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Complexity of homeowner wildfire risk mitigation: an integration of hazard theories

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Abstract. Each year wildfire affects communities in Canada, resulting in evacuations and, in some cases, loss of homes. Several Canadian wildfire management agencies have initiated mitigation programs aimed at reducing wildfire risk. Successful wildfire mitigation involves both community-level and homeowner action. This paper examines factors that influence wildfire mitigation by homeowners. We draw upon the general hazards and wildfire management literature to develop and test a theoretical model for homeowner wildfire mitigation that includes perceived risk, an evaluation of threat significance and the influence of perceived costs and benefits of mitigation. We used a mail survey to collect data from 1265 residents in six interface communities in the province of Alberta. Results showed a high level of completion for most mitigation activities. A structural equation model provided support for the hypothesis that the evaluation of threat involves weighing the negative effects of mitigation on homeowners' feelings of connectedness to nature and the cost of mitigation with the positive influences of fear, a sense of responsibility and perceived effectiveness of mitigation. Considering the total effects, threat assessment had the greatest effect on mitigation by homeowners, followed by perceived effectiveness of mitigation in reducing damage and not having financial resources for mitigation.

Additional keywords: natural hazard, risk perception, wildland–urban interface.

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Introduction

On average, 867 wildfires burn ~142 976 ha of forest each year in the Canadian province of Alberta (Tymstra *et al.* 2007). Some of these fires affect communities causing the evacuation of thousands of residents and in some cases, the loss of homes. The human effects are expected to worsen as annual area burned and fire severity increase with climate change (Flannigan *et al.* 2005; Tymstra *et al.* 2007) and more people live in the wildland–urban interface (WUI) (Peter *et al.* 2006).

Like many wildfire management agencies in North America, the agency responsible for forest fire management in Alberta (Alberta Sustainable Resource Development) has initiated a mitigation program aimed at reducing the wildfire risk to communities. The program includes educational resources, financial assistance and expertise for community mitigation and collaborative partnerships with communities, industry and other stakeholders (Alberta Sustainable Resource Development 2009). Successful wildfire management involves both community level and individual homeowner action. Homeowner action is directed either at reducing the hazard on their own properties or as part of collective decisions and actions at a community level (Jakes *et al.* 2007).

A substantial literature has developed around WUI homeowner completion of wildfire mitigation activities (e.g. Gardner *et al.* 1987; Fried *et al.* 1999; Winter and Fried 2000; McGee and Russell 2003; Monroe *et al.* 2003; Monroe and Nelson 2004; Nelson *et al.* 2004; McGee 2005; Brenkert-Smith *et al.* 2006). These studies have revealed that many homeowners have completed some mitigation on their property. Generally, low cost, low effort options that address multiple objectives (e.g. aesthetics) are more popular than removing vegetation (e.g. pruning and removing trees) or making structural changes to houses (e.g. installing a fire resistant roof).

Several qualitative studies have provided insights on factors that influence homeowner wildfire mitigation. Considerably fewer studies, however, have provided an empirical analysis of the factors that influence homeowners' mitigation within a multivariate framework. In this paper we aim to extend the understanding of factors that influence wildfire mitigation by homeowners by developing and testing a theoretical model that is grounded in the general hazards literature and incorporates elements from the wildfire management literature. Drawing upon findings from qualitative studies of wildfire mitigation and theories from the hazards literature (Protection Motivation

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Theory, Person-Relative-to-Event, Protection Action Decision Model) we situate several factors within a threat assessment and mitigation framework. This framework differs from earlier studies by modelling threat assessment as a mediating influence between perceived risk and mitigation and incorporating the influence of perceived costs and benefits of mitigation.

Literature review

A basic postulate of hazard mitigation is that action arises from a cognitive assessment that a hazardous event is likely to occur and its effects will be severe (Rogers 1975). The perceived risk of wildfire, however, has not shown a consistent association with adoption of mitigation measures. For example, Gardner *et al.* (1987) found perception of risk was associated with perceived importance of mitigation strategies. McGee (2005), however, found no association between perceived likelihood of wildfire affecting urban residents' property and the number of mitigation measures they had completed. Nelson *et al.* (2004) concluded that landowners' mitigation actions involve a trade-off between assessment of personal risk and landscape preferences. Similarly, although Collins (2009) found a positive correlation between perceived risk and level of wildfire hazard, he showed that mitigation decisions involve additional influences such as protecting amenity values and trust in fire suppression capabilities.

McCaffrey (2008) concluded that individual response to wildfire is more complex than simply acting upon a perceived risk. Rather, McCaffrey argued that perceived risk is highly subjective. Not only do homeowners have to judge a wildfire event as likely and that there will be damaging effects, they also have to believe that the personal consequences will be significant enough to warrant mitigation. Homeowners may perceive a wildfire as likely and that it will have damaging effects, but they may discount the significance of the threat by believing, for example, that a wildfire event will not occur in the immediate future, that firefighters will protect their property, or that the damage will not be significant. Thus, understanding homeowner mitigation requires an understanding of both an individual's perception of wildfire risk and the perceived costs and benefits involved in judging the threat as significant enough to warrant action.

The hazards literature suggests that in addition to attributes of homeowners (such as perceived risk), attributes of the mitigation measures also affect mitigation behaviour. Protection Motivation Theory (PMT), for example, posits that hazard mitigation is not only a function of a person's evaluation of a hazard as likely to occur and that its effects will be severe but is also influenced by perceived response efficacy (Rogers 1975). Hazard mitigation requires homeowners to believe that mitigation will be effective in reducing the risk. Winter and Fried (2000), for example, found that residents who perceived wildfires as random and uncontrollable and mitigation activities as ineffective, did not complete mitigation. In wildfire management, it is not only the efficacy of mitigation activities in reducing the risk but also the effect of the activities (e.g. tree removal) on landscape attributes that are important to homeowners. McCaffrey (2008) concluded that the cost of sacrificing aesthetics and connectedness to nature can outweigh the potential benefits of mitigation. Vegetation is often the defining feature of residential properties providing a sense of 'naturalness', privacy, serving as wind breaks, conserving energy, attracting wildlife and contributing to the aesthetics of the property (Brenkert-Smith *et al.* 2006). Brenkert-Smith *et al.* (2006) found that residents judged wildfire hazard reduction to be inflexible prescriptions that affect the aesthetic quality of their properties. Residents may view mitigation (e.g. vegetation management) as competing with highly valued landscape attributes, resulting in a trade-off between the cost of reducing desirable landscape attributes and the benefit of risk reduction (Monroe and Nelson 2004; Collins 2009).

Person-Relative-to-Event (PrE) theory builds upon PMT by including an appraisal of personal resources (Mulilis and Duval 1995). Self efficacy refers to the belief that an individual has sufficient resources (e.g. skills and money) to effectively mitigate the damaging effects of a threatening event. PrE hypothesises that people who judge their resources as sufficient relative to the perceived threat will engage in more mitigation activities. Self efficacy may be particularly relevant to wildfire mitigation because some wildfire mitigation activities, such as tree removal, require specialised skills and equipment and are expensive to complete. Homeowners are asked to bear the financial cost of mitigation today for a low probability, but potentially catastrophic event, at some time in the future (Daniel 2007). In addition, wildfire hazard reduction is not a one time event. Vegetation management, for example, requires repeated treatments to maintain the reduced risk and represents a continuing financial commitment.

Mulilis and Duval (1995) modified the PrE theory by incorporating attribution of responsibility for mitigation. They found that people who feel personally responsible for preparing for an event are more likely to complete mitigation activities than people who view the solution to the hazard as belonging to someone else such as government agencies. Regarding wildfire, individual landowners who have a sense of responsibility in preparing for a wildfire have been found to complete more mitigation activities and are better prepared for a wildfire event (McGee and Russell 2003; Martin *et al.* 2009). In contrast, few residents of an urban area in Canada attributed responsibility for protecting their properties to the homeowner and a sense of responsibility was not significantly related to completion of wildfire mitigation measures (McGee 2005).

In their Protection Action Decision Model (PADM) for earthquake hazard, Lindell and Perry (2000) include many of the same variables as PrE: attributes of the homeowner (e.g. perceived risk), beliefs about the effectiveness of mitigation activities and requirements for personal resources (e.g. skills and money). The PADM, however, includes additional variables such as social context in which mitigation occurs and personal experience with the hazard.

Social context includes the informal social interactions and networks that involve neighbours and family. Brenkert-Smith *et al.* (2006) found that social interactions can affect the acceptance and implementation of wildfire mitigation and concluded that mitigation around residential properties involves negotiations between household members that have differing perspectives on what constitutes a threat and the appropriate actions. Monroe and Nelson (2004) also found that

neighbourhood 'norms' create an expectation of acceptable landscaping and may prevent some homeowners from removing vegetation on their properties. In other words, wildfire mitigation on residential properties may involve assessing the threat relative to the level of support from family and neighbours.

Personal experience with a hazard is often assumed to enhance a person's sense of vulnerability effecting their perceived risk and threat assessment. Experience with wildfire, however, has been shown to have mixed influences on risk assessments. Although some studies suggest that experiencing a wildfire can increase the awareness of risk (Cohn *et al.* 2008), in some cases experiencing a wildfire has been shown to have no effect on perceived risk (Arvai *et al.* 2006; Martin *et al.* 2009; McGee *et al.* 2009) and in other cases experiencing a wildfire left people feeling that they are no longer vulnerable because of reduced fuel loads and the long intervals between potentially devastating fire cycles (Gardner *et al.* 1987; McGee *et al.* 2009). Arvai *et al.* (2006) suggest that affective responses that result from experiencing wildfire influence cognitive judgements of risk. They found that strong negative emotional responses (e.g. fear) to wildfire were correlated with higher levels of perceived risk from future wildfire events.

Finally, we include institutional factors in our model. The policy of wildfire suppression, not mitigation, has been the main focus of wildfire management agencies in Canada for decades (Pyne 2007). The reliance on fire suppression and its relative success in protecting people and resources from substantial harm may have created a complacency and trust in technology and firefighters. As Cohn *et al.* (2008) suggest the success of wildfire suppression in preventing devastating wildfire may have created the belief that it is possible to extinguish all wildfires as long as enough resources are allocated quickly. Thus, when wildfire threatens homes it may be viewed as a failure of protection agencies to suppress the fire rather than a failure of homeowners to mitigate their risk. The belief that firefighters can protect communities and homes may create a false sense of security that may reduce the sense of vulnerability and affect risk judgements.

Elements of PMT, PrE and PADM have been included in recent models designed to identify factors influencing wildfire mitigation activities of homeowners. Hall and Slothower (2009) incorporated PMT into an assessment of defensible space and found that people who perceived defensible space activities as being effective in protecting their homes and people with a positive attitude towards defensible space measures were more willing to create defensible space around their homes. Martin *et al.* (2007) also incorporated elements of PMT into an assessment of wildfire mitigation behaviour and found that perceived risk, response efficacy and self efficacy were associated with various stages in the decision to complete wildfire mitigation activities. Paton *et al.* (2006) incorporated many elements of PMT, PrE and PADM in a model of wildfire preparedness and found mitigation decisions were related to a connection to the natural environment, having sufficient resources to complete mitigation, the opinions of others and perceived effectiveness of mitigation. Similarly, Martin *et al.* (2009) found perceived risk, self efficacy and sense of responsibility were associated with completion of wildfire risk reduction measures.

The model

We developed a theoretical model of homeowner mitigation based on the hazard models and wildfire literature discussed previously (Fig. 1). Our model contributes to the wildfire risk literature by testing the hypothesis that the effect of perceived risk on mitigation is mediated by threat assessment within a context of perceived costs and the benefit of mitigation (response efficacy). We include perceived controllability of wildfire, wildfire experience and attribution of responsibility and an assessment of personal skills, financial resources, social support and perceived naturalness of mitigation as exogenous concepts.

We hypothesise that both perceived controllability of wildfire and negative emotional experience with wildfire have direct effects on perceived risk. Perceived naturalness of mitigation, social support from family and neighbours and attributing responsibility to the homeowner have direct effects on evaluation of threat significance. We use wildfire hazard potential as a proxy for homeowner mitigation activity and hypothesise that having skills and financial resources for mitigation and perceived effectiveness of mitigation in reducing the threat will have a direct effect on wildfire hazard potential.

Methods

Six communities (Hinton, Edson, Grande Cache, Whitecourt, Peace River and High Level) were selected for the study. The communities are situated in the Boreal Natural region of Alberta. An analysis of fuel types within a 50-km radius of the communities revealed that the communities are surrounded by predominantly a mix of coniferous (*Picea mariana* (Mill.) Britton, Sterns, & Poggenb., *Pinus contorta* Douglas ex Louden, *Pinus banksiana* Lamb.) and deciduous (*Populas tremuloides* Michx.) stands. Peace River differs by having more agricultural crop land. All of the communities were classified as high wildfire threat potential by the forest fire protection agency in Alberta (Alberta Sustainable Resource Development). Although landscape level risk assessments are not typically reflective of the risk to individual properties, simulation analysis of wildfire risk to the built environments in communities in the Boreal Natural Region of Alberta revealed significant risk from radiant heat and short- and long-range spotting. Whitecourt, one of our study communities, had 11% of its built environment rated as high or extreme exposure to radiant heat from a wildfire; 8 and 17% rated as high or extreme exposure to short-range spotting from airborne firebrands respectively, and 25% rated as moderate or high exposure to long-range spotting from airborne firebrands (Beverly *et al.* 2010). These risk assessments highlight the potential risk to homeowners and the need for effective risk reduction initiatives in our study communities.

A description of the communities is presented in Faulkner *et al.* (2009) and summarised here. The communities ranged in population from 3783 to 9738. The size of the communities ranged from 24.87 to 35.48 km^2 and population densities ranged from 121.5 people km^{-2} in High Level to 378 people km^{-2} in Hinton. All of the communities are dependent on natural resource extractive industries (e.g. forestry, mining and petroleum industries). Three of the communities (Grande Cache, Hinton and Whitecourt) had initiated community wildfire

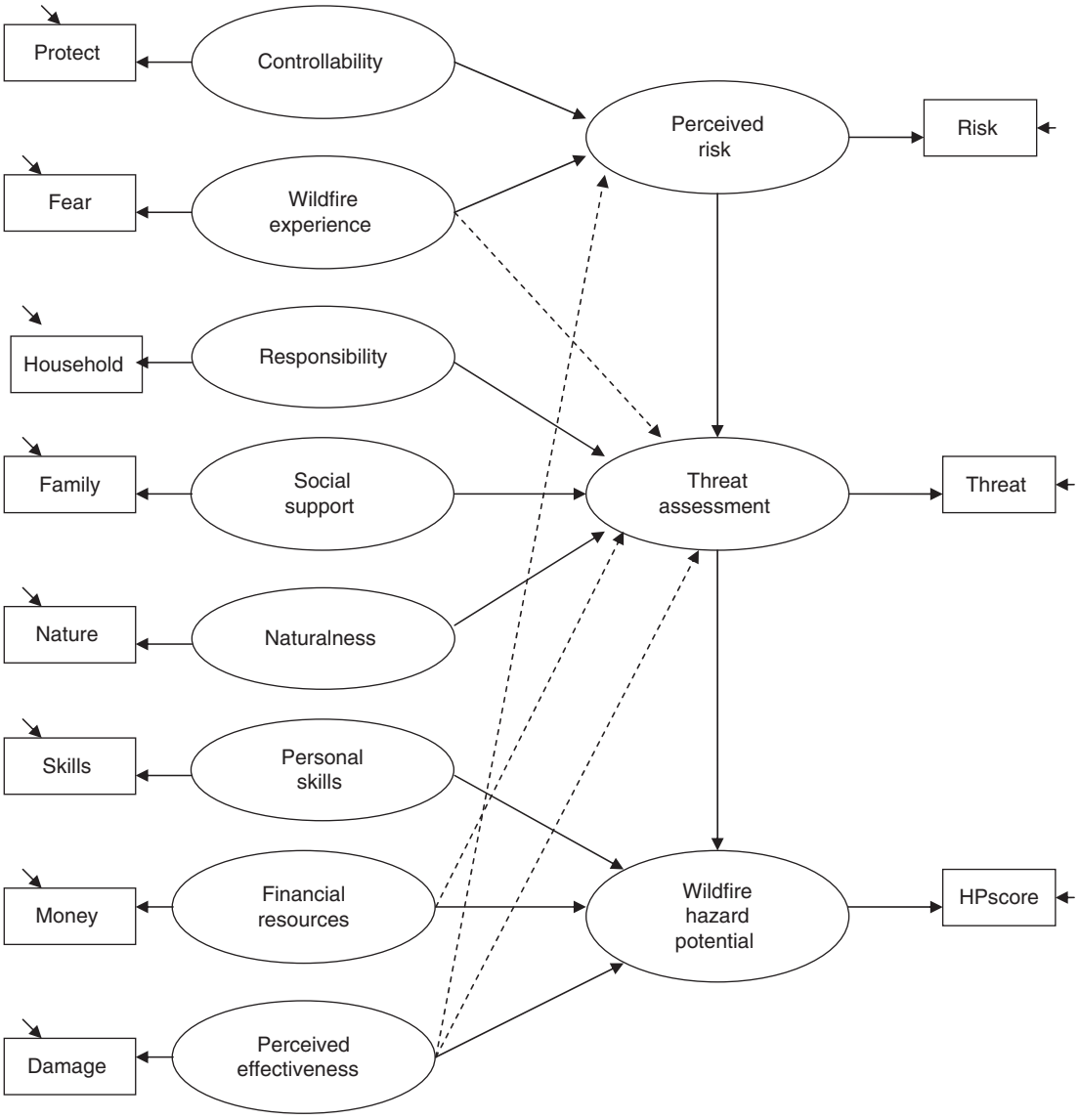

Fig. 1. Theoretical structural equation model for homeowner mitigation. Solid lines represent the initial model. Dashed lines represent paths added in the revised model.

protection measures including fuel modifications, public education campaigns and cross training of municipal firefighters. A comparison of homeowners in these communities with homeowners in the communities that had not initiated wildfire protection measures revealed no differences in homeowners' completion of mitigation activities on their properties (Faulkner *et al.* 2009).

A sample of 3452 single-family residential property owners was drawn from the list of owners ($n = 9084$) maintained by Alberta Land Titles. Residents of mobile home parks, apartment buildings and condominiums were excluded from the sample population because these residents typically do not control decisions regarding mitigation on their property. The community of Hinton was over-sampled to provide a representative sample of the community to meet obligations to one of our funding partners. Therefore, the data were weighted proportional to the expected observations from a simple random sample.

Data were collected by mail survey. An initial survey package containing a questionnaire, cover letter and business reply envelope was mailed in May 2007, followed 1 week later by a reminder postcard. One month after the initial mail out a second survey package was sent to those who had not responded. Adjusting for undelivered surveys, the response rate was 38.4% ($n = 1265$). The questionnaire collected data on several aspects of wildfire management including perception of risk, wildfire awareness and experience, mitigation activities, wildfire management preferences and demographic characteristics.

The endogenous concepts in the theoretical model are perceived risk, threat assessment and wildfire hazard potential. Perceived risk was assessed by respondents rating the level of

wildfire risk to their property in the next five years on a scale from 1 = no risk, to 7 = great risk. Threat assessment was evaluated using the statement 'I do not consider the threat of wildfires significant enough to warrant doing some of the activities' rated on a scale of 1 = strongly disagree, to 5 = strongly agree. We reverse coded responses to this statement to provide easier interpretation of the model results.

Wildfire hazard potential was assessed by calculating a score based on respondents indicating if they had completed or intended to complete 11 wildfire mitigation activities (Partners in Protection 2003). Activities was assigned points for completion, intention to complete within 1 year, intention to complete within 5 years, intention to complete in more than 5 years and no intention to complete (see Appendix 1). Our wildfire hazard potential score not only considers completed activities but also takes into account intended future behaviour by assigning a higher score (i.e. greater hazard potential) to more distant future activities. Behavioural intentions have been shown to be good predictors of future behaviour and have been applied extensively in human dimensions of natural resource management. Regarding wildfire, behavioural intentions have been used as indicators of support for fuels management (Bright *et al.* 1993; Vogt *et al.* 2005) and as a predictor of wildfire preparedness (Bright and Burtz 2006; Paton *et al.* 2006). For our wildfire hazard potential score, a completed activity was assigned a score of zero. Intention to complete an activity was assigned higher scores as the time frame increased. No intention to complete an activity was assigned the highest score. For example, if a respondent indicated they had a fire resistant roof we assigned a score of zero. If they did not have a fire resistant roof and were not planning on installing one they were assigned a score of 30. If they indicated they were planning on installing one within 5 years we assigned a score of 10 and if they planned on installing one in more than 5 years we assigned a score of 20. This rating is subjective, however, it takes into account the relative effectiveness of mitigation activities as suggested by Partners in Protection (2003) structure and site hazard assessment criteria and it assigns a higher hazard potential for intended behaviour. The wildfire hazard potential score was calculated by summing the points for each activity. Higher scores indicate a higher wildfire hazard potential.

The exogenous concepts in the model are perceived controllability by fire fighters, wildfire experience, responsibility, social support, naturalness, personal skills, financial resources and perceived effectiveness of mitigation. Perceived controllability was based on respondents' assessment of the likelihood that firefighters could protect their home if it was threatened by a wildfire on a scale of 1 = very unlikely, to 5 = very likely. Wildfire experience was based on respondents indicating if they had felt fear or anxiety because of a wildfire. Responses were coded as 1 = yes, and 0 = no. Responsibility for mitigation was assessed based on respondents' level of agreement that 'myself and my household' are 'responsible for reducing wildfire risks to my house and property, well before a wildfire occurs'. Social support was assessed with the statement 'if I made all or some of the changes, my family or neighbours would not like it' and naturalness was assessed with 'if I made these changes I would not feel as connected to nature'. Having adequate personal skills and financial resources were assessed with the statements 'I do not have the skills to complete some of the recommended activities' and 'it would be difficult to find the money to make some of these changes to my property' respectively. The perceived effectiveness of mitigation was assessed with the statement 'preparing for wildfires will significantly reduce damage to my house should a wildfire occur'. All of these statements were rated on a scale of 1 = strongly disagree, to 5 = strongly agree.

To test the hypothesised model in Fig. 1, maximum likelihood estimates were obtained using LISREL 8.80 (SSI Scientific Software International Inc., Chicago, IL). A covariance matrix was used as input to the structural equation model. Not applicable and missing responses were excluded resulting in 427 observations for the model estimation. We follow the recommendations of Hayduk (1987, pp. 118–123) and use single indicators for the concepts. We fixed the indicator loadings at 1.0 and, with exception of the wildfire hazard potential score, the error variances were fixed at 10%. Because we expected a higher level of measurement error associated with the reporting of actual and intended mitigation activities, we fixed the hazard potential score error variance at 20%.

Model fit was assessed using the Chi-square fit index, the root mean square error of association (RMSEA) and the adjusted goodness of fit index (AGFI). A good model fit should have a non-significant Chi-square value (Hayduk 1987, pp. 160–163), a RMSEA value below 0.05 (Jöreskog and Sörbom 1996) and an AGFI value between 0.95 and 1.0 (Hayduk 1996, p. 219).

We followed Kline's (2005) procedures for statistical tests for indirect effects. We tested the significance of indirect effects on wildfire hazard potential through one mediator (threat assessment) using Sobel's equation (Kline 2005) for computing the standard error of indirect effects. The indirect effects through two mediators (perceived risk and threat assessment) were assumed to be significant if all the component path coefficients were statistically significant at $P \leq 0.05$.

Results

Respondents were evenly split between males (49.7%) and females (50.3%). Their mean age was 47.65 years (s.d. = 13.15), 21.7% had a university degree and 35.2% had a total 2006 household income (before taxes) of more than C$100 000.

Table 1 presents the means and standard deviations of variables used in the model and Appendix 2 presents the correlations among the variables. Overall, homeowners' perceived a moderate wildfire risk ($M \approx 4.0$) to their properties in the next five years and were about neutral ($M \approx 3.0$) on their assessment that the threat is significant enough to warrant mitigation. Approximately 45% reported they had experienced negative emotions as a result of wildfire. On average, respondents agreed slightly that firefighters could protect their home if it was threatened by wildfire. They did not agree that mitigation activities would result in them feeling less connected to nature but agreed slightly that family and neighbours would not like some of the activities. They also agreed that their household is responsible for reducing the risk to their property. In terms of self efficacy variables, they felt that they had the skills to complete mitigation activities but identified money as preventing them from completing mitigation. Regarding response

Table 1. Means and standard deviations of model variables ($n = 427$)

Variable name	Variable description	Score	Mean	s.d.
Risk	Level of perceived risk to own property	1 = no risk to 7 = great risk	3.89	1.80
Threat	Threat is significant enough to warrant action	1 = strongly disagree to 5 = strongly agree	3.15	1.15
HPscore	Wildfire hazard potential score	0–112	33.81	25.32
Fear	Felt fear or anxiety because of a wildfire	0 = no 1 = yes	0.45	0.50
Protect	Firefighters will protect my home	1 = very unlikely to 5 = very likely	3.40	1.17
Nature	Would not feel as connected to nature	1 = strongly disagree to 5 = strongly agree	2.11	0.91
Family	Family would not like mitigation	1 = strongly disagree to 5 = strongly agree	3.36	0.81
Household	Myself and my household are responsible	1 = strongly disagree to 5 = strongly agree	4.10	0.81
Skills	Do not have the skills to complete activities	1 = strongly disagree to 5 = strongly agree	2.71	1.25
Money	Difficult to find the money for mitigation	1 = strongly disagree to 5 = strongly agree	3.35	1.13
Damage	Mitigation will significantly reduce damage to my house	1 = strongly disagree to 5 = strongly agree	3.66	1.01

Table 2. Distribution (%) of wildfire mitigation activities

Type of work	Completed	Plan to complete		
Vegetation and maintenance				
		within 1 year	within 5 years	do not plan to complete
Keep grass short and water frequently during the spring, summer and autumn	92.42	2.25	0.42	4.91
Remove shrubs, trees or fallen branches close to your house	77.43	6.08	1.35	15.14
Thin shrubs or trees so that nearby plants and trees do not touch	61.47	10.17	2.60	25.76
Prune large trees by removing all branches that are close to the ground	75.57	10.80	2.84	10.80
Remove needles, leaves and overhanging branches from the roof and gutters	77.96	17.43	2.10	2.51
Landscape with fire resistant materials and vegetation (such as rocks, aspen, maple or poplar trees)	44.44	8.26	6.12	41.18
Screen house vents, gutters and the underside of eaves with metal mesh	39.83	11.51	7.06	41.60
Screen or enclose the undersides of decks and porches	45.82	14.35	5.03	34.80
Structural				
		within 5 years	when it needs replacing	do not plan to complete
Install metal, asphalt, slate, tile or other fire resistant roofing materials on your roof	61.53	4.56	10.12	23.80
Install double or thermal pane or tempered glass in windows and exterior glass doors	59.57	9.57	12.03	18.82
Install stucco, metal, brick or other fire resistant exterior siding on your house	40.17	5.56	10.46	43.82

efficacy, respondents agreed that preparing for wildfires would significantly reduce the damage to their house.

Respondents indicated a high level of completion for most mitigation activities (Table 2). For example, ~77% reported that they had removed shrubs, trees or fallen branches, 61% thinned shrubs or trees and 62% had fire resistant roofing materials. The least popular activities were landscaping with fire resistant materials, screening vents, gutters and undersides of eaves, enclosing undersides of decks and porches and installing fire resistant exterior siding. These were also activities that people expressed the least likelihood of completing in the future.

The first step in the structural equation analysis was to test the hypothesised model (Fig. 1). According to our fit criteria the empirical data did not fit the hypothesised model (RMSEA = 0.079; AGFI = 0.900; $\chi^2 = 62.03$, d.f. = 17, $P = 0.0000$). The next step was to test an alternative model based on model diagnostics and modifications that made theoretical sense. The diagnostics suggested that threat assessment had a more prominent role in the model by serving as a mediator for other effects. The modification indices suggested that wildfire experience, financial resources and effectiveness of mitigation also influence people's assessment of the threat. This also makes theoretical sense: experiencing fear has a direct effect on evaluating the threat as significant enough to warrant action from wildfire and people weigh the financial cost and perceived effectiveness of mitigation against the perceived severity of the threat. The modification indices also suggested that perceived effectiveness of mitigation has a direct effect on perceived risk to one's property. We added these paths to the model which resulted in the data fitting the revised model (RMSEA = 0.021; AGFI = 0.967; $\chi^2 = 15.42$, d.f. = 13, $P = 0.2821$). In addition, a difference in Chi-square test showed a significant improvement in model fit ($\Delta\chi^2 = 46.61$, Δd.f. = 4, $P < 0.001$). Thus, we conclude that the empirical data fit the revised model. The squared multiple correlations indicated 16.9% of the variance in perceived risk, 27.5% of the variance in threat assessment and 19.6% of the variance in wildfire hazard potential were explained by the structural equation model.

The parameter estimates of the model are shown in Table 3. All parameter estimates were significant at $P \leq 0.05$

Table 3. Maximum likelihood estimates of structural path coefficients for wildfire mitigation model

	Perceived risk		Threat assessment		Wildfire hazard potential	
	Coefficient (s.e.) *t*-ratio	Standardised coefficient	Coefficient (s.e.) *t*-ratio	Standardised coefficient	Coefficient (s.e.) *t*-ratio	Standardised coefficient
Controllability	−0.483	−0.314	0	–	0	–
	(0.079)	(−)	(−)	(−)	(−)	(−)
	−6.107	–	–	–	–	–
Wildfire experience	0.678	0.19	0.342	0.151	0	–
	(0.178)	(−)	(0.109)	(−)	(−)	(−)
	3.81	–	3.122	–	–	–
Naturalness	0	–	−0.303	−0.241	0	–
	(−)	(−)	(0.061)	(−)	(−)	(−)
	–	–	−4.999	–	–	–
Social support	0	–	0.12	0.084	0	–
	(−)	(−)	(0.07)	(−)	(−)	(−)
	–	–	1.705	–	–	–
Responsibility	0	–	0.2	0.141	0	–
	(−)	(−)	(0.072)	(−)	(−)	(−)
	–	–	2.79	–	–	–
Personal skills	0	–	0	–	1.868	0.093
	(−)	(−)	(−)	(−)	(1.111)	(−)
	–	–	–	–	1.682	–
Financial resources	0	–	−0.174	−0.172	2.994	0.142
	(−)	(−)	(0.049)	(−)	(1.26)	(−)
	–	–	−3.56	–	2.377	–
Perceived effectiveness	0.439	0.245	0.13	0.114	−4.538	−0.191
	(0.092)	(−)	(0.059)	(−)	(1.307)	(−)
	4.758	–	2.377	–	−3.472	–
Perceived risk	0	–	0.136	0.214	0	–
	(−)	(−)	(0.032)	(−)	(−)	(−)
	–	–	4.323	–	–	–
Threat assessment	0	–	0	–	−5.476	−0.263
	(−)	(−)	(−)	(−)	(1.173)	(−)
	–	–	–	–	−4.668	–

(t-ratio > 1.96) with the exception of the effect of social support on threat assessment and the effect of personal skills on wildfire hazard potential. Examining the parameters of the endogenous concepts revealed that the higher the level of perceived risk the higher the level of agreement that the threat is significant enough to warrant mitigation. The effect of perceived risk on wildfire hazard potential was indirect, mediated by threat assessment. Threat assessment had a negative effect on wildfire hazard potential (i.e. the higher the threat significance rating, the lower the hazard potential score).

The parameters of the exogenous concepts show that perceived risk was influenced by wildfire experience; controllability of wildfire and perceived effectiveness of mitigation. The stronger the belief that firefighters could protect homes, the lower the perceived risk. Experiencing negative emotion because of a wildfire resulted in a higher perceived risk rating. Believing that preparing for wildfires will significantly reduce damage also had a positive influence on perceived risk.

Wildfire experience, effects of mitigation on naturalness, homeowner responsibility, financial resources and the belief that preparing for wildfires will significantly reduce damage influenced threat assessment. Experiencing negative emotion because of a wildfire, attributing responsibility for mitigation to the homeowner and believing that preparing for wildfires will significantly reduce damage had a positive effect on rating the threat as significant enough to warrant mitigation. In contrast, naturalness and financial resources had a negative effect on threat assessment. The more respondents agreed that mitigation reduces their connectedness to nature and that it would be difficult to find the money for mitigation, the lower they judged the threat significance.

Not having sufficient money for mitigation and perceived effectiveness of mitigation influenced wildfire hazard potential. The more respondents agreed that it would be difficult to find the money for mitigation, the higher the hazard potential score. The greater the perceived effectiveness of mitigation, the lower the hazard potential score.

To examine which factors have the greatest effect on wildfire hazard potential, we determined the total effects of each concept by examining their direct and indirect effects (Table 4). Controllability, experiencing fear, responsibility, the effect of mitigation on the naturalness of their property and perceiving a risk have their effects on wildfire hazard potential indirectly through threat assessment. These indirect effects, however, were small. Considering the total effects, threat assessment had the greatest effect on wildfire hazard potential followed by

Table 4. Standardised direct, indirect and total effects of exogenous and endogenous concepts on wildfire hazard potential
Unless noted otherwise, indirect effects are significant ($P \leq 0.05$) based on the criteria presented in Kline (2005, p. 162). Significance tests were performed on the non-standardised coefficients

Concept	Effects on wildfire hazard potential		
	Direct	Indirect	Total
Controllability	0	(−0.314)(0.214)(−0.263)	0.018
Wildfire experience	0	(0.190)(0.214)(−0.263) + (0.151)(−0.263)	−0.051
Responsibility	0	(0.141)(−0.263)	−0.037
Naturalness	0	(−0.241)(−0.263)	0.063
Social support	0	(0.084)(−0.263)[A]	−0.022[A]
Personal skills	0.093[A]	0	0.093[A]
Financial resources	0.142	(−0.172)(−0.263)	0.187
Perceived effectiveness	−0.191	(0.245)(0.214)(−0.248) + (0.114)(−0.263)	−0.235
Perceived risk	0	(0.214)(−0.263)	−0.056
Threat assessment	−0.263	0	−0.263

[A]Not significant at $P \leq 0.05$.

perceived effectiveness of mitigation in reducing damage and not having financial resources for mitigation.

Discussion

Much of the research on homeowner mitigation has been based on qualitative case studies focussed on the United States and Australia. These have been valuable in developing an understanding of the wildfire mitigation problem but are not generalisable to larger populations or different social, cultural and management contexts. The testing of empirical models of homeowner mitigation that are grounded in theory has only recently begun to emerge. Our study contributes to this literature by extending the understanding of homeowner mitigation to a Canadian context and by developing and testing a model that draws upon well-established theories from the hazards literature and incorporates concepts that are unique to wildfire (e.g. the belief that fire suppression will provide protection). Unlike previous empirical models of wildfire mitigation by homeowners, we distinguish between perceived risk and threat assessment and show that threat assessment is an important mediator in mitigation. Although this has been hypothesised in qualitative studies it has not been tested in empirical models.

Like studies in the United States (e.g. Winter and Fried 2000; Brenkert-Smith *et al.* 2006), this study found low cost, low effort mitigation activities popular among homeowners. In this Canadian study, however, homeowners also indicated a high level of completion of vegetation management and structural modification activities. Unlike many earlier studies, this study included an assessment of both completed activities and the intention to complete activities in the future. This approach showed that there are some activities that many homeowners have no intention of completing. Screening undersides of decks and porches and house vents, gutters and eaves appear to be fairly easy and inexpensive to complete, yet many homeowners indicated that they have no intentions of completing them. Only two of the potentially high cost, high effort activities had a large percentage who indicated that they had not completed them and had no intentions of completing them; landscaping with fire resistant vegetation or materials (e.g. rock, aspen, birch or poplar trees) and installing fire resistant siding. Fire resistant siding seems particularly contentious because respondents indicated they would not use fire resistant material even when the siding needed replacing. The reason for this is not clear but we speculate that vinyl siding is a popular material especially in new home construction and is a lower cost option than fire resistant alternatives.

The successful incorporation of elements from theoretical frameworks in the hazards literature (Protection Motivation Theory, Person-Relative to Event and Protection Action Decision Model) with elements that are unique to wildfire illustrates the complexity surrounding homeowner mitigation. In particular, our model provides empirical support for the hypothesis that homeowners must not only perceive a risk to their property, they also must judge the risk as significant within a context of perceived costs and benefits of mitigation. We found threat assessment central to wildfire mitigation. Threat assessment affected mitigation directly and acted as a mediator for other variables. Consistent with earlier literature which used qualitative assessments to suggest that homeowners weigh the costs and benefits of mitigation (Monroe and Nelson 2004; Nelson *et al.* 2004; McCaffrey 2008), we found the evaluation of threat significance involves an interplay between the negative effects of mitigation on homeowners' feelings of connectedness to nature and the cost of mitigation and the positive influences of fear, a sense of responsibility and perceived effectiveness of mitigation. Our model suggests that homeowners discount the risk by weighing the perceived costs and benefits and adjusting their judgements of threat significance accordingly (i.e. if residents feel that mitigation is too expensive or that it interferes with them feeling connected to nature they discount the risk to their property by downplaying its significance).

Uniquely relevant to wildfire management is the past success of wildfire suppression in protecting communities. In this study, the belief that fire fighters will protect their homes reduced the level of homeowners' perceived risk. This suggests that homeowners may have an inflated sense of protection and may not be aware of limits to fire suppression capability. In a separate study, interviews with residents who had experienced a wildfire event in Alberta found that some homeowners viewed government

promotion of homeowner mitigation as a downloading of government responsibility to the private land owner (McGee *et al.* 2005). They viewed wildfire threat as a failure of fire suppression rather than a risk reduction issue. Engaging homeowners in mitigation efforts will be more effective if the public is aware that in extreme fire events they cannot rely on fire suppression resources to save their homes and that effective wildfire management requires a combination of fire suppression and mitigation with a shared responsibility between governments and private landowners. Our findings suggest that fire agencies must clearly articulate government's role in fire suppression, limitations of fire suppression resources and homeowner responsibility in reducing their risk. They must emphasise that homeowners can make a difference by changing the level of risk to their property, to their community and to firefighters.

Unlike most other studies that have examined hazard experience, our wildfire experience indicator attempted to tap into an affective element of experience. Experience can be multifaceted ranging from the devastation of ones home to indirect exposure through media coverage of fire events. People may feel fear without having direct exposure to wildfire. For example, being put on evacuation alert or witnessing the damaging effects of fire on neighbouring communities can increase fear and anxiety among residents. Alternatively, residents may witness a wildfire near their community and not feel fear. The influence of fear in our model on both perceived risk and threat assessment supports the suggestion that affective responses rather than wildfire exposure play a role in cognitive judgements of risk and response (Arvai *et al.* 2006).

We used a novel approach in representing homeowner mitigation in our model. Thus, some comments about our dependent variable – the hazard potential score – seem warranted. Other studies examining influences on wildfire mitigation by homeowners have used a variety of approaches including a sum of completed mitigation activities (e.g. Paton *et al.* 2006), on-site hazard assessments (Collins 2009) and rating scales (Hall and Slothower 2009) as dependent variables. We assessed hazard potential using respondents' reported behaviour and behavioural intentions and weighted mitigation activities to reflect their relative effectiveness in reducing wildfire hazard as suggested by Partners in Protection (2003) site hazard assessment criteria. We felt this approach reflected mitigation decisions as negotiated outcomes that can occur over several years rather than discrete yes–no decisions. This approach, however, did not appear to improve the explained variance in homeowner mitigation. Studies examining the influence of social psychological concepts such as perceived risk and attitudes on homeowner mitigation have shown similar levels of explained variance (typically accounting for less than 20% of the variance) suggesting other factors influence homeowner mitigation (e.g. Collins 2009; Hall and Slothower 2009). Collins (2009) found that house contextual factors such as year of construction accounted for a larger explained variance in hazard exposure than social psychological variables. Fire resistant materials are more common in new home construction (e.g. asphalt roofing, thermal windows), thus, reducing wildfire hazard. At the time of this study, Alberta was experiencing an economic boom associated with the petroleum industry and a large increase in new housing. An examination of single family housing statistics expressed as a proportion of our sampling frame showed that ~15% of single family dwellings in our study communities were constructed between 2001 and 2005. This contextual factor could be an additional influence on mitigation that was not included in our model.

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Appendix 1. Points assigned to mitigation activities

Type of work	Completed	Plan to complete		
Vegetation and maintenance				
		within 1 year	within 5 years	do not plan to complete
Keep grass short and water frequently during the spring, summer and fall	0	2	5	10
Remove shrubs, trees or fallen branches close to your house	0	2	5	10
Thin shrubs or trees so that nearby plants and trees do not touch	0	10	20	30
Prune large trees by removing all branches that are close to the ground	0	2	3	5
Remove needles, leaves and overhanging branches from the roof and gutters	0	1	2	3
Landscape with fire resistant materials and vegetation (such as rocks, aspen, maple or poplar trees)	0	1	2	3
Screen house vents, gutters and the underside of eaves with metal mesh	0	2	4	6
Screen or enclose the undersides of decks and porches	0	2	4	6
Structural				
		within 5 years	>5 years	do not plan to complete
Install metal, asphalt, slate, tile or other fire retardant roofing materials on your roof	0	10	20	30
Install double/thermal pane or tempered glass in windows and exterior glass doors	0	1	2	3
Install stucco, metal, brick or other fire resistant exterior siding on your house	0	2	4	6

Appendix 2. Pearson correlations (and *P*-values) of model variables

	Risk	Threat	HPscore	Fear	Protect	Nature	Family	Household	Skills	Money
Threat	0.274	–	–	–	–	–	–	–	–	–
	(<0.0001)	–	–	–	–	–	–	–	–	–
HPscore	−0.045	−0.296	–	–	–	–	–	–	–	–
	(0.265)	(<0.0001)	–	–	–	–	–	–	–	–
Fear	0.184	0.185	−0.086	–	–	–	–	–	–	–
	(0.0001)	(0.0001)	(0.076)	–	–	–	–	–	–	–
Protect	−0.232	−0.011	−0.114	0.037	–	–	–	–	–	–
	(<0.0001)	(0.827)	(0.018)	(0.441)	–	–	–	–	–	–
Nature	−0.089	−0.290	0.087	−0.020	−0.004	–	–	–	–	–
	(0.066)	(<0.0001)	(0.018)	(0.683)	(0.937)	–	–	–	–	–
Family	−0.043	−0.143	0.153	−0.011	0.006	0.089	–	–	–	–
	(0.265)	(0.003)	(0.001)	(0.814)	(0.898)	(0.068)	–	–	–	–
Household	0.125	0.222	−0.133	0.046	−0.040	−0.076	−0.132	–	–	–
	(0.010)	(<0.0001)	(0.006)	(0.338)	(0.414)	(0.115)	(0.006)	–	–	–
Skills	0.018	−0.117	0.170	0.0129	−0.028	0.299	−0.087	0.016	–	–
	(0.711)	(0.015)	(0.001)	(0.790)	(0.569)	(<0.0001)	(0.070)	(0.738)	–	–
Money	0.054	−0.162	0.198	0.086	−0.076	0.131	−0.026	−0.030	0.369	–
	(0.265)	(0.001)	(<0.0001)	(0.076)	(0.115)	(0.007)	(0.586)	(0.534)	(<0.0001)	–
Damage	0.184	0.232	−0.218	0.089	0.166	−0.091	−0.197	0.259	−0.029	−0.007
	(0.0001)	(<0.0001)	(<0.0001)	(0.066)	(0.018)	(0.058)	(<0.0001)	(<0.0001)	(0.545)	(0.882)