot keep pace with fuel accumulation let alone reverse it, changing the behaviors of existing and potential homeowners in fire-prone areas is the most promising approach to decreasing the cost of suppressing wildfires in the wildland–urban interface and increasing the odds of homes surviving wildfire events. Wildfire education efforts encourage homeowners to manage their property to decrease wildfire risk. Such programs may be more effective with a better understanding of the factors related to homeowners' decisions to undertake wildfire risk–reduction actions. In this study, we measured whether homeowners had implemented 12 wildfire risk–mitigation measures in 2 Colorado Front Range counties. We found that wildfire information received from local volunteer fire departments and county wildfire specialists, as well as talking with neighbors about wildfire, were positively associated with higher levels of mitigation. Firsthand experience in the form of preparing for or undertaking an evacuation was also associated with a higher level of mitigation. Finally, homeowners who perceived higher levels of wildfire risk on their property had undertaken higher levels of wildfire-risk mitigation on their property.

Keywords Risk-reduction behaviors · Wildfire risk · Homeowner behavior · Wildland–urban interface · Survey

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Introduction

Wildfire-suppression costs have been affected by the influx of individuals choosing to live in the areas most susceptible to wildfires, the wildland–urban interface (WUI). Because current wildfire-suppression budgets in the United States are not sustainable, it is imperative that new and existing WUI residents mitigate the wildfire risk on their property to decrease the risk of losing their home in a wildfire event. Wildfire education programs are designed to inform WUI residents of the risk, provide information on mitigation options, and encourage them to take action. Recent case studies of WUI communities suggest that these education programs are somewhat successful in that property owners are fairly aware of wildfire risk, and many are taking action to decrease risk (Brenkert-Smith and others 2006; Cohn and others 2008; Nelson and others 2004; Martin and others 2009; McCaffrey and others 2011).

Understanding the factors related to wildfire-mitigation behavior is a first step toward the development of more effective wildfire programs. Case studies employing qualitative research methods have found that many factors are related to wildfire risk–mitigation decisions, including the local context in which wildfire decisions occur (Brenkert-Smith 2010), variation in perceived community capacity

(Agrawal and Monroe 2006), landscape type (Monroe and others 2006), vegetative type (Merrick and Vining 2006), place dependency (Collins 2008), issue salience (Daniel 2008), community policy (Winter and others 2009), and institutional incentives (Collins 2005). The results of these case studies highlight the diversity of WUI contexts and provide insight into wildfire risk–mitigation decisions of WUI residents within the community-specific context.

However, wildfire education efforts in the United States occur at many levels from the local volunteer fire department to the federal government. Therefore, it is necessary to understand what factors transcend specific-community contexts, which are most strongly associated with behavioral outcomes, and which should be prioritized in developing education and outreach programs for WUI property owners. Indeed, whereas property owners' actions are increasingly the focus of study, only some of the current research has specifically sought to identify factors related to property owners taking action to decrease risk using data beyond the community case–study scale. Addressing this gap can inform the development of effective programs that encourage risk-reduction efforts in the form of fuel reduction and structural improvements among WUI property owners.

In Colorado, counties often develop and implement programs to educate WUI property owners about wildfire risks. In this study, we analyze survey data from WUI residents in Larimer and Boulder Counties, two adjacent northern Colorado counties along the Front Range of the Rocky Mountains. This study makes two contributions to the current literature on homeowners and wildfire risk–mitigation behavior. First, we move beyond the case study approach to a general WUI population sample that transcends a single community or county-level wildfire education program. Second, we focus on factors identified in the hazards- and wildfire-specific literature to identify explanatory variables in a multivariate model of risk-mitigation behavior. This approach allows us to incorporate many of the key factors hypothesized to be related to wildfire risk–mitigation decisions into one model that can provide insight into the relative effect of the various factors.

Literature

The loss of homes due to wildfire in the WUI is determined by a multitude of factors. Unlike weather and wind patterns, ignitability of homes and the vegetation surrounding them are factors that can be controlled and altered by property owners. Despite variation in topography, forest type, and land use across WUI areas in the United States, the recommendations for risk reduction on private properties are fairly standard. Fire science indicates that the likelihood of major wildfire-related losses to WUI homeowners can be significantly decreased by improving structural characteristics and removing vegetative fuels for combustion in the areas surrounding homes known as the "home ignition zone" (Cohen 2000). Few data exist to document the extent to which these measures are being implemented or to systematically assess the factors related to adoption.

The literature provides some guidance on factors associated with mitigation outcomes; however, the majority of that research concerns hazards other than wildfire. Among the studies examining wildfire-mitigation behaviors, the majority of the work is case study–based, and findings have yet to be tested on samples from broader geographic areas, thus leaving it unclear to what extent factors found to be linked to mitigation outcomes are location-specific. Here we review the studies that have sought to identify determinants of intended or reported risk-reduction action among homeowners facing wildfire risk. We use this literature to inform the construction of the behavioral model to examine mitigation outcomes.

Factors Associated With Risk-Mitigation Behaviors

Demographics

In the literature on natural hazards, demographic characteristics, including age, sex, and income, have been found to be related to risk-related behavioral outcomes (Lindell 1997; Lindell and Whitney 2000; Tierney and others 2001). Research offering insight into the characteristics of WUI property owners and factors related to wildfire risk–mitigation behaviors, however, has yet to produce consistent findings. For example, Collins (2008) found income to be a significant determinant of mitigation behaviors, whereas Martin and others (2009) and Fischer (2011) failed to find such a relationship. Other characteristics of WUI homeowners, including retirement status, length of residence, and livelihood dependence, have been found to be significant determinants of mitigation outcomes (Collins 2008). The status of WUI residents (i.e., full-time or seasonal) has been linked to behavioral intentions (Bright and Burtz 2006) and behavioral outcomes (Collins 2008), but not so in all studies (Schulte and Miller 2010).

Most of the wildfire studies that have collected standard demographic data (e.g., age, sex, education, and income) as well as household characteristics, such as parcel size, vegetative conditions on parcel, or proximity to forest, have used the information to describe the study respondents or identify correlations rather than in a regression model of behavioral intentions or outcomes (Hall and Slothower 2009; Jarrett and others 2009; Martin and others

2007). However, Fischer (2011) included age as an explanatory variable in a model of whether landowners had treated their acreage to decrease fire risk and found that older respondents were less likely to have treated their land parcels to decrease wildfire risk.

Risk Perceptions

Protection Motivation Theory (PMT) posits that perceived risk, along with perceptions of capacity to respond to that risk, are necessary for action to take place (Rogers 1983) and has been used in several recent wildfire studies. Examining behavioral intentions, Martin and others (2007) found that mitigation intentions among homeowners with greater knowledge about wildfire were motivated by perceived risk severity, self-efficacy, and response efficacy, whereas no such link was showed in relation to action among those with less knowledge. Examining behavioral outcomes, Martin and others (2009) and Fischer (2011) found that greater risk perceptions were significantly related to higher levels of mitigation. Likewise, Nelson and others (2004) found that property owners who perceive greater wildfire risk were more likely to mitigate. McCaffrey (2002) also found that perceptions of modest levels of risk were related to the creation of evacuation plans, yet only homeowners with perceptions of very high risk took significant steps to decrease the amount of fuels on their properties (McCaffrey 2002). Despite this growing evidence of a positive relationship between risk perceptions and risk-mitigating behaviors, research regarding risk perception among WUI property owners continues to demonstrate inconsistencies (McCaffrey 2004). For example, research has found significant relationships between risk perception and willingness to implement defensive mitigation actions to be lacking (Hall and Slothower 2009) or found that homeowners declined to take action to decrease risk despite understanding and being concerned about risk (Nelson and others 2005). Other work, focusing on the more qualitative aspects of fire, has shown that homeowners who perceive fire as uncontrollable and random reject risk-reduction efforts (Winter and Fried 2000), whereas other research has found that WUI residents were "unduly optimistic about their risk" (Kumagai and others 2004).

Hazard Experience

The relationship between hazard experience and the adoption of risk-mitigating behaviors is tenuous in the natural-hazards literature (Tierney and others 2001). In the wildfire domain, recent qualitative work indicates that the link may well exist (McCaffrey and others 2011), but other studies have failed to find statistically significant relationships between recent fire experience and mitigation outcomes (Hall and Slothower 2009; Martin and others 2009; Schulte and Miller 2010). Importantly, results from qualitative wildfire studies highlight the fact that individuals' experiences and interpretations of an event can vary widely (McGee and others 2009), which may result in different behavioral outcomes.

Efficacy (Mitigation and Self)

The link between perceived efficacy of mitigation measures to decrease the risk of the threat at hand, also known as response efficacy, and behavioral outcomes has been documented in the broader hazards literature (Lindell and Whitney 2000; Tierney and others 2001) and is relatively intuitive. Expanding on this, the Theory of Planned Behavior (TPB) links perceived behavioral control of risk-reduction actions with attitude and beliefs about the behavior, and subjective norms, to behavioral intentions and outcomes (Ajzen 1991). Using TPB and PMT to examine intended and completed wildfire mitigation, one recent study found that intention to implement mitigation actions was significantly and positively related to perceived effectiveness of and general attitudes toward risk-reduction measures (Hall and Slothower 2009). Another, using PMT and other hazard theories, found a significant link between perceived effectiveness and mitigation (McFarlane and others 2011). Other recent work in the wildfire area, however, has not found a significant link between the two (McGee 2005; Schulte and Miller 2010).

In contrast, some studies have shown that self-efficacy (perceptions of one's ability to implement recommended actions) may also be a critical piece of the mitigation picture (Nelson and others 2004; Martin and others 2007, 2009). Indeed, homeowners who believed they were knowledgeable about wildfire risk were found to be more likely to take action to decrease risk based on perceptions of risk severity (Martin and others 2007). Corroborating this result, education of homeowners regarding their specific fire hazard and mitigation options has been found to increase homeowner involvement in fire prevention–related activities (McCaffrey 2004). These findings are consistent with other hazards research that has found significant correlations between risk perceptions and knowledge of a hazard with adoption of mitigation actions (Lindell and Whitney 2000). Still, education and knowledge about wildfire risk alone are not necessarily sufficient to impel action. Reluctance to engage in vegetation reduction has been found in property owners who have concrete and often experiential understandings of wildfire risk (Cohn and others 2008).

Furthermore, others have found that taking action to decrease risk is contingent on the belief that action will be effective and worth the tradeoffs (Steelman 2008).

Determining how homeowners characterize worthwhile tradeoffs remains elusive; however, some studies have found that time and cost required to implement measures may serve as obstacles to implementation (Hodgson 1995; Collins 2005), whereas other work has found that perception of cost or effort were not significant predictors of completed or intended behaviors (Hall and Slothower 2009).

Information Sources and Social Interactions

Sources of information about risk and the role they play in risk-reduction behaviors has been a central line of inquiry in the natural-hazards literature. Careful to acknowledge the relationship between information sources and social influence, research has explored the role that media, hazard expert, and informal sources of information play in providing information influencing social norms (Lindell 1997). In the wildfire arena, work examining information sources focuses on trust in agency information and forest management (Winter and others 2004; Vogt and others 2005), but less attention has focused on the link between mitigation behaviors and sources of information about wildfire risk or mitigation options. One recent study found that property owners reported that state or federal forest agency outreach provided motivation for wildfire-mitigation actions (McCaffrey and others 2011). A recent study, focused on the social amplification of risk (Kasperson and others 1988), highlighted the importance of nonexpert information sources and informal social interactions in shaping wildfire-risk perceptions along with traditional expert information sources (Brenkert-Smith and others *forthcoming*). Finally, findings in the broader hazards field have stressed the importance of informal sources of information and influence on risk-related decisions and encouraged pursuit of this line of inquiry (Short 1984; Lion and others 2002). To date, there have been mixed findings about the role that social interactions and context play in wildfire-mitigation outcomes. Although some studies have found that social bonds (McGee 2005) and relationships among community members (McCaffrey and others 2011) were not related to mitigation outcomes, other recent research has found that risk-reduction actions undertaken by one's neighbors, as well as community mitigation efforts, were significantly and positively linked to survey respondents' behavioral outcomes (Schulte and Miller 2010).

A Behavioral Model of Wildfire Mitigation

Based on the hazards and wildfire-risk literature summarized previously, we posit that wildfire-mitigation behaviors are related to demographic characteristics, risk perception, wildfire experience, perception of efficacy, and sources of wildfire information and social interactions. We model wildfire risk–mitigation (M*) as:

$$M* = \alpha_1 x + \varepsilon,$$

where x is a vector of explanatory variables that includes measures of demographics, risk perception, wildfire experience, perceptions of efficacy, and sources of information and social interactions; α_1 is a parameter vector; and ε is an error term. M* is a latent variable, but we do observe the number of mitigation actions that an individual completes.

Data

A survey was developed to provide insight into homeowners' decisions to implement wildfire risk–mitigation actions. A qualitative study (Brenkert-Smith and others 2006) and four focus groups with residents in the two target counties were used to inform the development of the survey. The survey included questions about wildfire-mitigation activity as well as questions about characteristics of respondents' property, such as parcel size, vegetative fuel conditions on own and neighboring properties, sources of information about wildfire, beliefs about the role of wildfire in nature, the controllability of wildfire, and sources of risk related to wildfire. A summary of the responses to every survey question can be found in Champ and others (2012a, b).

Setting

Boulder and Larimer counties in Colorado were ranked as 2 of the top 25 counties in existing wildfire risk in the United States (10th and 19th ranking, respectively) based on an assessment of the number of square miles of developed land within the WUI (Gude and others 2008). Using the same metric, Boulder and Larimer counties were ranked as the top 2 counties at risk of wildfire in Colorado (Gude and others 2008). In addition, a series of wildfires occurred across the study counties in recent years. The Fourmile Canyon fire in Boulder County in 2010 destroyed 169 homes and was at that time the most destructive wildfire, in terms of total losses, in Colorado's history. In 2012, the High Park Fire in Larimer County caused 1 death and destroyed 259 homes.

Target Population and Sampling

Using geographic information systems, geo-coded data from the county assessor's offices, as well as county wildfire-risk maps, we populated the counties' fire-prone WUI areas with parcel information for private residential properties. These maps allowed us to construct sample frames of residential parcels on which there were homes for each of the counties. From these sample frames, for

each county a random sample of 1,750 parcels with homes was selected yielding a total sample of 3,500 residential parcels with homes.

Survey Implementation

The survey was implemented in the summer of 2007. Respondents were given a choice of completing a Web-based (i.e., online) version of the survey or a paper survey. All potential participants were mailed a first class envelope with a letter of invitation to participate in the survey, a unique identifying number, a response card for those who wanted to participate using a paper survey, and a Web address and instructions for those who were interested in participating online. Participants who returned the postage-paid response card indicating their interest in completing a paper version of the survey were sent a survey, a letter with instructions and thanks, and a postage-paid envelope for returning the survey. Participants who chose to complete the survey on-line logged onto a Web site and usually completed the survey in 15–20 min. A second mailing was sent to all nonrespondents approximately 1 week after the first mailing. A third and final mailing was sent to remaining nonrespondents approximately 1 week after the second mailing.

The overall response rate was approximately 36 % for both counties. Boulder County respondents were more likely to choose to complete the web-based survey than Larimer County respondents. Seventy-five percent of the Boulder County respondents used the Web interface compared with 63 % of the Larimer County respondents (Table 1).

Measures of Wildfire-Risk Mitigation

Among recent studies, wildfire-mitigation intentions and behaviors have been measured in a number of similar but not identical ways. Because no study appears to have identified an approach without shortcomings, we defaulted to wildfire experts to guide the development of the instrument for this study. Based on consultation with wildfire experts from Boulder and Larimer counties, we developed a 12-item list of mitigation measures that both counties encourage homeowners to complete. Respondents were asked to report whether or not they had implemented each of the 12 items since moving onto their property. The list included vegetative fuel-reduction options within a 30-foot perimeter of the home as well as similar options in the zone 30–100 feet from the home. It also included a number of structural mitigation options commonly encouraged for wildfire-risk reduction. The measure does not include when the mitigation action was implemented or qualitative aspects of implementation, such as the intensity of the vegetative fuel reduction.

As mentioned in the literature review, few quantitative studies have examined factors associated with wildfire risk–mitigation behavior (Collins 2008; Martin and others 2007, 2009; McGee 2005; Schulte and Miller 2010). Although the survey questions used to measure mitigation effort were fairly similar across these studies and this study, the creation of a single measure of mitigation level varied. In three of the studies (Collins 2008; Martin and others 2007, 2009), a continuous variable was created to measure mitigation level by summing the number of mitigation actions the survey respondent said they had completed [or intended to complete (Martin and others 2007)]. Schulte and Miller (2010) combined the 5 mitigation actions into a dichotomous variable with 1 group being respondents who had completed the vegetation-management actions only and 1 group comprising those who completed vegetation-management actions plus at least 1 other type of mitigation action (e.g., heat-resistant windows, fire-resistant construction, etc.). We take a hybrid approach to creating a single mitigation variable from the 12 mitigation actions. The justification for this approach is that we know all mitigation actions are not commensurate and therefore deem it inappropriate to create a continuous variable as other have (Collins 2008; Martin et al 2007, 2009). However, much information is lost with a dichotomous categorization such as that taken by Schulte and Miller (2010).

Therefore, we categorized respondents into three groups based on the number of mitigation actions (M) they reported implementing. Specifically, an ordered categorical variables m was created such that:

$$m = \begin{cases} 1 \text{ if } M \leq 4 \\ 2 \text{ if } 4 < M \leq 9 \\ 3 \text{ if } M \geq 10 \end{cases}$$

The cut-off points for the three categories are admittedly a bit *ad hoc*. However, the use of three categories (low, mid, and high) is intuitively appealing, and the statistical differences between respondents in these categories are significant for each mitigation action ($P < .001$) as listed in

Table 1 Response rate by county

County	Initial letters	Undeliverable	Delivered	Completed and useable	Total	Response rate (%)
Boulder	1750	602	1148	316 (online), 105 (mail)	421	36.7
Larimer	1750	845	905	205 (online), 121 (mail)	326	36

Table 3. Likewise, as listed in Table 4, the three levels capture distinct groups of mitigators. Because *m* is an ordered categorical variable, we estimated this model using an ordered logistic regression.

Independent Variables

We used the hazards- and wildfire-risk literature summarized previously to inform the inclusion of explanatory variables in the mitigation model. We included variables from the five categories suggested by the literature (demographic and parcel characteristics, risk perception, wildfire experience, efficacy, and wildfire information sources and social interactions). In addition, we controlled for the county (Boulder or Larimer), the version of the survey (mail or web), and lot size. The definitions of the variables are listed in Table 4.

Results and Discussion

Study Design Factors

Due to the fact that we provided two options for survey response (mail and on-line), it was important to assess whether or not responses to questions varied significantly by mode of administration (Dillman 2000). Furthermore, because the survey was administered in two counties in which fire outreach, education, and code enforcement run primarily through county-based programs, it was also important to assess whether or not responses varied significantly by county. In both counties, the distribution of responses to four questions were statistically different between mail and on-line survey respondents ($P < .001$): (1) number of people <18 years old living in the current residence, (2) race, (3) employment status, and (4) age. In Boulder County, there were statistical differences between the modes of response based on an additional question: income. Age was the only factor that was related to mitigation outcomes in a statistically significant manner because older respondents implemented more mitigation measures overall and were more likely to adopt structural mitigation measures than younger respondents. In the estimated model, we included variables for county and mode of administration. In the regression model of mitigation behaviors discussed later in the text, we find that estimated coefficients on county and mode of administration are significantly different from zero (Table 4).

Respondents

Overall, the average respondent was 56-years-old with very few <24 (.4 %) years or >75 (4.6 %) years old. Slightly more men (54 %) than women responded and almost all of the survey respondents identified "white" as their racial group (96.4 %). Seventy-five percent of the respondents were married (Table 2).

The respondents were highly educated with 36 % having advanced degrees. Although we are not able to compare the demographic characteristics of the survey respondents to United States Census data for the WUI areas only, the survey respondents were more educated and wealthier than residents in the counties as whole. Mean income also appears to be higher within the study sample than the rest of the counties. It is not surprising that the WUI respondents would have somewhat different demographic characteristics than the counties as a whole because both WUIs are within commuting distance of major universities (Colorado State University in Larimer County and University of Colorado in Boulder County) and are desirable locations due to their proximity to environmental amenities.

In comparing respondents based on mitigation level, we see significant differences between levels based on marital status ($P < .05$) and income ($P < .05$). As discussed later in the text, we include a proxy measure for income in the regression model and find the estimated coefficient to be positive and statistically significant (Table 4).

Parcel Characteristics

Important to issues of fuel management, lot size varied among study respondents. The majority of respondents own parcels that are .25–2 acres (41.6 %) or >2 acres (52.2 %). Only 45 respondents (6.2 %) reported owning parcels <.25 acre. We find statistically significant differences in mitigation level in relation to lot size ($P < .001$) and subsequently include lot size as a control variable in our regression model. As described in the next section, we focus the analyses and discussion of this article on mitigation outcomes, which include vegetative fuel reduction beyond 100 feet of respondents' homes. Therefore, we exclude the 45 respondents who live on parcels <.25 acre in the analyses that follow.

Mitigation Behaviors

Almost all respondents had completed at least one wildfire risk–reduction action, and the average number of actions completed was 6.22. Overall, the most commonly implemented action was installing a visible house number (71.9 %), whereas the most common fuel-reduction action was removing dead or overhanging branches within a 30-foot perimeter of the home (70.6 %). The least common measure was a structural change: installing fire-resistant siding to the home (19.1 %). A complete list and description of each item and frequency of implementation is provided (Table 3).

Table 2 Demographic characteristics of survey respondents by mitigation level ($n = 747$)

Characteristics	% Overall ($n = 747$)	% Low ($n = 234$)	% Mid ($n = 401$)	% High ($n = 112$)
Age				
Mean	55.9	52.72	56.9	58.3
Sex				
Male	54.2	51.3	56.0	53.2
Female	45.8	48.7	44.0	46.8
Race				
White	96.4	94.4	97.3	97.1
Other[a]	4.8	3.0	5.6	5.1
Marital status**				
Never married	8.7	13.6	6.9	5.6
Married	74.9	70.9	74.9	82.4
Divorced	11.3	12.1	12.0	7.4
Widowed	5.1	3.5	6.1	4.6
Education				
Some college or technical school	19.3	20.1	14.3	12.1
College graduate	29.7	29.6	31.0	25.2
Some graduate work	11.4	8.0	12.8	13.1
Advanced degree	35.8	32.7	35.9	41.1
Employment				
Full-time	38.5	39.3	39.1	35.2
Part-time	7.3	9.0	6.1	8.3
Self-employed	19.9	20.9	18.7	22.2
Retired	31.1	25.9	33.5	32.4
Unemployed	3.2	5.0	2.6	1.9
Income**				
<$25,000	4.2	7.5	1.8	6.3
$25,000–$34,999	7.3	8.6	6.9	6.3
$35,000–$49,000	11.4	10.2	12.9	8.4
$50,000–$74,999	19.2	22.0	18.6	15.8
$75,000–$99,999	17.3	12.4	20.4	15.8
$100,000–$124,999	15.3	17.2	14.7	13.7
$125,000–$200,000	17.3	14.0	18.3	20.0
>$200,000	8.0	8.1	6.3	13.7
Lot size (acre)***				
<.25	6.2	9.9	5.5	1.8
.25 to 2	41.6	42.5	45.5	25.9
>2	52.2	47.6	49.0	72.3

[a] Respondents had the option to respond to all categories that applied

*** $P < .01$

** $P < .05$

* $P < .1$

In comparing respondents by mitigation level, we see significant differences ($P < .001$) between mitigation levels for each mitigation action. Interestingly, we see that the most common activities for low-mitigators are mowing long grasses around the home to decrease wildfire risk (48.2 %) and installing a clearly visible house number (45 %). This fuel-reduction action could be considered typical yard maintenance, i.e., no different than the types one might practice in a typical suburban neighborhood. In contrast, among high-mitigators the most common activities are removing dead or overhanging branches within a 30-foot perimeter of the home (100 %) and pruning limbs so the lowest branches are 6–10 feet from the ground within a 30-foot perimeter of the home (98.2 %). We also see that approximately 50 % of mid-level mitigators and nearly all of the high-mitigators implemented vegetative fuel–reduction actions in the 30- to 100-foot zone from the home, whereas ≤10 % of the low-mitigators chose to implement any of these actions.

Table 3 Wildfire risk–reduction actions ($n = 677$)

Description	Percent who completed action			
	% Overall	% Low ($n = 191$)	% Mid ($n = 376$)	% High ($n = 110$)
Vegetation actions				
Pruned limbs so lowest limb is 6–10 ft from the ground within a 30-ft perimeter from your house or other buildings (limb30)	57.3	13.6	67.6	98.2
Thinned trees and shrubs within a 30-ft perimeter from your house or other buildings (thin30)	58.3	13.6	69.7	97.3
Removed dead or overhanging branches in area within a 30-ft perimeter from your house or other buildings (br30)	70.6	24.1	85.6	100
Pruned limbs so the lowest is 6–10 ft from the ground in the area 30–100 ft from your house or other buildings (limbgt30)	42.1	4.2	45.2	97.3
Thinned trees and shrubs in area 30–100 ft from your house or other buildings (thingt30)	45.6	4.7	51.6	96.4
Removed dead of overhanging branches in area in the area 30–100 ft from your house or other buildings (brgt30)	50.2	10.5	56.6	97.3
Structural actions				
Installed a fire-resistant roof (roof)	50.7	21.5	52.4	95.5
Installed fire-resistant siding on your house or other buildings (side)	19.1	3.7	18.6	47.3
Installed screening over roof vents (screen)	23.6	6.3	20.5	64.5
Other actions				
Installed house number in clearly visible place (number)	71.9	45.0	80.6	89.1
Mowed long grasses around your home to decrease wildfire risk (mowf)	70.3	48.2	74.7	93.6
Cleared leaves and pine needles from your roof and/or yard to decrease wildfire risk (leavesf)	62.2	22.5	73.4	92.7
Mean no. of completed actions	6.22	2.18	6.97	10.69

All actions are significantly different by mitigation level, *** $P < .01$ based on contingency table analyses

Factors Associated With Mitigation Behaviors

Contingency table analyses allows for an examination of the relationship between mitigation levels and the independent variables in isolation before moving on to the multivariate model, which controls for confounding factors. In Table 4, we see that level of mitigation is related to many of the independent variables as expected. As described later in the text, many of these relationships also hold in the multivariate model, but a few do change.

Unlike a linear model, the interpretation of the coefficient estimates in an ordered logistic regression is not straightforward (Agresti 2002). To facilitate interpretation of the coefficients and allow for a comparison of the relative effects, a proportional odds ratio is calculated by taking the exponent of the estimated coefficient. The proportional odds ratio is an estimate of the odds of being in a higher response group (mitigation level) for a one-unit increase in the explanatory variable holding the other explanatory variables in the model constant.

Overall, we see that many of the explanatory variables in the ordered logistic regression have significant coefficient estimates bearing evidence to the many factors related to wildfire-mitigation behaviors (Table 4). The study design elements (version and county) are not related to mitigation level. However, the lot size variable had a positive and statistically significant coefficient suggesting that individuals with larger lots reported higher levels of mitigation (Table 5).

When we consider the demographic variables, we see that older respondents, as did women, reported higher levels of mitigation. The coefficient on the income proxy variable is negative and significant at the 10 % level suggesting that respondents who said they did not have the money for wildfire-risk mitigation performed lower levels of wildfire-risk mitigation. The results from the regression model for age and income proxy are consistent with the results from the contingency table analyses as well as some previous wildfire studies (Collins 2008; Fischer 2011). We did not see a statistically significant relationship between sex and mitigation level in the contingency table analysis.

The two measures of perceived wildfire risk both have significant coefficients, but the signs were different on the two measures. Respondents who did not think their property was at risk of wildfire had lower levels of mitigation, whereas respondents who thought the vegetation on their property at the time of purchase contributed to wildfire risk had higher levels of mitigation.

Table 4 Associations between mitigation and explanatory variables

Variables	χ^2
Parcel characteristics	
Lot size (n = 677) (0 = ≤2 acres; 1 = >2 acres)	17.201***
Demographic characteristics	
Age (quartiles) (n = 631)	23.639***
Sex (n = 645) (1 = female; 0 = male)	.385
Do not have the money for wildfire risk–mitigation actions (n = 648) (1 = agree; 0 = otherwise)	10.953***
Risk perception	
Property is not at risk of wildfire (n = 653) (1 = agree; 0 = otherwise)	32.371***
Vegetation on property when purchased or rented (1 = contributes to wildfire risk; 0 = does not contribute)	32.903***
Wildfire experience	
Evacuated (n = 670) (1 = ever evacuated or prepared to evacuate; 0 = otherwise)	23.619***
Fire within 10 miles (n = 670) (1 = wildfire within 10 miles of property; 0 = otherwise)	19.630***
Efficacy (mitigation and self)	
Actions to decrease risk of loss from wildfire are not effective (n = 653) (1 = agree; 0 = otherwise)	1.587
Time it takes to implement risk-reduction actions (n = 651) (1 = strong consideration; 0 = otherwise)	.726
Physical difficulty of doing the work (n = 643) (1 = strong consideration; 0 = otherwise)	.639
Lack of specific information about how to decrease risk (n = 645) (1 = strong consideration; 0 = otherwise)	24.993***
Wildfire information sources & social interactions	
Neighbors, friends, or family members (n = 575) (1 = use source; 0 = otherwise)	14.271***
Local fire department (n = 631) (1 = use source; 0 = otherwise)	44.751***
County wildfire specialist (n = 575) (1 = use source; 0 = otherwise)	66.971***
Media (n = 587) (1 = use source; 0 = otherwise)	3.670
Talk about fire (n = 626) (1 = ever talked about wildfire with neighbor; 0 = otherwise)	33.997***

Contingency table analyses (*** $P < .01$; ** $P < .05$; * $P < .1$)

Having experienced a wildfire within 10 miles of the property did not seem to affect the mitigation level. This result differs from the contingency table analysis result. In contrast, experience with wildfire in terms of having been evacuated was positively related to higher levels of mitigation in a statistically significant manner. These results are similar to those of previous wildfire studies. McGee and others (2009) found that having been evacuated led to implementation of new mitigation measures. However they also found that other types of experience with wildfire, such as losing a home during a fire, had little effect on the adoption of new mitigation measures. Likewise, a recent study by Martin and others (2009) found that direct experience with wildfire was not significantly related to mitigation behavior.

The coefficient estimate on the measures of mitigation efficacy (agreement with the statement "actions to decrease the risk of loss due to wildfire are not effective") was not significantly different from zero. This result is consistent with what we found in the contingency table analyses and may indicate that other processes, such as the development of social norms regarding mitigation behavior, may be playing role in mitigation outcomes. Indeed, acting in ways that comply with social norms may provide feelings akin to a "warm glow" (Videras and Owen 2006), that is, norms may make some actions more desirable in particular social contexts (or increase social costs associated with not taking action). Norms and social learning may be especially important in contexts in which levels of risk are changing in relation to environmental change (Wolfe 1993).

With respect to the three measures of self-efficacy (time, physical difficulty, and lack of specific information), we see that only lack of specific information has a negative statistically significant coefficient estimate. This negative and significant relationship between lack of specific information about how to decrease risk and lower mitigation outcomes is important because the study counties have engaged in ongoing work to educate WUI homeowners. This finding may indicate that some portions of the WUI populations in these counties are either not recipients of the education efforts or that they require a more tailored information regarding their parcel's risk or more personalized information about how to implement generic recommendations. If either is the case, it indicates that there is still room for education and outreach programs in the study area to reach new populations who require additional information to take action to decrease risk.

The final variables included in the model are those related to information sources and social interactions. We

Table 5 Ordered logistic regression with dependent variable = mitigation level

	Coefficient (SE)	Proportional odds ratio (SE)
Thresholds		
α = hml_mit = 0	2.541 (.760)***	
α = hml_mit = 1	5.955 (.806)***	
Study design		
Version (1 = Web; 0 = mail)	.219 (.220)	1.245 (.2767)
County (1 = Larimer; 0 = Boulder)	−.288 (.198)	.750 (.150)
Parcel characteristics		
Lot size (0 = ≥2 acres; 1 = >2 acres)	.595 (.190)***	1.812 (.009)***
Demographic characteristics		
Age (year)	.030 (.009)***	1.031 (.009)***
Sex (1 = female; 0 = male)	.387 (.194)**	1.473 (.287)**
Do not have the money for wildfire risk–mitigation actions (1 = agree; 0 = otherwise)	−.474 (.281)*	.622 (.177)*
Risk perception		
Property is not at risk of wildfire (1 = agree; 0 = otherwise)	−1.537 (.399)***	.215 (.086)***
Vegetation on property when purchased or rented (1 = contributes to wildfire risk; 0 = does not contribute)	.798 (.198)***	2.221 (.440)***
Wildfire experience		
Evacuated (1 = ever evacuated or prepared to evacuate; 0 = otherwise)	.555 (.202)***	1.742 (.352)***
Fire within 10 miles (1 = wildfire within 10 miles of property; 0 = otherwise)	.277 (.236)	1.320 (.310)
Efficacy (mitigation and self)		
Actions to decrease the risk of loss due to wildfire are not effective (1 = agree; 0 = otherwise)	.357 (.790)	1.429 (.570)
Time it takes to implement risk-reduction actions (1 = strong consideration; 0 = otherwise)	−.027 (.245)	.973 (.237)
Physical difficulty of doing the work (1 = strong consideration; 0 = otherwise)	−.241 (.251)	.786 (.197)
Lack of specific information about how to decrease risk (1 = strong consideration; 0 = otherwise)	−.589 (.277)**	.555 (.155)**
Wildfire information sources & social interactions		
Neighbors, friends, or family members (1 = use source; 0 = otherwise)	−.396 (.205)*	.673 (.138)*
local fire department (1 = use source; 0 = otherwise)	.416 (.218)*	1.516 (.332)*
County wildfire specialist (1 = use source; 0 = otherwise)	.880 (.213)***	2.411 (.517)***
Media (1 = use source; 0 = otherwise)	−.133 (.193)	.875 (.170)
Talk about fire (1 = ever talked about wildfire with neighbor; 0 = otherwise)	.681 (.245)***	1.975 (.484)***
Pseudo–R square (Nagelkerke)	.304	
−2 Log Likelihood	867.932	

Low (0) = 0–4; mid–level (1) = 5–9; high (2) = 10–12] ($n = 533$)

*** $P < .01$

** $P < .05$

* $P < .1$

see that obtaining wildfire information from the county specialist had the strongest positive effect on mitigation level. We also see a positive effect on mitigation level associated with obtaining information from the local fire department. We speculate that the messages from these two sources are tailored to local or even parcel-level specificities that homeowners are likely to contend with in the mitigation-decision or -implementation process. In contrast, obtaining wildfire information from neighbors, friends, or family members had a negative and significant relationship with mitigation level. However, having talked with a neighbor about wildfire was found to have a positive and significant effect on mitigation level. These two results are curious. We know that informal social interactions have been documented to play a significant role in influencing disaster responses; however, the role they play in mitigation decisions is not well understood (Lindell 1997; Tierney and others 2001). Recent work suggests that informal interactions among neighbors play an important role in spreading wildfire information in part because more knowledgeable residents interpret fire information and their actions serve as interpretations of generic information to

local landscapes (Brenkert-Smith 2010). We speculate that the curious results in our model, i.e., a positive effect on mitigation level from informal social interactions (talking with a neighbor about wildfire) and the negative effect on mitigation levels from using receiving neighbors, friends, or family members as sources of wildfire information, are due to the nature of the questions. The survey question that asked about sources of information broadly lumped "neighbors, friends, and family members" together, and this collection of sources may reflect a wide range of possible types of information and influence. In contrast, "talking with a neighbor about wildfire issues" may reflect more tailored and personalized information, risk considerations, and social influence that are shaped by the risk interdependency of adjacent parcels in fire prone areas (Kunreuther and Heal 2003). In contrast, general information, such as that provided by media sources, was not associated with behavioral outcomes. Thus, despite the fact that local media frequently and national media periodically cover wildfire issues, particularly in times of increased risk or during fire events, we did not find these sources of information to be associated with behavioral outcomes.

Looking at the estimated proportional odds ratios for the statistically significant coefficients other than age, we see that the largest effect on mitigation level is associated with using the county wildfire specialist as a source of information about wildfire risk. (We exclude age in this discussion because it is a continuous variable, thus the interpretation of the odds ratio is that a year increase in age results in a 1.030 increase in the odds of a higher mitigation level.) It is possible that individuals who interact with the county wildfire specialist are most ready to take action and that this results in the strong relationships between this information source and mitigation level.

Acknowledgement by the survey respondents that the vegetation contributed to wildfire risk on their property when they purchased or decided to rent the property also had a strong effect on mitigation level. Of course, moving onto a property with dense vegetation leaves more room for mitigation action, but it is also possible that the type of respondent who recognizes that vegetation is a source of risk may also give rise to this result.

Conclusions

The data and analyses described in this study provide insight into the complex decision-making context associated with wildfire-mitigation actions. We extend the previous literature in this area in two ways. First, we moved beyond the case study approach to a general WUI population sample that covered two counties along the Front Range of the Colorado Rockies. This sample frame provided respondents exposed to diverse wildfire-education programs. Second, we focused on key factors identified in the hazards- and wildfire-specific literature to identify explanatory variables in a multivariate model of risk-mitigation behavior. This approach allowed us to test the hypothesized relationships and provided insight into the relative effect of the various factors.

The results of this study suggest that holding all else constant, receiving wildfire information from the county wildfire specialists in both Larimer and Boulder Counties had a strong positive relationship with mitigation level. This positive effect is stronger than the positive effect of obtaining information from the local fire department or the negative effect of obtaining information from neighbors, friends, or family members (although we saw a positive effect in talking specifically about wildfire with a neighbor). Although county programs provide general wildfire-hazard information, one of the major aspects to the county outreach programs involves property evaluations during which owners can receive personalized information specific to their properties. Furthermore, county specialists attend community meetings to discuss wildfire-risk and -mitigation options with property owners. The one-on-one consultations and local community meetings provide opportunities for sharing personalized and specific wildfire information.

Another strong relationship was found between believing that vegetation on the property contributed to wildfire risk at the time of the respondent moved in and mitigation outcomes. Although denser vegetation will give increase the need to complete more mitigation actions, it is also possible that individuals who recognize the relationship between vegetation and fire risk will more actively mitigate the risk. In other words, it is possible that this result reflects the need for an understanding of the problem before taking action.

We also found that previous experience with wildfire, in the sense of having been evacuated or prepared to evacuate, had a significant effect on the level of wildfire mitigation undertaken. Given the large wildfires in Larimer and Boulder Counties in recent years, the number of WUI homeowners who have been evacuated at least once has increased substantially. The results of our study suggest that this experience may result in higher levels of mitigation.

With respect to constraints to taking action, we did not find time or physical difficulties to be the issue. This is a notable finding because performing fuel reduction on even a small parcel can be time consuming and physically challenging. However, lack of funds to undertake wildfire risk–mitigation actions appears to be a constraint. Many wildfire programs do provide funds to homeowners to defray or match wildfire-mitigation expenses. The results of this study suggest this to be a reasonable approach likely to move homeowners to take action.

The bottom line is that the results of this study suggest several factors can be addressed by wildfire programs

intending to move homeowners to higher mitigation levels. Likewise, we must acknowledge the existence of some factors that cannot be controlled by those who administer wildfire education programs (i.e., age, sex, evacuation experience, etc.) yet are related to mitigation behaviors. However, this information can inform the design of wildfire education programs.

As with most studies, some caveats must be discussed. As noted in the data section, we removed the 45 respondents whose parcels are <.25 acre. We did this because we wanted to assess how many mitigation measures were undertaken by survey respondents and evaluate factors associated with those actions and to ensure that we did not have any respondents for whom the 30- to 100-foot vegetative fuel–reduction actions were not applicable. This is not to say, of course, that each mitigation measure is applicable to each lot; however, the WUI areas surveyed in this study are characterized by varied terrain at medium to high risk of wildfire, and mitigation actions represent the standard protective measures property owners can take to decrease the risk of wildfire damages and losses. Lacking an adequate proxy for parcel-level wildfire risk is a limitation with which most studies of wildfire-risk behaviors or intentions currently contend. This limitation, however, points to interesting future questions regarding whether or not owners on densely situated, smaller parcels engage in different patterns of mitigation activity due to their proximity, the added role that trees may play in providing privacy screens, and the often closer proximity to fire-suppression resources in the form of local volunteer fire departments often situated in such neighborhoods. Examining varying approaches to mitigation based on how homes are sited on a lot, density of structures, and parcel sizes are areas for future research.

In all data collection efforts, tradeoffs are associated with how the instrument is designed, the questions stated, and the behaviors measured. There are a few limitations to the data that should be mentioned. First, the mitigation measures in this study are self-reported and may be subject to social-desirability bias. Second, the dichotomous nature of the responses regarding whether or not a respondent has implemented the 12 queried measures may not capture whether or not the respondent "partially" implemented a measure; indeed, they may have thinned "some" trees within 30 feet of the home and reported the measure completed. Finally, the survey did not seek to create specific timelines for respondents' wildfire experiences or actions. As such, we do not make any claims regarding the causal direction of the relationships described.

Despite these limitations, the data set and findings are useful. These data were collected across a multitude of communities within two adjacent counties that face similar wildfire-risk conditions. The model of mitigation behaviors identifies key factors associated with risk-reduction behaviors that transcend jurisdictional boundaries. Although we do not know whether findings will be replicated in other WUIs across the country, the strength of the findings in the model indicate that whereas local processes may be important and unique at the community level, key determinants to mitigation outcomes that span some of these differences can be identified and made available to wildfire specialists seeking to improve outreach and education efforts.

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