

Risk, knowledge, and trust in managing forest insect disturbance

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Abstract: Understanding perceptions of risks, awareness, and trust in management agencies is critical to effective management of large-scale forest insect disturbance. In this study, we examined regional variation in public perceptions of risk, compared public and land managers' perceptions, and examined knowledge and trust as factors in shaping public perceptions of a mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) infestation. Survey data were collected from residents ($n = 1303$) in three regions of Alberta and from land managers ($n = 43$) responsible for MPB management. Results showed that residents had moderate or great concern for MBP risks, they were not well informed about MPB, and they showed slight trust in the provincial government and forest industry to manage the beetle. There was regional variation in perceptions of risks, knowledge, and trust. Land managers were less concerned about nontimber effects and had higher trust than the public. A positive correlation between trust and risk perceptions appears to contradict the risk literature. This relationship may be influenced by an intervening effect of knowledge. These results call for more attention to the content of risk messaging and the effects of trust and knowledge on the general public who take up these messages.

Résumé : Il est essentiel de comprendre la perception des risques, le niveau de conscientisation et le degré de confiance dans les organismes de gestion pour gérer efficacement les perturbations à grande échelle causées par les insectes forestiers. Dans cette étude, nous avons examiné la variation régionale de la perception des risques par le public, comparé la perception du public et celle des gestionnaires et examiné les connaissances et la confiance en tant que facteurs qui façonnent les perceptions du public concernant l'infestation du dendroctone du pin ponderosa (DPP) (*Dendroctonus ponderosae* Hopkins). Des données d'enquête ont été collectées auprès de résidents ($n = 1303$) dans trois régions en Alberta et de gestionnaires ($n = 43$) responsables de la gestion du DPP. Les résultats montrent que les résidents étaient modérément à très préoccupés par les risques que représente le DPP, qu'ils n'étaient pas bien informés au sujet du DPP et qu'ils avaient peu confiance dans le gouvernement provincial et l'industrie forestière pour la gestion du dendroctone. La perception des risques, les connaissances et la confiance variaient selon les régions. Les gestionnaires étaient moins préoccupés par les effets non reliés à la matière ligneuse et avaient une plus grande confiance que le public. Une corrélation positive entre la confiance et des perceptions des risques semblent contredire la littérature portant sur les risques. Cette relation peut être influencée par un effet dû à l'intervention des connaissances. Ces résultats suggèrent qu'on accorde plus d'attention au contenu du message concernant les risques et aux effets de la confiance et des connaissances sur le grand public qui reçoit ces messages.

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Introduction

Recently, North America has experienced some of the largest and most severe forest insect disturbances in recorded history (Bentz et al. 2010). Available host species and climate suitability suggest a high potential for continued persistence and range expansion of some species (Bentz et al. 2010; Safranyik et al. 2010). As forest insect infestations spread across the landscape, they pose a potential risk to ecosystems and have social and economic consequences affecting watersheds, wildlife habitat, carbon storage, forest fire risk, timber supply, and recreation (Alberta Sustainable Resource Development 2007a; Nealis and Peter 2008).

Managing forests that may experience rapid and unprecedented changes because of expanding infestations has pre-

sented challenges for managers and decision makers (Flint et al. 2009). Management agencies have had to adapt from typical disturbance management strategies, such as salvage logging, to control strategies focused on prevention, early detection, and rapid response (Alberta Sustainable Resource Development 2007a; Safranyik et al. 2010). Adding to the forest management challenge are the social and economic implications of infestations. Multiple stakeholders with multiple values, differences in community vulnerability and adaptive capacity, and changes to local economies suggest that understanding public perceptions of the risks associated with large-scale disturbances, public awareness of infestations, and trust in agencies to manage infestations will be critical to effective management.

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In this study, we investigated aspects of forest insect disturbance management that have garnered little attention in the literature. We used a mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) infestation in Alberta and examined regional variation in public perceptions of risks, compared public and land managers' perceptions, and examined knowledge and trust as factors in shaping public perceptions.

Public and expert response

Variation in the biophysical and socioeconomic vulnerability of infested areas suggests that the impacts of forest insect disturbances are unlikely to be uniform across the landscape (Flint 2007; Qin and Flint 2010). Several studies have found variation in community vulnerability and response to infestations, public perceptions of risk, and acceptability of the management response, suggesting that the human dimension of forest insect disturbance is complex and dynamic. Flint (2006), for example, showed that communities at different stages of a spruce bark beetle (*Dendroctonus rufipennis* (Kirby)) outbreak in Alaska had spatial and temporal variations in perceived effects and concluded that the dynamic nature of the infestation (the timing and magnitude) contributes to variation in local community response and willingness to accept particular control measures. Similarly, studies of public perceptions of MPB infestations in western Canada found regional variation in attitudes toward MPB and preferences for MPB control options in national parks (McFarlane et al. 2006; McFarlane and Watson 2008).

It has also been shown that there is regional and temporal variation in the social and economic effects from changes in timber supply resulting from large-scale forest insect outbreaks. Patriquin et al. (2007) predicted that economic impacts from MPB will vary by region, with more diverse economies better able to absorb the shock of reduced timber supply in British Columbia and that in the short term, regional economies will benefit from an increased timber supply from salvage logging. In the longer term, however, regional economies will suffer as the timber supply decreases. Similarly, Parkins and MacKendrick (2007) showed that communities in British Columbia with different levels of beetle activity varied in their social, political, and institutional capacities to adapt, with some communities being more vulnerable to beetle effects than others.

In addition to regional variation, it has been well documented that public perceptions of risks to ecosystems differ from those of experts with regard to what the risks are and the severity of their effects. For example, in rating the risks to water ecosystems, the public rated acid rain, drought, flooding, mining, landfills, ozone depletion, logging roads, pesticides, and clearcut logging as posing greater risk than did the experts (McDaniels et al. 1997; Cavanagh et al. 2000). Lazo et al. (2000) concluded that the public generally perceives risks to ecosystems from global climate change as having greater impacts than what the experts perceive. In a study of perception of wildfire risk, Zaksek and Arvai (2004) found that experts had a better understanding of the technical aspects of wildfire risk but a more limited assessment of wildfire effects than the public. The public expressed concern over decreased biodiversity, unemployment, and reduced recreational opportunities as potential effects whereas

experts seldom considered these in their wildfire risk assessments.

With a forest insect infestation, local residents may be faced with watching their forest change from verdant landscapes rich in economic and lifestyle values to standing grey sticks that present a daily reminder of what has been lost. Experts such as resource managers, on the other hand, may focus their attention on strategic goals such as reducing the risk to timber supply and preventing insect spread. Although differences in public and expert perception of risk are noted in the literature, we did not find any studies examining public and expert judgements related to forest insect disturbance.

Knowledge and trust

Differences in public and expert judgements are often attributed to a poorly informed public (Slovic 1999). This perspective on public ignorance has led to ongoing research and public communication to change attitudes and influence public judgement about a wide range of public risk issues (e.g., Loomis et al. 2001). Despite decades of ongoing research in this field, the link between knowledge and risk perception is not very stable. For instance, studies of public perceptions of MPB in national parks in western Canada found that respondents were not knowledgeable of basic information about the beetle. Yet with increased knowledge of MPB, public concern about MPB risks declined in relation to perceived effects on the local ecosystem (McFarlane et al. 2006; McFarlane and Watson 2008). Other studies involving technological risks such as nuclear power and chemical hazards, however, show that knowledge is seldom a good predictor of perceived risk or public response to risk (Sjöberg 1999; Slovic 1999). Even when the public is informed of the risk, their risk judgements often incorporate many subjective and contextual factors such as a liberal or conservative political orientation (Whitfield et al. 2009).

One factor that has received prominence in the risk literature is trust in experts, industry, and agencies (e.g., Sjöberg 1999; Siegrist and Cvetkovich 2000; Earle 2010). Trust in experts and management agencies is integral to risk judgements and acceptance of risk management options and has been shown to be an important factor in the public's acceptance of forest management options aimed at reducing the risks from natural disturbance. Confidence in experts and trust in government agencies to be open and fair and make good decisions have been associated with acceptance of fuels management, such as prescribed burning and forest thinning, in wildfire risk reduction (e.g., Shindler and Toman 2003; Winter et al. 2004). Similarly, acceptability of forest management strategies following natural disturbance has been shown to be highly dependent on trust in the management agency (Olsen and Shindler 2010). Confidence in land managers has also been shown to decrease the perception of threats to ecological well-being and community well-being among residents in areas with forest insect infestations (Flint 2007). Some think, however, that the influence of trust on risk judgements might be greatest when people have little knowledge of the risk (Siegrist and Cvetkovich 2000; Bronfman et al. 2008; Earle 2010). In the absence of knowledge, people rely on sources of information that they trust (e.g., experts) when assessing risk. On the other hand, when people are familiar with a risk, they rely on their own knowledge and trust

in experts or authorities has little influence on their risk judgements.

In summary, this review of the literature identifies (i) important variations in risk awareness and vulnerability across populations and communities, (ii) differences in risk perception between the general public and experts, and (iii) important conceptual and empirical linkages between risk judgements, knowledge, and trust. As a contribution to this literature, we address the following research questions. (1) Is there variation in public perceptions of risks associated with forest insect disturbance among regions with differing infestation histories and current levels of infestation and differing forest sector dependence? (2) Do the public and experts differ in their perceptions of the risks and trust in government and industry? (3) Are knowledge and trust associated with perceptions of infestation risks?

Methods

Mountain pine beetle context

Since the 1990s, the MPB has increased in population and spread beyond its historical range in North America affecting most of the western United States, southern British Columbia, and western Alberta. Although there is uncertainty about future MPB spread, it is predicted that the beetle is likely to persist outside its historical range and will continue to extend its range under climate change (Bentz et al. 2010; Safranyik et al. 2010).

The province of Alberta has historically recorded small, localized endemic populations and outbreaks. Recently, however, MPB infestations have spread to ecosystems and communities that have no prior experience with the beetle through expansion of local populations and beetle immigrations from the neighbouring province of British Columbia (Alberta Sustainable Resource Development 2007a).

Although native to lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Englem.) forests, the beetle appears to be able to adapt to other species such as jack pine (*Pinus banksiana* Lamb.), a predominant species in much of Canada's boreal forest (Safranyik et al. 2010). Alberta is considered the first line of defence in keeping the beetle from invading the boreal jack pine forests and potentially spreading across Canada to its eastern coast. Alberta Sustainable Resource Development, the provincial government department responsible for forest management on provincial Crown lands in Alberta, has developed a MPB management strategy and action plan aimed at containing and minimizing the infestation along the eastern slopes of the Rocky Mountains and preventing spread of the beetle into the boreal forest (Alberta Sustainable Resource Development 2007a, 2007b).

Study regions

We drew upon the expertise of the Foothills Research Institute MPB Ecology Activity Team, a partnership of provincial government and forest industry land managers and municipal leaders (hereafter referred to as the Activity Team), to divide the western forested portion of the Province of Alberta into study regions based on historical and current outbreaks of MPB. Three regions were identified: southwest, west-central, and northwest (Fig. 1). The forests in these regions are primarily lodgepole pine or a mix of lodgepole and

Fig. 1. Study regions of a public survey of mountain pine beetle (*Dendroctonus ponderosae*) management in Alberta.



jack pine (Alberta Sustainable Resource Development 2007a) and thus are the most vulnerable areas for MPB infestation. Potential economic vulnerability was assessed on the basis of economic dependency on the forest sector in each region. The levels of economic dependency for each of the census subdivisions (CSD) of the study regions in 2006 were obtained from previous work conducted by W.A. White and M. N. Patriquin (Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, personal communication). They used the percentage of the economic base of a CSD that is associated with the forest industry as an indicator of forest sector dependency (Stedman et al. 2007). This approach is similar to previous classifications of forest dependence in Canada (Nadeau et al. 2007; Natural Resources Canada 2006) where each CSD is classified as high (50% and more), moderate (25%–49%), low (1%–24%), and no (0%) forest sector dependency.

The southwest study region is within the historic range of MPB and is experiencing a current outbreak. This region has a history of MPB outbreaks. The first was recorded in the 1940s and another in the 1970s that continued into the 1980s. The current infestation has been present since 2002. The major communities in the southwest are Canmore and the Municipal District of Crowsnest Pass. The southwest is

the least forest dependent of our three study regions. None of the five CSDs comprising the region are classified as moderate or high, three are classified as low, and two are classified as having no forest dependence. Forest dependency of the CSDs ranged from 0.2% to 3.0%.

At the time of our study, the west-central region had no recorded endemic beetle populations and no historic or current outbreaks of MPB. There is, however, a high potential for beetle population growth in the region because of conditions favourable to the beetle. The major communities are Hinton, Edson, and Rocky Mountain House. Of the 16 CSDs comprising the west-central region, none are classified as high, nine are classified as low, two are classified as moderate, and five (31%) have no forest dependence. Forest dependency of the CSDs ranged from 2.0% to 44.3%.

The northwest region also had no recorded history of MPB but at the time of our study was experiencing a large outbreak resulting from long-range dispersal of beetles from British Columbia in 2006. The major communities are Grande Prairie, Grand Cache, Peace River, and Whitecourt. The northwest is the most forest dependent of the study regions. Of the 42 CSDs comprising the region, 86% have some level of dependency: 30 are classified as low and seven as moderate. None of the CSDs are classified as high dependency. Six are classified as having no forest dependency. Forest dependency ranged from 1.2% to 45.0%.

At the time of this study, all of the regions were being subjected to MPB management. Treatments included single-tree treatments such as cut and burn, harvesting areas of infested trees, and processing the trees to kill the beetles, forest industry adjusting its harvest plans to log healthy but susceptible areas before they were attacked, and prescribed burning.

Survey samples

A sample of residents from the three study regions was recruited by telephone in 2009 to participate in a mail survey. In total, 5647 qualified respondents were contacted; respondents had to be 18 years of age or older and equal numbers of men and women were sought. Of these, 1994 (35%) agreed to participate in a mail survey: 643 from the southwest, 649 from the west-central, and 702 from the northwest.

Experts in this study were represented by land managers responsible for management of provincial Crown lands in Alberta. A sample of land managers was obtained by consulting with the Activity Team to identify provincial government and forest industry managers involved in MPB management on industrial Crown lands and provincial parks. These included the provincial forest area forest health officers, directors of woodlands operations of forest companies, provincial park managers in the study regions, and managers and directors of forest health and parks in the provincial headquarter offices in Edmonton. Forest industry land managers were included in this sample because the MPB management strategy is dependent on collaboration and cooperation from the forest industry to adjust harvest plans and carry out salvage logging. Thus, forest industry land managers have technical knowledge of the beetle and are an important actor in MPB management. A total of 68 land managers were identified, comprising about an equal proportion of government and forest industry representatives. The sample represented

Table 1. Potential ecosystem and social risks of mountain pine beetle (*Dendroctonus ponderosae*) identified by study region and land managers.

Potential risks	Study region (Alberta)							
	Southwest		West-central		Northwest		Land managers	
	Mean (SD)	% great concern	Mean (SD)	% great concern	Mean (SD)	% great concern	Mean (SD)	% great concern
Ecosystem risks								
Changes to wildlife habitat	3.24 (0.90) a	48.60	3.45 (0.80) b	63.86	3.36 (0.86) ab	57.22	2.83 (0.76) c	14.29
Increased risk of forest fires	3.21 (0.91) a	48.61	3.31 (0.83) a	51.57	3.32 (0.86) a	53.77	3.26 (0.86) a	48.84
Increased runoff and higher waterables	3.21 (0.87) a	45.56	3.27 (0.89) a	50.12	3.03 (0.94) b	38.24	3.17 (0.80) ab	39.02
Falling trees	2.82 (0.99) a	29.59	2.89 (0.99) a	33.09	2.83 (1.02) a	31.39	2.40 (0.90) b	11.63
Social risks								
Loss of scenic quality	3.40 (0.83) a	58.58	3.54 (0.72) b	66.35	3.43 (0.82) ab	61.31	2.72 (1.05) c	25.58
Loss of the forest as an economic resource (e.g., forestry, tourism)	3.11 (0.97) a	44.52	3.51 (0.77) b	65.21	3.56 (0.73) b	67.51	3.68 (0.62) b	73.68
Changes to the forest for recreation	3.14 (0.95) a	46.14	3.30 (0.85) b	51.08	3.21 (0.93) ab	49.36	3.02 (0.77) ab	27.91
Loss of community identity tied to the forest	2.91 (1.02) a	34.43	3.03 (0.94) a	38.48	2.91 (0.96) a	31.94	2.80 (0.93) a	24.39

Note: Rated on a scale of 1 to 4 where 1 = no concern, 2 = slight concern, 3 = moderate concern, and 4 = great concern. Any two means in a row that do not share a letter are significantly different at $p < 0.05$ according to the Tukey–Kramer test.

Table 2. Percentage of correct responses on true or false statements about the mountain pine beetle (*Dendroctonus ponderosae*).

Statement	Study region (Alberta)		
	Southwest	West-central	Northwest
The mountain pine beetle is a naturally occurring insect in parts of western Alberta	62.2	51.2	44.1
A single mountain pine beetle can kill a young tree	44.1	40.8	38.8
The mountain pine beetle is spread mainly by birds carrying it from one tree to another	79.1	69.8	73.0
The mountain pine beetle infests mostly old pine trees	43.5	41.3	37.9
Mild winters have contributed to the current mountain pine beetle outbreak	93.9	91.5	88.2
The mountain pine beetle was imported to Canada from Europe	31.5	24.8	20.3
The suppression or prevention of forest fires has contributed to the current mountain pine beetle outbreak	52.5	47.2	38.7
The mountain pine beetle is found in forests across Canada, from Newfoundland to Vancouver Island	39.6	39.1	36.4
Mean (SD) summed knowledge score	4.47 (1.86) a	4.06 (2.04) b	3.83 (1.95) b

Note: Maximum possible knowledge score = 8. Any two means in a row that do not share a letter are significantly different at $p < 0.05$ according to the Tukey–Kramer test.

Table 3. Mean (SD) rating of trust in the provincial government and forest industry among study regions and land managers.

Trust statement	Study region (Alberta)			
	Southwest	West-central	Northwest	Land managers
I trust the provincial government to implement a responsible and effective mountain pine beetle management program	3.16 (1.22) a	3.17 (1.23) a	3.16 (1.21) a	3.63 (1.24) b
I trust the forest industry to adjust its practices to minimize the impacts from the beetle	2.78 (1.27) a	3.26 (1.28) b	3.24 (1.18) b	3.65 (1.17) b

Note: Statements were rated on a scale of 1 to 5 where 1 = strongly disagree and 5 = strongly agree. Any two means in a row that do not share a letter are significantly different at $p < 0.05$ according to the Tukey–Kramer test.

nearly all of the people responsible for devising and implementing MPB controls in the province.

Survey packets for the public samples containing a questionnaire, a cover letter, and a postage paid business reply envelope were mailed in September 2009. A reminder postcard was mailed about 2 weeks later and another complete survey package was mailed to people who had not responded about 6 weeks after the initial mailing. The returns for the mail survey were 473 (74%) from the southwest, 424 (66%) from the west-central, and 406 (59%) from the northwest. This level of response gives a sampling error of less than $\pm 5\%$ 19 times out of 20 for each region. Considering that there were 1303 completed surveys out of 5694 initial telephone contacts, the overall response rate was 23%.

Age and education of the public respondents were compared with data from the 2006 Canada Census (Statistics Canada 2008) to gauge the representativeness of the sample to the population. CSDs were selected that best corresponded to the sample region boundaries.

The questionnaire for the land managers was administered via the internet using Zoomerang survey software. Invitations to participate in the survey were sent by e-mail in September 2009. Two reminder e-mails were sent to nonrespondents

about 1 week and 3 weeks after the initial invitation. Each respondent could answer the survey only once. Forty-three land managers completed the survey representing a 62% response rate.

The questionnaire

The questionnaire assessed perceptions of risk, attitude toward the MPB, acceptability of management options, satisfaction with response to the beetle, trust in government and the forest industry, awareness of MPB and its management, sources of MPB information, and demographics. A subset of variables was selected for use in this study.

Following much of the literature on perceived risk from forest insect disturbance, risk perception was assessed as levels of concern about potential risks from the MPB infestation (Flint 2007; Qin and Flint 2010). A series of potential ecosystem and social risks (Table 1) were identified by consulting the Advisory Team, media reports (S. Romanowski. 2009. Mountain pine beetle media analysis: articles published from 2000 to 2008 in Alberta newspapers. Unpublished report, Foothills Research Institute, Hinton, Alta.), and the literature (Flint 2007; Parkins and MacKendrick 2007; Nealis and Peter 2008). Respondents rated their level of concern

Table 4. Demographic characteristics among study regions and land managers.

Demographic characteristic	Study region (Alberta)			Land managers
	Southwest	West-central	Northwest	
% female	45.4	46.3	48.0	12.5
% university degree	46.9	18.0	16.4	71.1
% forest dependent	9.91	22.90	25.79	na
Mean age (years)	52.2 a	51.7 ab	49.3 b	45.9 b

Note: Percentages are significantly different at $p < 0.001$ based on a χ^2 test of independence. Any two means in a row that do not share a letter are significantly different at $p \leq 0.05$ according to the Tukey–Kramer test. na, not applicable.

with the risks on a four-point scale whereby 1 = no concern, 2 = slight concern, 3 = moderate concern, and 4 = great concern.

Public knowledge was assessed using eight true or false statements (Table 2) that were based on MPB information from Alberta newspapers or readily available from the internet. Response options for the true or false statements were “mostly true”, “mostly false”, and “not sure”. A knowledge score was created for each respondent by summing the number of correct true–false responses.

Two statements were used to assess trust in the provincial government and forest industry in managing the MPB (Table 3). Respondents rated their level of agreement with each statement on a scale from 1 = strongly disagree to 5 = strongly agree.

Data analysis

Statistical analyses were performed using SAS 9.2 (SAS Institute, Inc., Cary, North Carolina). Differences among the three regions and land managers mean ratings were analyzed using analysis of variance and the Tukey–Kramer multiple comparison test. A χ^2 test of independence was used to examine the association between regions and land managers and sex, level of education, and forest dependence. Spearman rank order correlations were used to examine the association between perceived risks, knowledge, and trust. A significance level of $p \leq 0.05$ was used in the statistical tests. A “no opinion” option was provided for the risk and trust statements and these responses were deleted from the data analysis. Less than 5% of respondents chose the no opinion response on the risk statements and less than 7% chose this option on the trust statements.

Results

Demographics

Respondents from the three regions differed in level of education, dependence on the forest sector, and age (Table 4). The southwest respondents had significantly more people with a university degree and fewer who were dependent on the forest sector compared with respondents from the west-central and northwest. Northwest respondents were significantly younger than the southwest respondents. There were no differences among the regions in the gender of respondents. The land managers differed from the public respondents: they were primarily male with a university education and they were younger than the southwest respondents.

Compared with the 2006 census estimates, the public respondents were older and had higher levels of education

than the general population. However, the pattern of the distribution of education among the survey respondents reflected that of the census, with west-central and northwest respondents having similar levels of education and southwest respondents having considerably higher levels of education. To examine if differences in age and education distributions between survey respondents and the 2006 census might affect the survey results, we tested correlations between age, education, perceived risks, and the trust statements. Age was not correlated with perceived risks or the trust statements. Education showed a modest and significant negative correlation with two risk statements (risk of forest fires $r_s = -0.135$ and economic impacts $r_s = -0.085$) and the two trust statements (trust in the provincial government $r_s = -0.090$ and trust in the forest industry $r_s = -0.095$). These findings are consistent with the literature in which, with the exception of gender, demographics typically have negligible effects on perceived risks and trust judgments (e.g., Savage 1993; Slovic 1999; McFarlane et al. 2006; Earle 2010). Therefore, we conclude that the discrepancy between the demographic composition of the survey respondents and the general population will have little effect on the study results.

Perceived risks

On average, respondents in all regions rated most of the ecosystem and social risks as moderate or of great concern (mean ≥ 3.0) (Table 1). With the exception of falling trees, ecosystem risks were rated as a concern in all regions. The social risks were also rated as a concern with the exception of loss of community identity tied to the forest. Overall, loss of scenic quality was a great concern for about 62% of respondents. This was followed by loss of the forest as an economic resource (58%) and changes to wildlife habitat (56%). Although about one third of respondents expressed great concern regarding falling trees and loss of community identity, these were of less concern than the other risks.

There was some regional variation on perceived risks. Based on the means and percentage of respondents who indicated “great concern” on the risk statements, scenic quality, risk of forest fires, and changes to wildlife habitat were the greatest concerns for southwest respondents. Scenic quality, loss of the economic resource, and changes to habitat were of the greatest concerns for west-central respondents. The northwest respondents rated loss of the economic resource as their greatest concern followed by scenic quality and loss of habitat. The southwest respondents seem to be slightly less concerned about risks. Fewer of these respondents indicated a great concern over the risks and the southwest had significantly lower mean concern ratings than the west-central re-

Table 5. Spearman correlations (*p* values) of perceived risks, trust, and knowledge.

Risk statements	Public (<i>n</i> = 708)			Land managers (<i>n</i> = 34)	
	Trust province	Trust industry	Knowledge	Trust province	Trust industry
Ecosystem risks					
Changes to wildlife habitat	0.070 (0.062)	0.106 (0.005)	-0.193 (<0.0001)	0.253 (0.149)	0.161 (0.362)
Increased risk of forest fires	0.119 (0.002)	0.142 (0.0001)	-0.083 (0.027)	0.210 (0.232)	0.296 (0.089)
Increased runoff and higher watertables	0.047 (0.216)	0.106 (0.005)	-0.041 (0.272)	0.075 (0.673)	-0.176 (0.319)
Falling trees	0.072 (0.056)	0.091 (0.016)	-0.203 (<0.0001)	0.313 (0.072)	0.169 (0.340)
Social risks					
Loss of scenic quality	0.084 (0.026)	0.055 (0.144)	-0.127 (0.001)	0.211 (0.230)	0.159 (0.367)
Loss of the forest as an economic resource (e.g., forestry, tourism)	0.172 (<0.0001)	0.217 (<0.0001)	-0.127 (0.001)	-0.006 (0.975)	0.475 (0.005)
Changes to the forest for recreation	0.084 (0.026)	0.036 (0.335)	-0.100 (0.007)	0.109 (0.536)	0.161 (0.362)
Loss of community identity tied to the forest	0.089 (0.016)	0.105 (0.005)	-0.133 (0.001)	0.144 (0.418)	0.161 (0.363)

Note: Trust province = I trust the provincial government to implement a responsible and effective mountain pine beetle management program. Trust industry = I trust the forest industry to adjust its practices to minimize the impacts from the beetle. Knowledge = summed knowledge score. Risk statements were rated on a scale of 1 to 4 where 1 = no concern, 2 = slight concern, 3 = moderate concern, and 4 = great concern. Trust statements were rated on a scale of 1 to 5 where 1 = strongly disagree and 5 = strongly agree. Bold indicates significant at $p \leq 0.05$.

spondents on changes to wildlife habitat, loss of scenic quality, and changes to forest recreation. They also had significantly lower ratings on loss of forest as an economic resource than both the west-central and northwest regions.

Loss of the forest as an economic resource and increased risk of forest fires were of greatest concern for land managers. Nearly 75% of the land managers rated economic impact as a great concern and nearly 50% rated increased risk of forest fires as a great concern. Differences in mean concern ratings show that land managers were substantively less concerned about wildlife habitat, loss of scenic quality, and falling trees than respondents in the three regions and were more concerned about economic risk than respondents in the southwest. Land managers did not differ from the public respondents on the mean rating of concerns for increased risk of forest fires, increased runoff and higher watertables, changes to forest recreation, and loss of community identity.

Knowledge and trust

Responses on the true-false statements suggest that public respondents were not well informed about basic MPB facts (Table 2). The only statement that nearly all respondents (91%) answered correctly was that mild winters have contributed to the MPB outbreak. A majority also knew that MPB is not spread by birds (73%) and that it is a naturally occurring insect in parts of western Alberta (53%). A minority knew that the beetle infests mostly old pine trees (41%), that fire suppression has contributed to the outbreak (46%), that a single beetle cannot kill a young pine (41%), that the beetle was not imported from Europe (26%), and that the beetle is not found across Canada (38%). Overall, the public respondents had a mean knowledge score of 4.14 (SD = 1.96) out of a possible maximum score of 8.0. There was some variation among the regions on knowledge. Respondents in the southwest had a significantly higher mean knowledge score than respondents from the west-central and northwest regions.

Overall, public respondents showed only slight trust in the provincial government to implement a responsible and effective

MPB management program (Table 3). There were no significant differences among the regions on trust in the provincial government. Respondents in the west-central and northwest regions also showed slight trust in the forest industry to adjust its practices. Respondents in the southwest, however, did not trust the industry to adjust practices (mean < 3.0). Land managers had significant and substantively higher scores on trust in the provincial government than respondents from the three regions. Land managers also scored a significantly higher level of trust in the industry than respondents in the southwest.

Correlation analyses

Correlations between trust in the provincial government and the forest industry as well as the public's knowledge of MPB and perceptions of MPB risks are presented in Table 5. Public trust in the provincial government to implement a responsible and effective MPB management program shows a positive correlation with five of the eight risk statements and public trust in the forest industry shows a positive correlation with six of the risk statements. Three of the risks (risk of forest fires, loss of the forest as an economic resource, and loss of community identity) are correlated with trust in both the provincial government and the forest industry. Public knowledge of MPB has a negative correlation with seven of the eight risk statements. Expert trust in the provincial government is not correlated with any of the risk statements and expert trust in the forest industry has a positive correlation with only one risk statement (loss of the forest as an economic resource). Although the correlations are significant, the strength of the correlations are low to moderate ($0.084 < r_s < 0.475$).

Discussion

In this study, we examined public perceptions of MPB and its management in three regions of Alberta that vary in their MPB histories, current MPB infestation, and forest sector de-

pendence. There were some notable differences among the study regions. Respondents in the northwest, the most forest sector dependent region in the study and where the beetle made a recent and dramatic invasion from British Columbia, expressed the greatest concern for loss of the forest as an economic resource whereas other regions expressed the greatest concern over loss of scenic quality. Although we did not explore economic dependence on nonforest sectors such as tourism, the southwest and west-central regions are adjacent to several protected areas including Banff and Jasper national parks, which are popular tourist destinations and important contributors to the local economies. Thus, dependence on nonextractive forest resources may be a factor influencing concerns for scenic quality in these regions.

The differences among regions in this study provide further support to the hypothesis that different communities experience and respond to insect disturbance in diverse ways. Residents in Alaska (Flint and Haynes 2006) and in Colorado (Qin and Flint 2010) experienced and responded to local beetle infestations based on sociocultural, economic, and environmental characteristics of their community. Taken together, this body of literature suggests that as the MPB infestation continues to spread, it will be essential to understand the public's response and judgements in newly infested areas and to tailor management and communication to address local concerns. For example, in Alberta, tailoring responses that address regional concerns (developing management strategies that explicitly address scenic quality in the southwest and west-central regions and economic impacts in the northwest region) is likely to be more acceptable in the long term than a uniform response across the province.

Although land managers and residents were similar in some of their risk judgements, managers were less concerned about nontimber impacts (scenery, wildlife, and recreation) of MPB. Land managers' concerns were focused primarily on economic impacts and fire risk. Economic impacts were also a concern of residents. Residents, however, were concerned about a broader array of risks including scenic quality and changes to wildlife habitat. Land managers also expressed higher levels of trust in the provincial government and forest industry. Differences between experts and the public have been found with other ecological risks such as climate change (e.g., Lazo et al. 2000) and are often attributed to differences in knowledge. However, expert and public perception differences are generally more complex, involving other factors such as differences in values, political ideology, and professional socialization (Sjöberg 1999; Rowe and Wright 2001). Land managers in this study are focused on traditional forest management concerns (economic impacts and fire risk) and this focus will inevitably influence public messaging and management strategies. Although the public might share land managers' concerns over these risks, they have additional concerns that might not be receiving adequate attention and could serve as a potential source of dissatisfaction with the response to MPB. Müller (2011), for example, found that large-scale transformations of landscapes by bark beetle infestations in the Bavarian Forest conflicted with cultural meanings of landscapes and led to political conflict over appropriate management strategies.

The relationship between trust and risk perception is found to be of particular interest in this study with results that ap-

pear to run counter to several other studies. The positive correlation between public trust and risk ratings seems to contradict much of the risk literature that has found higher levels of trust associated with lower risk (e.g., Siegrist 2000; Siegrist and Cvetkovich 2000; Bronfman et al. 2008; Needham and Vaske 2008). We think that this apparent contradiction is a reflection of land managers' and other experts' judgements of MPB risk and their role in communicating MPB risk to the public. Sjöberg (1999) described the role of experts as either risk protectors (alleviating public concern of a hazard) or risk promoters (warning the public of a hazard). In Alberta, land managers and other experts have acted primarily as risk promoters warning of the economic and ecological consequences of the infestation through local media (S. Romanowski. 2009. Mountain pine beetle media analysis: articles published from 2000 to 2008 in Alberta newspapers. Unpublished report, Foothills Research Institute, Hinton, Alta.). In other words, it appears that the public trusts and believes the experts' message that the MPB is a risk to ecosystems and communities. Therefore, another important aspect of public acceptance for MPB interventions may be the maintenance of this trusting relationship between land managers and residents of these regions. This may be influenced, however, by an intervening effect of knowledge. Our findings suggest that as knowledge of MPB increases, concern over the potential risks decreases such that an informed public may be less concerned over the environmental and social risks and less supportive of land managers' efforts to control the beetle. McFarlane et al. (2006) also found that as knowledge among residents of British Columbia and Alberta increased, their attitudes toward MPB became more positive and public support for management intervention declined. Similarly, Müller and Job (2009) found that tourists who were informed about bark beetle infestations in a German national park evaluated the infestation more positively. The potential interaction between knowledge and trust is supported further by our finding that in the case of low knowledge (the public), there is a reliance on trust in making risk judgements. However, those most knowledgeable of MPB (i.e., the experts) do not rely on trust in making their risk judgements. This suggests that in the early stages of an MPB infestation, trust may be integral to the public's risk judgements and acceptance of management strategies. However, when public knowledge of MPB increases, they do not rely on trust in experts and trust becomes less important in risk judgements (Siegrist and Cvetkovich 2000). These results call for more attention to the content of risk messaging and the intervening effects of trust and knowledge on people who take up these messages.

The necessity to formulate a rapid response to the MPB and the considerable time involved in negotiating a management strategy with local citizens presents challenges (Flint et al. 2009; Mackenzie and Larson 2010). Unlike conventional forest management plans, the rapid response required to control insect disturbances leaves little time to develop trusting relationships, educate the public, or incorporate local concerns into a management response. The sense of urgency for a response to the MPB seems to be shared by the public and is probably another factor influencing risk judgements and acceptance of management strategies. As the sense of urgency diminishes, however, increasing public awareness and

fostering trusting relations are likely to be integral to risk judgements and support of MPB management over the longer term.

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