Perceptions of risk and vulnerability following exposure to a major natural disaster: The Calgary flood of 2013

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Abstract

Many studies have examined the general public's flood risk perceptions in the aftermath of local and regional flooding. However, relatively few studies have focused on large-scale events that affect tens of thousands of people within an urban center. Likewise, in spite of previous research on flood risks, unresolved questions persist regarding the variables that might influence perceptions of risk and vulnerability, along with management preferences. In light of the opportunities presented by these knowledge gaps, the research reported here examined public perceptions of flood risk and vulnerability, and management preferences within the city of Calgary in the aftermath of extensive flooding in 2013. Our findings, which come from an online survey of residents, reveal that direct experience with flooding is not a differentiating factor for risk perceptions when comparing evacuees with non-evacuees who might all experience future risks. However, we do find that judgments about vulnerability—as a function of how people perceive physical distance—does differ according to one's evacuation experience. Our results also indicate that concern about climate change is an important predictor of flood risk perceptions, as is trust in government risk managers. In terms of mitigation preferences, our results reveal differences in support for large infrastructure projects based on whether respondents feel they might actually benefit from them.

Keywords: flooding, natural hazards, climate change, risk perception, risk management

1. Introduction

With increased clarity and awareness regarding the link between climatic change and weather extremes, comes greater concern about certain natural hazards. This heightened level of concern is not unfounded; climate-induced natural disasters seem to be steadily increasing in their frequency since 1900. While this global trend can, in part, be accounted for by improved methods for reporting and data collection over this time period, recent research suggests a strong and positive correlation between climatic change and the incidence of hydrological, meteorological, and climatological hazards [(1, 2)].

According to data from the United Nations Office for Disaster Risk Reduction and the International Disaster Database (EM-DAT)[1], one of the starkest trends can be observed for the incidence of

[1] See https://www.unisdr.org/we/inform/disaster-statistics and http://www.emdat.be.

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hazardous storms and floods[2] (Figure 1). Over the past decade alone, we have observed an increase in the frequency and severity of extreme weather events, such as floods, and the associated damages [3]. In many urban areas, overland flooding is of particular concern because of the increased human presence—in terms of population, property, and infrastructure—in regions susceptible to flood-related risks. These concerns are exacerbated by climate change, which is expected to influence flood and drought regimes [4].

Insert Figure 1 about here.

Highly industrialized and developed countries—like Canada, the United States, and much of Europe—have not been immune to this trend. In Canada specifically, the risk of severe overland flooding is, along with wildland fire, one of the country's most prevalent natural hazards [5, 6]. One recent Canadian flood stands out for its severity: The 2013 flood event in Calgary, Alberta (Figure 2).

Insert Figure 2 about here.

In the winter of 2013, the southern region of the province of Alberta experienced higher-than-normal precipitation and, as a result, robust snowpack at elevation. By late spring, the ground at lower elevations in the Rocky Mountains and foothills region was heavily saturated, with significant snow accumulation remaining in higher elevations [6, 7]. On 19 June 2013, a 72-hour period of extreme rainfall began at both low and high elevations; this event rapidly accelerated snowmelt at higher elevations, increased the overall rate of runoff, intensified flow rates in the city's local rivers—the Bow River and Elbow River—and caused local reservoirs to far exceed their capacity. Soon thereafter, the Bow and Elbow Rivers spilled over their banks.

Within the City of Calgary, a state of emergency, which lasted 15 days, was called on 20 June 2013 in advance of the peak flood level. Approximately 75,000 people (of an overall population of approximately 1.1 million people) were placed under a mandatory evacuation order, and left their homes for a period of time ranging from days to weeks depending upon the neighborhood in which they lived.

[2] Hazardous storms include short-lived, micro- to meso- scale extreme weather and atmospheric conditions that last from minutes to days. Floods are classified as the occurrence, movement, and distribution of surface and subsurface freshwater and saltwater.

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Flooding was not isolated to the Calgary metropolitan area. Approximately 25,000 additional people were evacuated from 26 other southern Alberta municipalities located near Calgary. Extensive flooding and record-breaking discharge rates caused erosion of the river channels, and destroyed or heavily damaged private property and city infrastructure—including roads and bridges—in the floodwater's path. Across all of southern Alberta, which includes Calgary, five people lost their lives and total financial damages were estimated at more than $6 billion [(8)]. Today, more than three years after the flood, the recovery is still not complete.

The flood in Calgary provides a unique opportunity to study flood risk perceptions and risk management preferences in a large urban center that has suffered significant damages. Also, Calgary—and Alberta more generally—are Canada's hub for the oil and gas industry, and because of this are well known for their mixed feelings about climate change[3]. Therefore, it was particularly interesting to study climate risk perceptions at a time when a changing climate is influencing how we think about natural disasters, and in a place where ambivalence toward climate change is pervasive.

The connection between flooding, flood experience, and risk perceptions have been the subject of several studies. For example, Botzen *et al.* [(9)], in a study of Dutch residents living across a wide geographic area (vs. concentrated in a single urban center), showed that prior experience with flooding was positively related to judgments about flood risk; these results make sense, but leave open questions about what constitutes experience in this case; was it the *indirect* experience of *observing* a flood within a community, or was it *direct* experience associated with *evacuation*? Our study sought to disentangle the question of experience according to evacuation status during the 2013 Calgary flood. Thus, we hypothesized that people living in an at-risk community during the Calgary flood, *and who were evacuated in 2013*, would perceive greater risk in comparison with people who did not live in an at-risk community, and with people who did but who were not evacuated.

It is also noteworthy that the most recent major floods in the Netherlands occurred in 1993 and 1995, 12 to 14 years prior to the research conducted by Botzen *et al.* [(9)]; this is an important

[3] In the Alberta Issues Poll, conducted in December 2015, 68% of those surveyed did not support government action on climate change; 68% did not support a carbon tax; and 50% did not support a transition toward renewable energy.

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consideration because time decreases the influence experience has on risk perceptions [10]. Along similar lines, a recent study of a New Zealand flood plain by Lawrence *et al.* [11] suggest that prior flood experience is also positively associated with risk perceptions; however, their work was also more than a decade removed from the most recent flood, sampled people from a wide geographic area who did not experience floods in the same way, and did not include data analyses that could account for the significance of their findings.

With these challenges in mind, we were mindful of conducting our research as quickly as practical following the flood since a reduction in the temporal distance between exposure and our study could conceivably influence risk perceptions. For example, in the case of wildfires, prior research has found that direct experience—via evacuation—with a natural hazard leads to dampened risk perceptions relative to people who lived nearby but experienced a near miss. These types of differences may be especially pronounced when the feelings of elevated concern associated with the near-miss [12]—or the misplaced feelings of relief after having lived through a 1-in-500 year event [13]—are still quite salient in the minds of respondents.

In addition to experience with flooding, respondents' ability to cope with natural disasters may also influence risk perceptions. Assessments of "coping appraisal" can be used to assess ones' belief that they have the necessary skills and resources to take effective risk management action. Prior research on coping appraisal, which builds upon protection motivation theory [14], suggests that it is a combination of knowledge about appropriate risk reduction behaviours, and the belief that an individual can take action, which may influence risk perceptions and preferences regarding risk management [15-17]. Based on these findings, we hypothesized that higher self-ratings of coping appraisal would be associated with lower levels of risk perception. In addition, we hypothesized that living in a flood risk community would raise knowledge about risk reduction actions but lower beliefs that individual action can meaningfully reduce personal flood risk.

Similarly, recent research has also focused on the connection between prior experience with flooding and risk mitigation preferences. Working in The Netherlands, for example, Zaalberg *et al.* [15] surveyed 519 people living in a flood-prone area, showing that—in addition to feeling more vulnerable and worrying more about future flooding—victims of prior floods felt more positive about mitigation options when compared to non-victims. The same general trend holds when we consider heightened flood risk perceptions as a function of elevated concern about climate change [18]. Based on these findings, we hypothesized that respondents in at-risk communities, and

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especially those who had direct flood experience in 2013 because they were evacuated from their homes, would be more supportive of a broad array of risk mitigation initiatives. Likewise, we hypothesized that greater levels of concern about climate change, would be associated with heightened levels of risk perception amongst respondents in at-risk communities.

In addition to these variables, we were also interested in exploring the influence of public trust in government risk managers on risk perceptions. While we were not motivated by an exploration of the underlying mechanisms of trust—e.g., for a discussion of social trust and shared values, see Siegrist et al. [19]—we were interested in the presence of an inverse relationship between trust and risk perception. Specifically, we hypothesized that higher levels of trust in government risk management would offer people—especially in at-risk communities—a measure of near- and long-term security, reflected in lower levels of perceived risk.

Finally, we sought to draw together insights from risk analysis and applied research in geography as a means of estimating respondents' sense of vulnerability. For the purposes of our research, we adopt the definition of vulnerability as proposed by the IPCC [20]. Our primary interest in vulnerability focuses on the degree to which a system, or a component of a system, is susceptible to a hazard; the IPCC's definition of vulnerability also accounts for the ability of systems, or a component of a system, to cope with the outcomes of exposure to a hazard. Specifically, we were interested in behavioral moderators—exposure to a natural hazard—of geographic reasoning [e.g., see 21] as a means of assessing respondents' level of perceived vulnerability to flood risks.

A fundamental assumption of our research is that our collective understanding of human-environment interactions can be enhanced if we account for psychological traits such as cognitive processes that might underlie spatial reasoning. For example, geographers and risk analysts readily accept that spatial distance is an important correlate of certain behaviors and perceptions [22]. We, therefore, sought to assess respondents sense of vulnerability by using a novel, measure of perceived minimum-safe-distance; we expected that perceptions of minimum-safe-distance would be driven largely by prior flood experience and not necessarily just the physical distance between respondents and a high-risk flood zone. We hypothesized that, when it comes to feelings about risk, how people *judge* or *perceive* distance based on past exposure to flooding matters just as much—and perhaps more—than a spatial measure of minimum-safe-distance.

2. Methods

2.1 Sample

An online survey was conducted in Calgary, Alberta, Canada between September and October, 2015. The survey was deployed by Insightrix Research, using a pre-recruited panel and probability sampling. Sampling focused on owners or renters of homes and condominiums, and did not include businesses or commercial properties. Respondents were recruited based on the community in which they lived; in response to an optional question, respondents could report their street address, which we used to calculate the straight-line distance between at-risk homes and the 100-year[4] inundation line; see below.

We surveyed residents of Calgary who did not live within the flood plain and, therefore, were not at risk of flooding. In addition, we surveyed people who lived within at-risk communities as defined by the 100-year inundation line; these communities straddled the Bow and Elbow Rivers and parts of them were under evacuation orders during the flood of 2013. Because these communities are large and diverse in terms of topography, and because the evacuation orders during the 2013 flood were issued according the city blocks that were inundated or likely to be inundated, not everyone in an at-risk community was *required* to evacuate. Therefore, we also asked respondents in at-risk communities to indicate if they were required to evacuate during the 2013 flood.

According to our sampling frame and our differentiating questions, we were able to divide our sample into three groups: respondents who lived in at-risk communities who were evacuated (E), respondents who lived in at-risk communities who *were not* evacuated (NE), and respondents who did not live in a community at risk for flooding (NFZ). Though large parts of the city were influenced by the flood, we have defined direct flood experience as those who were evacuated as a result of the risk of flooding.

[4] In fact, the flood experienced in Calgary in 2013 was closer to a one-in-500-year flood; i.e., a flood with an annual incidence probability of 0.02. However, at the time of the flood, and when this research took place, the city of Calgary did not possess a 500-year hazard map. So, the frame of reference used during this research was the 100-year inundation line.

Both genders were approximately equally represented (50.7% identified as female, and 48.5% identified as male). According to the most recent census data for Calgary, the sample was slightly older and more educated than the general population. Likewise, the frequency of homeowners in the sample, was slightly higher than the average for Calgary (Table I).

The initial sample consisted of 806 residents. A total of 43 respondents were removed from the sample for having spent less than half of median time (7 minutes) on the survey; this accounted for 22 respondents from evacuated communities, and 21 respondents from communities that were not in the flood zone. In total, 763 respondents were included in the final sample. A total of 384 (50.3%) of these respondents did not live in the flood plain (NFZ). The remaining 379 (49.7%) respondents lived in communities that received evacuation orders; within this group, 198 respondents (26%) were evacuated (E) while 181 respondents (23.7%) were not (NE).

2.2 Survey Instrument

The primary dependent variables in this research were citizens' perceptions of risk, and their preferences for flood risk management options. The risk management options were selected based on what was under consideration by the City of Calgary and the Province of Alberta in 2015, when the research was conducted.

Participants were asked to characterize the risk of a major flood across the city of Calgary, like the one experienced in 2013, over the next 5 and 100 years. Responses were collected on 5-point Likert scales, which ranged from "very low risk" (1) to "very high risk" (5); the midpoint (3) was labeled as "moderate risk".

Respondents' preferences about flood risk management alternatives were assessed using 7-point Likert scales, which ranged from "weak" (1) to "strong" (7) support; "moderate support" served as the midpoint (4). The alternatives themselves were selected in consultation with the flood mitigation strategists from the City of Calgary's Water Resources office; the alternatives chosen for this research ranged from small-scale efforts aimed at public education and risk communication, to large-scale and resource intensive infrastructure projects (Table V).

In terms of independent variables, we asked participants to respond to a series of three statements about climate change, which were adapted from Tobler et al. [23]; these three statements—which were: (1) *I worry that the state of the climate is changing*; (2) *Climate change will have severe*

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consequences for humans and for nature; and (3) *Taking steps to protect our climate is important for our future*. Responses to all three statements were collected on 7-point Likert scales, which ranged from "strongly disagree" (1) to "strongly agree" (7). Responses to these statements were later combined to create a single scale dealing with climate change concern (Cronbach's α = 0.931).

Coping appraisal was studied from the perspective of "response efficacy" and "self-efficacy". Self-efficacy refers to a respondents' general value orientation regarding the belief in their ability to overcome challenges. Response efficacy, in comparison, is based on respondents' judgments regarding their ability to take specific actions that would meaningfully lower risk (namely, flooding in the case of this research). Coping appraisal was, therefore, measured using two separate 6-item scales. Higher scores on both of these scales implied a high coping appraisal. Strong inter-item reliability was observed for both scales, where Cronbach's α = .916 for self-efficacy, and Cronbach's α = 0.848 for response-efficacy.

The first coping appraisal scale was adapted from Schwarzer and Jerusalem (24), assessed self-efficacy via self-reported agreement with the following questions: *I can solve difficult problems if I try hard enough*; *It is relatively easy for me to accomplish the goals I set for myself*; *I am confident that I can deal efficiently with unexpected events*; *I am resourceful when it comes handling unforeseen situations*; *I am able to remain calm when facing challenges or difficulties*; and *When I am confronted with a challenge or a problem, I can usually find more than one solution to it.* Agreement with these questions was measured using 7-point Likert scales where 1 = strongly disagree, and 7 = strongly agree.

The second scale, adapted from Bubeck et al. [(10)], focused on response-efficacy and asked for respondent's agreement with the following questions: *I am capable of taking personal action that will lower my risk of future flood damage*; *It is worth the effort to take personal action aimed at lowering my risk of future flood damage*; *I am knowledgeable about the range of personal actions I could take in order to lower my risk of future flood damage*; *I have the time that would be required for me to take personal action to lower my risk of future flood damage*; *I have the money that would be required for me to take personal action to lower my risk of future flood damage*; and *I am motivated to take action in order to lower my risk of future flood damage*. As above, agreement with these questions was measured using 7-point Likert scales where 1 = strongly disagree, and 7 = strongly agree.

Trust in government risk management action was assessed via a 7-item scale. Two items focused on respondents' trust in the ability of the city government (item 1) and provincial government (item 2) to reduce the future risk of major flooding in Calgary; two items focused on respondents' trust in the ability of the city government (item 3) and provincial government (item 4) to protect homes; two items focused on respondents' trust in the ability of the city government (item 5) and provincial government (item 6) to protect public health and safety; and, one item focused on respondents' trust in both governments' ability to deploy engineering solutions that would reduce the future risk of major flooding in Calgary (item 7). Responses for all items were collected on 7-point Likert scales where 1 = low trust and 7 = high trust. Strong inter-item reliability was observed for this scale, where Cronbach's $\alpha = 0.922$.

We also assessed the role that past experience plays in respondents' feelings about risk and vulnerability; to do so, we developed a proxy measure that accounted for perceptions of minimum-safe-distance. Here, we geocoded respondents' addresses—for those who provided them—using ArcGIS, and calculating straight-line distances from each respondents' home to the edge of the 100-year flood inundation zone. The distances, in meters, served as the independent variable used for physical distance to a high-risk flood zone. The dependent measure in this case was respondents' opinion about how close they live to a high-risk flood area in Calgary; responses were provided on a 10-point Likert scale, which ranged from "I live a safe distance away" (1) to "I live dangerously close" (10).

The survey instrument closed with a series of demographic questions (Table I).

2.3 Data Analysis

We performed multiple regression analysis to examine the effects of demographics, opinions about climate change, coping appraisal, and trust in government risk management action on near- and long- term flood risk perceptions.

To test the influence flood experience has on response- efficacy and self- efficacy, an analysis of variance (ANOVA) with Tukey's *post-hoc* test was used.

A moderated regression model was used to test for the influence of being evacuated on perceptions of minimum-safe-distance when considering the inundation zone of a high-risk flood area. This was done to determine if flood experience—namely evacuation status—was a moderating factor, and if

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perceptions of minimum-safe-distance changed based on evacuation experience. As described by Aiken and West (25), the interaction term was tested by evaluating evacuation experience × distance in meters to the 100-year inundation zone. Perceptions of distance to a high-risk flood area was used as the explained variable.

Multivariate analysis of variance (MANOVA) was used to test for differences between across risk mitigation alternatives. Comparisons were made across the three respondent groups outlined above: NFZ, NE, and E. Specific differences across these groups were established using Tukey's *post-hoc* tests.

3. Results

3.1 Flood risk perceptions

With respect to near-term risk perceptions, a multiple regression analysis (Table II) revealed that, relative to respondents who are not at risk of flooding, living in an at-risk community without having been evacuated (NE) significantly increased perceived risk at the $p \leq 0.01$ level; living in an at-risk community *and* being evacuated (E) also led to elevated risk perceptions at the $p \leq 0.05$ level. In addition, concern about future climate change was positively related to higher near-term risk perception ($p \leq 0.001$). Finally, trust in government action was inversely related to near-term risk perceptions; here greater trust dampened perceived risk ($p \leq 0.001$). Each of these findings was consistent with our hypotheses. Our findings regarding coping appraisal and near-term risk perceptions did not support our hypotheses.

In the same model of near-term risk perceptions, gender was initially a significant predictor when considering only demographic factors of risk perception and flood experience; specifically, women perceived greater levels of risk under both circumstances ($p \leq 0.01$). However, when concern about climate change and trust in government action were added to the model, gender was no longer a significant predictor. Multicollinearity was not a concern for these results, the correlation between variables was small (r <0.4) and the variance inflation factors (VIF) ranged between 1.06 and 1.23.

For long-term risk perceptions, and in contrast to our hypotheses, a multiple regression (Table II) revealed that living in an at-risk community regardless of one's evacuation status, did not lead to heightened risk perceptions when compared with respondents who were not at risk of flooding ($p \geq 0.05$). However, some of the demographic variables were significant: Though gender was never

found to be a significant predictor of long-term risk perceptions, both home ownership (vs. respondents who were renting) and age (above the median for Calgary of between 40 and 49 years of age) were positively related to long-term risk perception at the $p \leq 0.05$ and $p \leq 0.001$ levels, respectively. In line with our hypotheses, concern about climate change and trust in government action remained significant (with trust in government action maintaining its inverse relationship) at the $p \leq 0.001$ and $p \leq 0.01$ levels, respectively. Further in line with our hypotheses, self-efficacy was shown to have a significant inverse influence on long-term risk perceptions ($p \leq 0.01$); response-efficacy, by contrast, was not a significant predictor of risk perception. Again, multicollinearity was not a concern. The correlation between variables was small (r <0.4) and the variance inflation factors (VIF) ranged between 1.06 and 1.25.

Insert Table II about here.

3.2 Response- efficacy and self-efficacy

To examine coping appraisal further, response-efficacy and self-efficacy were examined in isolation to determine if beliefs were influenced by 2013 flood experience. An ANOVA (Table III) revealed a significant effect for response-efficacy, indicating that flood experience influenced views towards taking personal action to lower flood risks ($F_{2, 760} = 3.85$, $p \leq .05$). Contrary to our hypothesis, response-efficacy was significantly greater for those outside a flood risk region ($\bar{x}$ = 4.37, SD = 1.14) than for those who were evacuated ($\bar{x}$ = 4.1, SD = 1.28, $p \leq .05$), indicating that evacuation experience lowers perceived ability to reduce personal flood risk. In further contrast to our hypotheses, self-efficacy remained stable and did not differ significantly based on 2013 flood experience ($F_{2, 760} = 1.48$, $p \geq .05$).

Insert Table III about here.

3.3 Perceptions of vulnerability and minimum-safe-distance

We sought to determine if exposure to a natural hazard, like the flood of 2013, influences perceptions of risk and feelings of vulnerability that can be captured in how respondents judge variables such as minimum-safe-distance. To examine how flood experience influences judgments of distance in relation to physical distance, a moderated regression model was used. Specifically, a hierarchical multiple regression was conducted to assess the increase in explained variation by the addition of an interaction term between physical straight-line distance to the 100-year inundation line (in meters) and evacuation status to a main effects regression model.

In line with our hypotheses, flood experience in 2013 (i.e., evacuation status of those living in a flood risk community) moderated the effect of physical distance on perceptions of minimum-safe-distance, as shown by a statistically significant increase in the total variation explained; $\Delta F_{1, 258}$ = 4.06, $p \leq .05$ (Table IV, Figure 3). In other words, the experience of being evacuated (E) during the flood of 2013 resulted in respondents perceiving that they lived closer to the high-risk inundation zone—and, hence, felt more vulnerable—when compared to respondents who were not forced from their homes (NE). In addition, without evacuation experience perceptions of distance to a high-risk inundation zone decreased slowly as physical distance from the high-flood risk region increased. In comparison, those with direct flood experience felt more vulnerable at equivalent physical distances (Figure 3).

Insert Table IV about here.

Insert Figure 3 about here.

3.4 Mitigation preferences

A series of six questions dealing with participants' support for different mitigation actions currently being considered in the City of Calgary were posed. These actions ranged in project scope from rather straightforward initiatives, such as enhanced risk communication efforts to promote informed decision-making, to large scale (and very costly) engineered solutions, such as the construction of a large off-stream reservoir to collect flood water outside of the Calgary city limits in the event of a severe flood in the future (Table V).

A MANOVA revealed a significant multivariate effect ($F_{12, 1512}$ = 4.75, $p \leq 0.001$) based on flood experience and support for mitigation, indicating that experience during the 2013 flood had a significant impact on some mitigation preferences.

Specifically, flood experience significantly influenced support for provision of flood insurance ($F_{2, 760}$ = 4.59, p = 0.01), with those who were evacuated indicating higher levels of support when compared to those who did not live in a community at risk of flooding (p=.007). Likewise, responses to the government annexing high-risk properties significantly differed ($F_{2, 760}$ = 3.8, p = 0.02), with those who were in a flood risk community but not evacuated indicating higher levels of support when compared to those who live outside of the flood zone (p=.018). We also observed differences in support for mandating the modification of hydroelectric dams located along the Bow River (which

traverses the city of Calgary) for the purpose of flood control ($F_{2, 760}$ = 7.19, p = 0.001). A Tukey's *post hoc* comparison indicated that respondents who were evacuated were more supportive of this option than those who did not live in a community at-risk for flooding (p=.001, Table V).

Preferences for the construction of additional, permanent flood barriers were also influenced by flood experience ($F_{2, 760}$ = 13.22, p ≤ 0.001). *Post hoc* tests revealed those not in the flood zone and not evacuated were less supportive of this option ($\overline{x}$ = 4.83, SD = 1.47) when compared to respondents who lived in the flood zone but were not evacuated ($\overline{x}$ = 5.27, SD = 1.37, p = 0.002), and respondents who were evacuated ($\overline{x}$ = 5.42, SD = 1.39, p ≤ 0.001).

Finally, flood experience was a significant determinant of support for a high-cost infrastructure project: the construction of an off-stream reservoir, approximately 30 km to the west of Calgary, which would capture and temporarily store water during a severe flood event ($F_{2, 760}$ = 8.77, p ≤ 0.001). *Post hoc* testing showed that respondents who lived outside of the flood zone were less supportive of this option ($\overline{x}$ = 4.82, SD = 1.57) when compared to respondents who lived in the flood zone but were not evacuated ($\overline{x}$ = 5.19, SD = 1.54, p = 0.02), and respondents who were evacuated ($\overline{x}$ = 5.35, SD =1.54, p ≤ 0.001).

In sum, all of our findings regarding mitigation preferences supported our hypotheses with only one exception: Enhanced risk communication with homeowners ($F_{2, 760}$ = 2.08, p ≥ 0.05) did not differ based on flood experience in the 2013 flood.

Insert Table V about here.

4. Discussion

The purpose of this research was to further our understanding of how people perceive flood risk, as well as their management preferences in the aftermath of a major flood.

Overall, our results (Table 2) indicate that, for a flood of this magnitude, it is not evacuation status *per sé* that influences risk perceptions. In our study, *both* evacuees and non-evacuees who live in at-risk communities demonstrate elevated risk perceptions over the near-term when compared with people who do not live in an at-risk community. As such, the important factors of risk perception for

near-term risks of the magnitude experienced by residents of Calgary in 2013 appears to be the potential for future exposure, and not simply past evacuation experience.

On the surface, these results seem to contradict prior research, which typically concludes that direct-flood experience is an important motivator of elevated risk perceptions. Prior research speculates that these elevated levels of risk perceptions can be linked to a reliance by respondents on the availability heuristic [26]. This line of reasoning suggests that prior experience with flooding—as would be the case if one was evacuated—leads people to overestimate the probability of future floods; this, in turn, drives elevated risk perceptions [11, 15, 27-29].

In our study, merely having lived in an at-risk community—regardless of evacuation experience in 2013—leads to elevated risk perceptions in the near-term. Given the vividness and magnitude of the 2013 flood, we are not surprised in hindsight that people who were not evacuated in 2013, but who lived in at-risk communities as defined by being within the 100-year inundation zone for Calgary, also had greater levels of near-term risk. With a large-scale natural disaster in a concentrated urban center like Calgary, a sense of uncertainty about *if* one might be affected in the future is replaced by an acknowledgement that a lack of exposure may have been the result of a stroke of luck. In other words, *if* you were lucky enough to escape direct exposure while living in an at-risk community during the Calgary flood of 2013, you may not be so lucky the next time. This result is akin to the "post-exposure wake-up call" experienced by unaffected neighboring communities in the aftermath of other natural hazards, namely a major wildland fire [12].

Likewise, because of the magnitude and salience of the Calgary flood, it is likely that the majority of community members felt affected to some degree. For people living in Calgary, the outpouring of concern and support for flood victims was substantial. Even for those living outside of Calgary, the flood of 2013 was impossible to miss, be it through either the wall-to-wall coverage provided by the mainstream media or online social networks such as Twitter and Facebook. This kind of salient, shared experience, in turn, likely served to elevate risk perceptions regardless of one's personal, direct experience with the flood [29].

This trend was not observed for long-term risk perceptions. Our results here suggest that experience is not influential in terms of raising risk perceptions associated with exposure in the distant future. More abstract characterization of 100-year risks may explain this; according to construal level theory [30], long-term flood risks are constructed at a higher level; i.e., less concretely when compared with

how people may think about exposure to a risk in the near-term. As such, prior experiences are likely to be discounted when people are asked to think about exposure far into the future.

But, according to our study, similarities between evacuated and non-evacuated respondents in at-risk communities only goes so far. Specifically, our results also reveal that evacuation status in the 2013 flood does lead to heightened feelings of vulnerability. When perception of minimum-safe-distance to a high flood risk area was used as a proxy for vulnerability, evacuation experience was found to have a significant influence (Figure 3, Table IV). Specifically, people who experienced the flood firsthand, because they were forced to evacuate, judged themselves to be closer to a high-risk area even when we controlled for physical distance.

The difference observed in this study between flood risk perceptions and vulnerability reinforces the idea that these are similar, but distinct concepts [(31)]. Risk is a function of the likelihood and consequences of a hazard; flooding, in this case. Vulnerability, while it is clearly dependent upon the risk being considered, also must account for the challenges associated with recovering from the negative consequences of exposure. Thus, one's ability to both cope with—and recover from—exposure to the risk are encapsulated in judgments about concepts like minimum-safe-distance [(32)].

It was also noteworthy that, in terms of demographic components of risk perception, only age was a significant predictor of long-term—but not near-term—risk perceptions with older adults perceived lower levels of long-term flood risk. We believe this to be the case because, as older adults think about the future, they view themselves as being increasingly less likely to reside in the area; in other words, a decrease sense of worry about future risks as one isn't going to be around to experience them. These results are tempered, however, by home ownership, likely because homeowners are interested in protecting their investments, as such perceive higher levels of long-term flood risk when compared to renters.

Beyond age and home ownership, we did not detect many of the trends observed by others. For example, neither gender, income, nor education level was found to be a significant predictor of near- or long-term risk perceptions. We know from a raft of prior studies that women generally perceive higher levels of risk than men [(33-35)], and that lower levels of education are sometimes associated with elevated risk perceptions [(36, 37)]. Once again, we believe that that the extent of the flooding, and the resulting damages were so prominent that they dampened in respondents' minds any of the demographic characteristics that would normally account for differences in perceived risk.

The Calgary flood of 2013 followed another major flood in the city, which occurred in 2005. Much of the discussion in the news and popular media in the weeks and months following the 2013 flood emphasized that, because of climatic change, the probability of future floods of a similar scale was very high. Add to this the magnitude of the resulting damages—over $6 billion in damages as we note above—and it becomes difficult to imagine that these factors would supersede demographic characteristics that might otherwise lead to relatively small differences in perceived risk [29].

To explore this idea further, we accounted specifically for concern about climate change as a predictor of flood risk perceptions. Our results suggest that concern about climate change is of greater significance when it comes to explaining flood risk perceptions than evacuation experience (Table 2). Our findings mirror those observed in other studies, which also showed that high levels of concern about climate change in the future are tightly linked to concerns about future flood risk [18, 38-40].

This relationship makes particular sense in southwestern Alberta, which is located in the foothills of the Canadian Rocky Mountains. The effects of climate change in this area are expected to more frequently bring heavy snowpack at elevation, more rapid warming during the transition from winter to spring, and heavy rain during this same time period [5, 7]; these were precisely the conditions that led to the flood of 2013, so it stands to reason that the probability of future flood events will increase.

From the standpoint of risk communication, these results offer an interesting opportunity for risk managers in the area. Rather than focusing on the negative affect invoked by flooding [27] or previous experience [15], risk communicators may instead wish to focus on raising awareness about climate change in the area. Prior research supports the idea that, over and above cultural variables, higher levels of knowledge about climate change lead to elevated risk perceptions [41]; this, in the case of the Alberta experience, may lead to a greater appreciation for flood risks in the area, especially after the memories of extreme events—like the Calgary flood of 2013—fade.

Our results suggest that trust in government risk management actions—whether they unfold at the local, provincial, or federal level—has a significant association with lowering near- and long-term risk perceptions. Once again, these findings align with prior research [42-44]. The belief that risk management actions by government can be trusted to reduce future risks offers people a measure of near- and long-term security, which in turn is reflected in their perceptions of risk.

In line with previous research [10], coping appraisal was not found to be significant in terms of shaping short-term flood risk perceptions. However, contrary to prior findings, we did observe a significant effect of coping appraisal—in terms of self- efficacy—on long-term risk perceptions. Specifically, higher self-ratings of self-efficacy—i.e., the confidence in one's ability to cope with adversity—was related to elevated risk perceptions over the long-term only and did not significantly differ based on 2013 flood experience. This result is difficult to explain. Perhaps confidence that one will be able to cope with future adversity makes it easier to come to terms with the elevated probability associated with long-term risk because people feel like time to prepare is on their side. If this were true, the challenge from a risk management standpoint is overconfidence [45] regarding the ability to cope with future risks, which may lead people to delay actions that may mitigate the effects of future exposure. However, we are uncomfortable with any definitive conclusions in this regard; more research as it relates to this finding is necessary.

Focusing on the influence of flood experience in shaping coping appraisal, those who were evacuated do not seem to feel they have the resources and ability to take action to lower personal flood risk. This may be a result of the magnitude of the Calgary flood; having witnessed what major flooding can do to the area, it may be difficult to imagine mitigation approaches that would serve to reduce future risk. However, self-efficacy remained stable regardless of flood experience, indicating that individuals' beliefs *about themselves* was preserved despite evacuation experience. This suggests that response-efficacy—the belief that specific risk management actions will reduce future exposure— is more malleable than self-efficacy. Therefore, future risk communications may wish to target building an individual's sense of capability in taking protective action. Positive feelings in terms of self-efficacy and the malleable nature of response-efficacy, could be leveraged by risk communications that encourage people to take or support preventative measures aimed at securing their personal and material safety.

To this end, our research also explored respondents' support for different flood risk management strategies currently under consideration by the local and provincial governments (Table V). We observed no statistically significant difference in respondents' high degree of support for better risk communication about future floods, which is understandable. Following a flood of this magnitude, most would want to be better informed about risks and risk management options, even if the link between risk information and improved risk management decisions is tenuous at best [12, 46].

We did, however, observe significant differences in terms of respondents' support for requiring the provision of overland home flood insurance. Those who were evacuated revealed greater support for mandatory insurance provision than those who would not directly benefit from this option being available.

Support for the annexation of at risk homes along the Bow and Elbow Rivers showed that those who live in an at-risk community but were not evacuated are more supportive of this option than those who live outside the flood risk area. No significant difference was detected between those who were evacuated and those who do not live in an at-risk community. We believe this to be the case because evacuees would be the ones who might feel most like they would lose their homes to such a program which, in turn, would trigger loss aversion and a decline in support for such a policy.

Further, we observed significant differences across a set of three potentially effective but also controversial risk management options, that would require the construction of, or modifications to, costly infrastructure. Among the most controversial of these options, respondents living in at-risk areas, regardless of their experiences during the 2013 flood, were more supportive of constructing an off-stream dry reservoir 15 kilometers away in the neighboring village of Springbank that could be activated to capture water during peak-flow flood events; the proposed reservoir would have a storage capacity of 70.2 million cubic meters and would cost $264 million (CAD). A similar trend was observed for projects aimed at constructing permanent flood barriers along the Bow and Elbow Rivers. Finally, only those that were evacuated revealed greater support for the option of re-tasking some existing dams located upstream of Calgary from power generation to flood control. Taken together, these findings make a great deal of intuitive sense: We expect less support for costly infrastructure projects from people who would not directly benefit from them, namely respondents who do not live in an at-risk area. Likewise, since these initiatives all address future risks, and because of the salience of the 2013 flood (discussed above), we did not anticipate significant differences in support based on prior flood experience.

Over a longer period of time, and without exposure to future flood events, we anticipated that support for all mitigation options would decrease as flood risks fade from memory. Each of construal level theory [30], the availability bias [26], and our own results concerning long-term flood risk perception support this prediction. As such, the near-term poses the best opportunity for policy makers and respondents in our study—as well as for anyone who has been recently exposed to

natural hazards—to make substantial headway in terms flood risk management and resilience building.

To conclude, this study advances our understanding of variables that influence flood risk perceptions, judgments about vulnerability, as well as the influence direct experience with flooding has on mitigation preferences. Many of our findings run counter to what has been reported in other studies of flood risk perceptions. We believe this to be the result of the severe nature and broad scope of flooding in Calgary, which provided the contextual basis for our research.

Additional research is clearly needed to further deepen our understanding of risk perceptions in the context of natural hazards. In our view, specific attention should be paid to the large-scale events that are more difficult for respondents to trivialize, and hence may provide a more robust picture of the complexities inherent in the formulation of risk judgments. Without research of this type, which we admit is challenging from both an implementation and analytic standpoint, we are concerned that the insights we gain about risk perceptions and management preferences will fail to fully account for the complexities that define at-risk people and communities.

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Table I. Key sample demographics with corresponding census data for the city of Calgary. [*] denotes most recent census data (from 2011) for Calgary from Statistics Canada. [**] denotes most recent data (from 2014) from the Canada Revenue Agency.

	Median Age	Percent Women	% Post-Secondary Education	Median Income	% Home Ownership
Sample	50 - 59	51%	83%	$90,000 -$119,999	79%
Calgary	40 - 49[*]	49%[*]	67%[*]	$104,530[**]	72%[*]

Table II. Regression model for near-term (5-year) and long-term (100-year) risk perceptions (n = 763).

	5-Year Risk Perceptions			**100-Year Risk Perceptions**		
	B	*SE*	*β*	*B*	*SE*	*β*
Gender	0.09	0.077	0.042	-0.117	0.072	-0.058
Age (Above Median)	-0.003	0.004	-0.028	-0.016	0.004	-0.15***
Education (Above Median)	0.001	0.004	0.008	0.006	0.004	0.051
Income (Above Median)	0.001	0.001	0.035	0.001	0.001	0.022
Home Ownership (vs. Rentals)	0.102	0.096	0.039	0.202	0.089	0.082*
At-Risk Community – NE	0.248	0.094	0.100**	0.14	0.088	0.06
At-Risk Community – E	0.19	0.093	0.078*	0.153	0.087	0.067
Climate Change Concern	0.209	0.023	0.342***	0.187	0.021	0.324***
Coping Appraisal – Self-Efficacy	-0.006	0.042	-0.005	0.109	0.039	0.108**
Coping Appraisal – Response-Efficacy	0.064	0.035	0.071	-0.049	0.033	-0.059
Trust in Government Action	-0.106	0.029	-0.133***	-0.081	0.027	-0.109**
R^2		0.13			0.14	
F (df1, df 2)		9.79*** (11, 693)			9.99*** (11, 706)	

**p ≤ 0.05; **p ≤ 0.01; ***p ≤ 0.001*

Table III. ANOVA comparing response-efficacy and self-efficacy as a function of flood experience. Comparisons were made across three groups: respondents who *were* evacuated (E); respondents who lived in a community at risk for flooding but who *were not* evacuated (NE), and respondents who did not live in a community at risk for flooding (NFZ). (*denotes a significant difference between groups).

NFZ	**NE**	**E**	*F*	*p*	*Tukey Results*

	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*			
									NFZ *vs.* NE^{ns}
Response-Efficacy	4.37	1.14	4.37	1.22	4.10	1.28	3.85	0.02	NFZ *vs.* E*
									NE *vs.* E^{ns}
									NFZ *vs.* NE^{ns}
Self-Efficacy	4.99	1.01	5.08	1.00	4.90	1.00	1.48	> 0.05	NFZ *vs.* E^{ns}
									NE *vs.* E^{ns}

Significance level for Tukey's post-hoc comparisons: **p ≤ 0.05; **p ≤ 0.01; ***p ≤ 0.001; ns = no significant difference.*

Table IV. Hierarchical multiple regression analysis predicting the influence of experience on perceived minimum-safe-distance (n = 262).

	Model 1			**Model 2**		
	B	*SE*	*β*	*B*	*SE*	*β*
Distance to 100-Year Inundation Line	-0.002	0.00	-0.39***	-0.002	0.00	-0.34***
Evacuation Experience	0.73	0.36	0.12*	1.09	0.40	0.18**
Interaction Term (Distance × Experience)				-0.002	0.001	-0.13*
R^2		0.19			0.21	
F (df1, df 2)		32.21***(2, 259)			23.08*** (3, 258)	
ΔF (df1, df 2)					4.06* (1, 258)	

**p ≤ 0.05; **p ≤ 0.01; ***p ≤ 0.001*

Table V. MANOVA comparing flood risk mitigation strategies as a function of flood experience. Comparisons were made across three groups: respondents who *were* evacuated (E); respondents who lived in a community at risk for flooding but who *were not* evacuated (NE), and respondents who did not live in a community at risk for flooding (NFZ). (* denotes a significant difference between groups). The overall analysis was significant ($F_{12, 1512} = 4.75$, $p \leq 0.001$).

	NFZ		**NE**		**E**		*F*	*p*	*Tukey Results*
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*			
									NFZ *vs.* NE^{ns}
Enhanced risk communication so that home and business owners may make more informed, personal risk management decisions.	5.49	1.35	5.59	1.27	5.32	1.43	2.08	≥ 0.05	NFZ *vs.* E^{ns}
									NE *vs.* E^{ns}

Require insurance companies to provide mandatory overland flood insurance to homes and businesses in flood-prone areas.	4.41	1.87	4.60	1.95	4.92	1.93	4.59	0.01	NFZ *vs.* NE^{ns} NFZ *vs.* E** NE *vs.* E^{ns}
Government annexation of homes and businesses in the flood prone areas, and converting them into flood green space.	4.09	1.90	4.56	1.85	4.31	2.00	3.80	0.02	NFZ *vs.* NE* NFZ *vs.* E^{ns} NE *vs.* E^{ns}
Permanently modify the operation of upstream hydroelectric facilities (dams) for flood control purposes.	5.16	1.26	5.39	1.27	5.57	1.28	7.19	0.001	NFZ *vs.* NE^{ns} NFZ *vs.* E*** NE *vs.* E^{ns}
Construct additional permanent flood barriers within Calgary to protect vulnerable infrastructure and communities.	4.83	1.47	5.27	1.37	5.42	1.39	13.22	≤ 0.001	NFZ *vs.* NE** NFZ *vs.* E*** NE *vs.* E^{ns}
Construct an off-stream reservoir, outside of Calgary, which would temporarily store water during a severe flood event.	4.82	1.57	5.19	1.54	5.35	1.54	8.77	≤ 0.001	NFZ *vs.* NE* NFZ *vs.* E*** NE *vs.* E^{ns}

Significance level for Tukey's post-hoc comparisons: **p ≤ 0.05; **p ≤ 0.01; ***p ≤ 0.001; ns = no significant difference.*

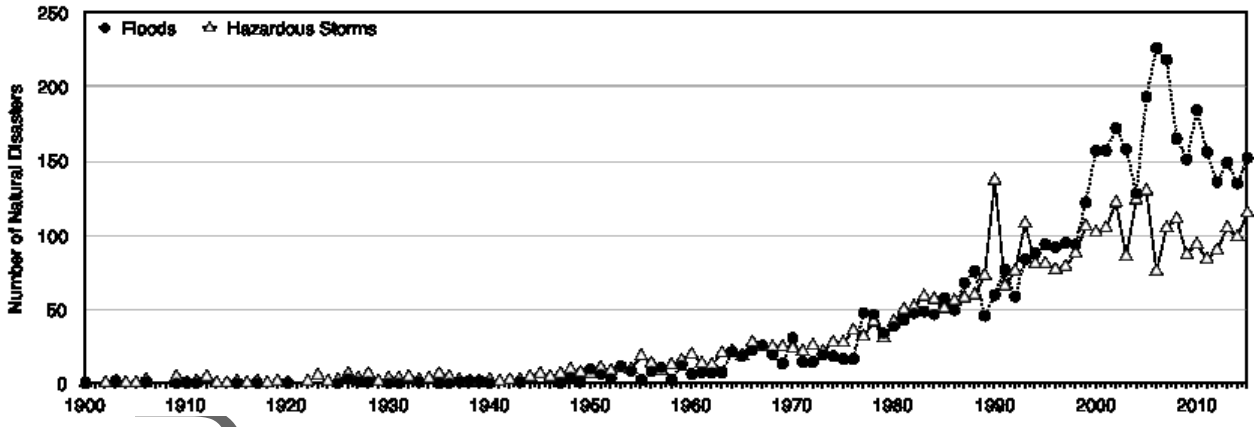

Figure 1. Annual global incidence of natural disasters (1900 – 2015) associated with flooding and hazardous storms. For a disaster to be entered into the EM-DAT database, ten or more people must be reported killed, 100 or more people must be displaced, a state of emergency must have been declared, *or* a call for international assistance must have been made.

Figure 2. Calgary, Alberta, Canada

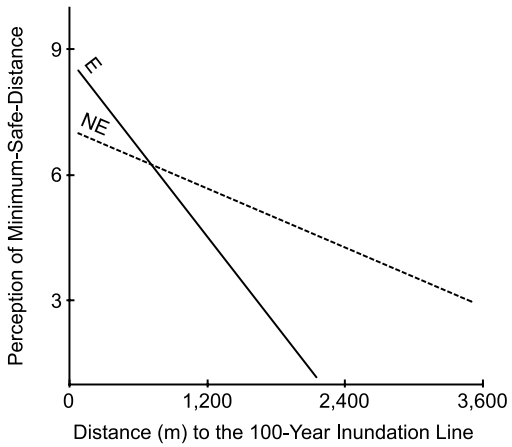

Figure 3. Interaction between perceptions of minimum-safe-distance and physical distance (m) moderated by flood experience between evacuated (E) and non-evacuated (NE) respondents.