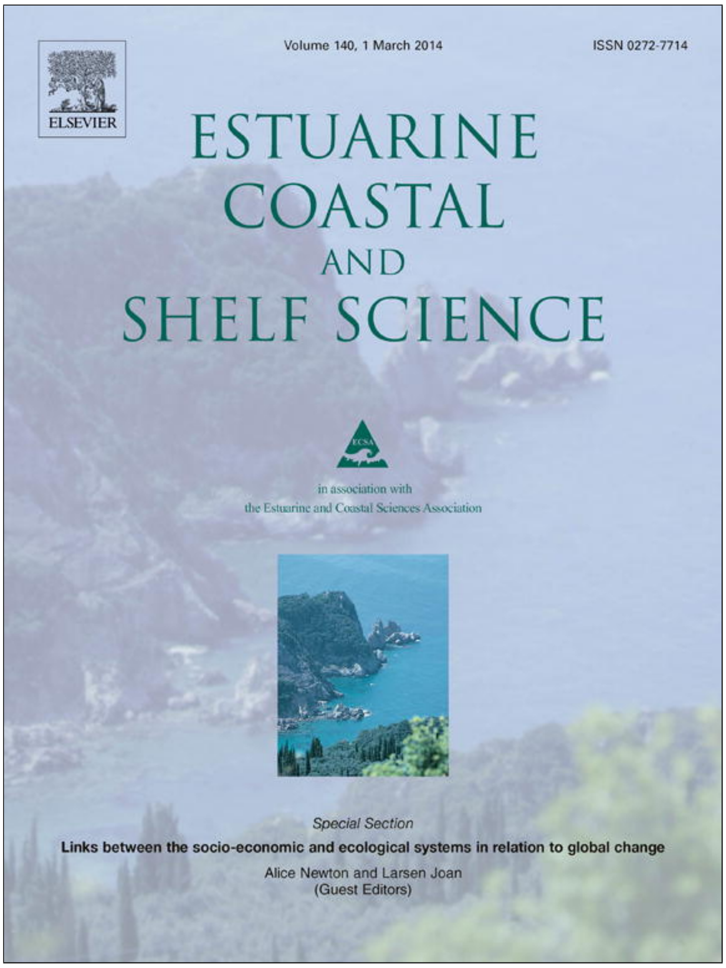
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Climate change awareness and strategies for communicating the risk of coastal flooding: A Canadian Maritime case example

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A B S T R A C T

Rising sea levels, due to thermal expansion of the ocean, and higher frequency and intensity of coastal and inland storms threaten coastal communities worldwide. The implementation of pro-active, planned adaptation to reduce community vulnerability is strongly dependent upon people's perception of the threat posed to their communities at the local scale. Unfortunately, the scarcity of research into effective risk communication limits our understanding of how climate change evidence can most effectively raise risk awareness and inspire community adaptation.

With a focus on a case study situated in the Tantramar area of South-East New Brunswick, Canada – an area subject to very large tidal forces from the Bay of Fundy – this study set out to assess public awareness about the link between climate change and elevated risk of regional dyke failure, measure how different multi-media visualizations influence public risk perception, and provide general recommendations for the development of flood risk communication strategies in coastal zones.

The results from 14 focus groups ($n = 157$ participants) revealed that 81% of respondents felt that the problem of climate change was considerable or severe. However, when asked for their assessment of personal vulnerability to dyke failure and subsequent coastal flooding, only 35.6% considered themselves to be at considerable or severe personal risk. Gender, education, and age were found to significantly influence initial risk perception to varying degrees, and were also associated with changes in risk perception following the communication session. While geovisually-enhanced communication strategies, involving 3D flood animations and web-based GIS maps, were no more effective at raising risk awareness than a non-enhanced communication package, qualitative responses suggested that the geovisualizations had greater emotional impact ("shock"), and contributed disproportionately to an expressed desire to become politically and socially active around the issue. In conclusion, in addition to presenting evidence in a clear and compelling way, effective coastal flood risk communication requires a supportive framework capable of building trust and encouraging public dialogue. Recommendations towards creating this framework are provided.

1. Introduction

Climate change is a problem of global scope, with significant consequences for coastal communities. Risks include increased sea levels due to thermal expansion of the ocean, a higher frequency and intensity of coastal and inland storms, and accelerated erosion (Dronkers et al., 1990; Wu et al., 2002). Unfortunately, these zones are also heavily populated (Dronkers et al., 1990). In the face of these threats, pro-active, planned adaptation to reduce community vulnerability is highly desirable. But the implementation of particular adaptation strategies is complicated by the 'wicked' nature of the climate change problem (Bord et al., 1998): there is a general lack of public awareness, or worse, complete misunderstanding, which undermines the public's willingness to participate or support adaptation efforts (Seacrest et al., 2000; Lorenzoni et al., 2007; Jude, 2008); differential perception of the appropriate balance between long- and short-term considerations can lead to divergent opinions about the efficacy of candidate options (Lorenzoni and Pidgeon, 2006); and the fact that people generally resist making uncomfortable behavioural changes (Bord et al., 1998; McKenzie-Mohr, 2000; Seacrest et al., 2000).

A recent Gallup Poll reported that 55% of Americans worry a great deal or fair amount about global warming (Newport, 2012), but historically, this has varied between 50% and 72% (Lorenzoni

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and Pidgeon, 2006). As summarized by Lorenzoni and Pidgeon (2006), a 1992 Gallup Health of the Planet (HOP) survey revealed that 13 of 24 countries (of which eight were European) had >50% of respondents indicate climate change to be a serious problem. In a more recent, 2004 European survey poll, the greatest proportions of concerned respondents resided in Sweden (68%), Luxembourg (58%), Germany (57%), the Netherlands (53%) and Finland (53%). Twenty-six percent of all EU-25 respondents felt they lacked information specifically about climate change (Lorenzoni and Pidgeon, 2006). While perceptions vary, there is a general and widespread belief in the seriousness of global climate change (Bord et al., 1998; Lorenzoni and Pidgeon, 2006).

How does this general acceptance of the immediacy of the climate change problem translate to the local scale? Do people understand the threats facing their own community? Bickerstaff et al. (2004, cited in Lorenzoni and Pidgeon, 2006; Burningham et al., 2008) provide evidence that in the U.K., individuals in areas directly vulnerable to climate change are often unaware of the connection to their local areas, or fail to see a potential impact on their day-to-day lives. A key challenge facing regional coastal managers, therefore, is how to develop public communication tools capable of effectively illustrating possible future scenarios at meaningful scales while simultaneously involving the public in the difficult discussions surrounding adaptation (Jude, 2008).

Risk communication is complicated by idiosyncrasies in the way people perceive environmental threats, and research has shown that this is partially shaped by human psychology. For example, people tend to draw inferences from information without regard for the weight of the evidence ('insensitivity to sample size', Tversky and Kahneman, 1974), display overconfidence in their ability to derive accurate inferences (Slovic, 1987), and exhibit arbitrariness in their risk tolerances (Burgman, 2005). Research has also shown that peoples' perceptions of climate change are also heavily influenced by such factors as social background, cultural orientation, and behavioural disposition, which complicates the planning of risk communication materials (Slovic, 1987; Nicholson-Cole, 2005). The paucity of research on effective risk communication led Sterman (2011) to declare this a major bottleneck limiting the effective application of science to climate policy. At worst, poor risk communication efforts leave a "knowledge vacuum" that will be filled by "error, disinformation and falsehood" (Sterman, 2011: 402). Left to their own devices, risk communication recipients will create their own "mental models" to interpret the information they are exposed to (Moser and Dilling, 2004).

Even if clearly articulated adaptation plans are in place, gaining public support (i.e., instilling the intention to adapt, Grothmann and Patt, 2005) is very unlikely to occur without successfully communicating the risk of inaction. Sterman (2011) further argues that risk communication strategies will only be successful when they are informed by a thorough understanding of the publics' beliefs. Further to this notion, Pelletier and Sharp (2008) suggest that the form and nature of the communication has also to accommodate the "psychological state" of the intended recipient. The general public is unlikely to accept adaptation strategies (i.e., be in a "decision phase") without first passing through a "detection phase".

In practice, risk communicators often rely too heavily on technical experts' opinions about what should be communicated rather than directly assessing the perception states of their intended audiences. Also, most communication products are produced for and by domain experts, leaving their effectiveness in the public communication arena unevaluated (Lieske, 2012). People respond differently to the presentation of different information, coloured by education, gender, etc. Willingness to act is also eroded by overreliance on public infrastructure, e.g., dykes. This can lead to a dangerous, false sense of security in their integrity and reliability (see Tobin, 1995).

The present study originated out of a number of pragmatic concerns. First, while global models for temperature increases and sea level rise are widely available, community planners typically have no specific information on potential impacts at the local level. Second, a significant role played by local planning authorities is to advise and make recommendations to existing and prospective land owners in flood risk zones. Sporadic and episodic events can be difficult to imagine until they actually occur, so visualizations offer a way to "talk about" the associated risks and vulnerabilities.

The chief question posed by this study is whether it is possible to communicate coastal flood risk in a way that appeals to the widest range of people's personalities but is, at the same time, constructive, and less likely to push people into maladaptive positions (e.g., fatalism, anti-social behaviour). Visualizations, ranging from conventional 2D maps to 3D animations, may have an important role to play in raising people's awareness and encouraging them to form an adaptation intention. As a theoretical tool to support spatial reasoning, and as a means to stimulate spatial imagination, visualization has a long and established history in geographic research (Tukey, 1977; MacEachern et al., 1992; Andrienko et al., 2003; Keim et al., 2005). It is expected that visualization has an important role to play in climate change communication through its capacity to make sporadic (e.g., flooding) or gradual (e.g., erosion) risks 'visible'. With a focus on the Tantramar area of South East New Brunswick, this article builds on the research described in Lieske (2012) to advance the following goals:

1. Assess public awareness about local climate-change impacts, in particular, elevated risk of coastal flooding in the Tantramar;
2. Measure how different multi-media visualizations influence public risk perception and assess their potential for enhancing risk communication;
3. Provide general recommendations for the development of flood risk communication strategies in coastal zones.

2. Methods

2.1. Tantramar study area

The Tantramar Region is situated in South-East New Brunswick, Canada, and is governed by four municipal governments (of which the Town of Sackville is one), one aboriginal First Nation, and nine local service districts. Situated at the head of the Bay of Fundy (Fig. 1), the region is subjected to strong tidal forces, and relies on a dyke system to protect the Town of Sackville, an interprovincial railway and highway, and surrounding agricultural lands. Current 1-in-10 year extreme storm levels are estimated at 8.9 m ± 0.1 m (CGVD28 datum), which has the capacity to overtop 89% of the existing dyke system (average height: 8.6 m) and flood approximately 20.6% of the town (Lieske and Bornemann, 2011). As summarized by Roness and Lieske (2012), the population is well educated (14% have university certificates, diplomas or degrees, 12% have apprenticeship or trades certificates or diplomas, and 18% have college, CEGEP or other non-university certificates or diplomas), with a median age of 42 (compared to the Canadian median age of 40.6, based on 2011 census), and generally high rates of labour force participation (64.6%), and high levels of home ownership (82%).

2.2. Sampling design

Initially, potential focus group participants were randomly and individually solicited via newspaper advertising, media presentation, and word-of-mouth. This survey approach was largely

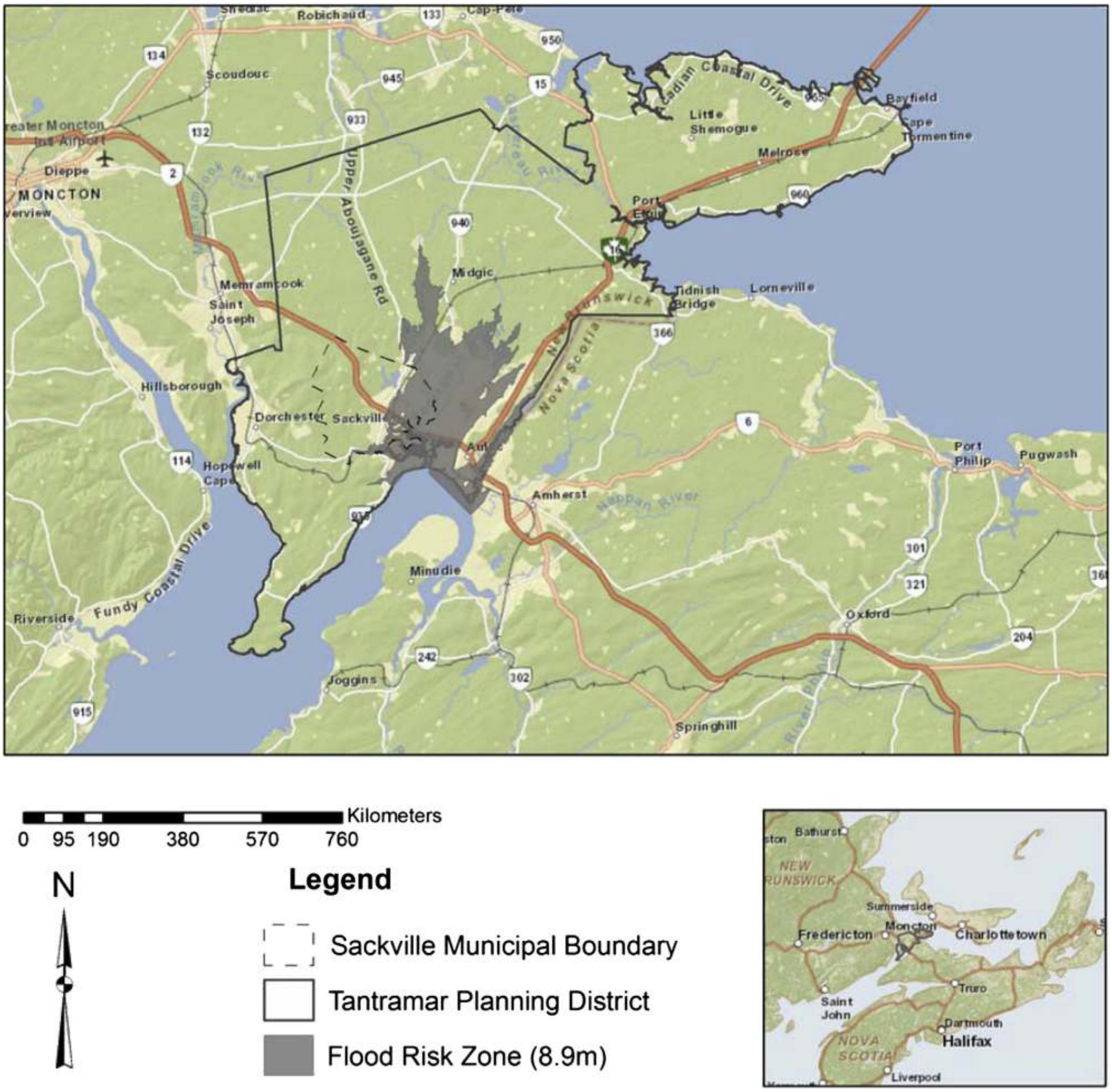

Fig. 1. Map of the Tantramar region within the Province of New Brunswick, Canada. Also indicated is the Sackville Municipal boundary, and the flood risk zone at an 8.9 m (CGVD28 datum) extreme sea level. The basemap is OpenStreetMap (http://wiki.openstreetmap.org).

unsuccessful, attracting less than a dozen people. To improve recruitment, schools, professional bodies and non-governmental, community-based organizations were contacted and presentations delivered during their normal meeting times from October, 2011 to March, 2012.

Sessions commenced with participants completing a pre-focus group questionnaire (Section 2.3). Focus group attendees were free to decline to participate, and no personal identifiers (e.g., name, home address) were recorded to ensure anonymity. Focus group content consisted of one of three randomly assigned communication treatments (Section 2.4), which took from 45 min to an hour to complete. All treatments were initiated using the baseline communication material, which involved the presentation of a series of Powerpoint (Microsoft Corporation, 2002) slides accompanied by a verbal commentary by the authors. Treatments two and three were augmented by the presentation of special geovisualizations (Section 2.4). The sessions ended with participants completing a post-focus group questionnaire, which replicated the same questions as appeared in the pre-focus group version, supplemented by a number of open-ended, qualitative questions. At no point prior to completion of the post-focus group questionnaire were participants given an opportunity to discuss the treatment materials with each other.

2.3. Assessment of risk perception

As with Lorenzoni et al. (2007), this study employed a mixed-methods approach combining both quantitative and qualitative approaches within pre- and post-focus group surveys. As pointed by Lorenzoni et al. (2007: 498) this "allows a certain degree of triangulation of the findings and underlines their complementariness".

Perceptions were assessed in the pre-focus group survey using four key questions:

1) "Do you feel that global climate change is a problem?"
2) "Do you think there is a link between a possible failure of the Tantramar dykes and climate change"?
3) "How likely to you think the risk is of a dyke failure in the Tantramar?"
4) "How vulnerable are you to the risk of a Tantramar dyke failure?"

A number of socio-demographic variables have been previously identified to influence risk perception, including: age, gender, annual family income, highest level of educational attainment, and home ownership status (NRC, 2006; Burningham et al., 2008). All of these variables were gathered as part of the pre-focus group assessment.

The same four key questions were also administered in the post-focus group survey, with a participant-provided code word used to link the responses to particular individuals while preserving anonymity.

2.4. Communication strategies (treatment types)

Study participants were exposed to one of three different treatments: base communication strategy, base communication strategy + animations, or base communication strategies + animations + dynamic web map. The latter two treatments are referred to as "geovisually-augmented". Participants were administered a survey prior to the communication treatment, and afterwards, and given no opportunity to discuss the materials until the survey portion of the session was complete.

2.4.1. Base communication strategy

All three treatments shared the same base communication strategy, which involved a verbal presentation and a series of static images. The following hierarchy of topics were considered: (1) the general phenomenon of global climate change, with a focus on empirical evidence such as a time-series plot of sea levels recorded by the Saint John tide gauge – it was anticipated that this would help to counteract possible cognitive biases, e.g., denial of climate change as theoretical or unknowable; (2) presentation of locally-relevant sea level estimates under current 1-in-10 year expected return frequencies, based on a report by Daigle (2011); (3) an overview of the role played by engineered dykes in the Tantramar area, their vulnerability to erosion, and their susceptibility to being overtopped by new sea levels under intensified storm surge events, anticipating a possible overreliance on these structures on the part of the public (see Tobin, 1995); and (4) an overview of the potential flood zone under 8.9 m and 9.7 m "bath tub" models.

Attention focused on communicating the risk of dyke compromise by illustrating the probability of occurrence and the maximum extent of floods under 8.9 m and 9.7 m sea levels. Economic and social impacts of flooding were not discussed, nor were short-term emergency responses and long-term community-wide adaptation strategies mentioned.

Data was obtained from a number of sources (Table 1) and led to a number of derived products, for example, sea level-specific flood extents and vulnerable infrastructure. The base communication strategy presented static flood maps as part of the Powerpoint presentation, and also made a paper map available for closer examination by interested participants.

2.4.2. Geovisually-augmented communication strategies

Communication strategies two and three, in addition to disseminating the base communication package (Section 2.4.1), also presented special geovisualizations. Treatment two was augmented by an animated version of the Saint John tide gauge (Fig. 2), as well a 3D animation of the flooded downtown core of the Town of Sackville (Fig. 3). Previous studies in climate change communication have identified animations as potentially simpler to understand than traditional maps (e.g., Jude, 2008), though they are also more resource intensive to develop (Lai et al., 2010). The 3D visualization was created using ArcScene (ESRI, 2012), and involved the simultaneous display of both the flood zone and 3D buildings, based on both LiDAR and high-resolution orthometric imagery (Table 1). A movie clip (wmv) was created using ArcScene, focussing on the downtown commercial core of the Town of Sackville.

Treatment three offered these same animations as well as a dynamic, web-based interactive GIS map (Fig. 4). A key advantage of a web-based GIS is the ability to flexibly view the scale and perspective, e.g., allowing consideration of both the entire planning district as well as individual neighbourhoods. It allows interactivity, facilitates spatial reasoning, and also provides a platform preparatory to wider dissemination of geographic information about climate change threats (Kingston et al., 2000).

2.5. Statistical analysis

Given that Likert scores are ordinal data, initial risk perception and change in risk perception was modelled using either proportional odds logistic regressions or multinomial (polytomous) logistic regressions (Fox, 2002; Collett, 2003). Proportional odds logistic regressions were preferred unless inflated Akaike Information Criterion (AIC) values indicated that their simpler structure was too restrictive. Proportional odds models were estimated using the *polr* function in the "MASS" library (Venables and Ripley, 2002), and multinomial models fitted using the *multinom* function of the

Table 1
Summary of datasets used in the study.

Dataset	Source	Date	Description	Derived product(s)
LiDAR	Leading Edge Geomatics, Govt. of New Brunswick (GNB), ACASA	November 9, 2009 and December 18, 2010	High resolution elevation data (15 cm vertical precision, 30 cm spacing)	Sea level flood extents, building heights, dyke centreline elevation
Property mapping	Service New Brunswick (SNB), Tantramar Planning District Commission (TPDC)	April 2011	Location of property parcels, zoning and land use	Identification of property at risk
High resolution orthometric imagery	Leading Edge Geomatics, GNB, ACASA	November 13, 2009	10 cm ortho-imagery	Building footprints
Topographic	SNB	1996	Transportation, hydrographic and elevation (1.5 m vertical precision, 30 m spacing)	Identification of assets at risk, elevation used to construct DEM where LiDAR unavailable.
Environmental and cultural areas	Parks Canada	2011	National historic sites and conservation areas	Identification of assets at risk

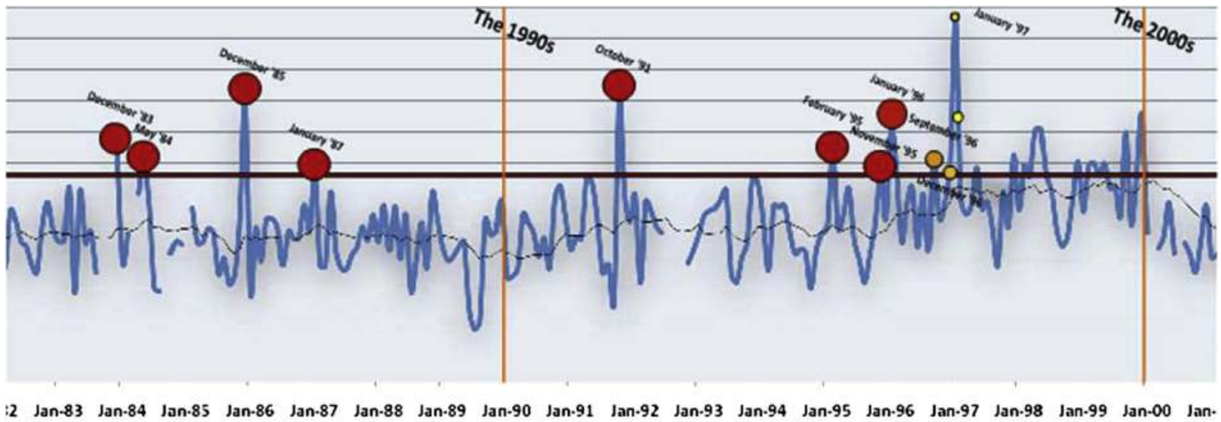

Fig. 2. Adobe Flash-enabled viewer for displaying an animated time series of tide gauge records for the City of Saint John, New Brunswick. Sea levels (ranging from 4.2 m to 5.6 m a.s.l.) were indicated on the *y*-axis, with the heavy red bar indicating the 95th percentile value of 4.8 m (a.s.l.). Animated icons indicated when a tide level exceeded the 95th percentile (reprinted with permission from Geomatica 66: 255–265, published by the Canadian Institute of Geomatics). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

"nnet" library (Venables and Ripley, 2002). Both libraries are implemented in the R Statistical Package (R Development Core Team, 2012).

All socio-economic variables were entered into an initial model, and a stepwise model selection procedure applied using the *stepAIC* function in the MASS library (Venables and Ripley, 2002). The *stepAIC* function uses changes in AIC values to determine which variables should be retained in the final model. Given that participants were sampled as part of their school, professional, and non-governmental community groups there was a possible hierarchical structure in the data. However, preliminary analysis of the data using mixed effects, ordinary least squares (OLS) regressions indicated models with a random effects term for group membership fit either more poorly or no better than a purely fixed effects model. In other words, the socio-economic characteristics of the study participants influenced their risk perceptions independent of which community group they were sampled from. For this reason, participants were pooled in the subsequent analysis.

Fig. 3. Three-dimensional visualization of the probable worst-case flood depth for a 1-in-10 year, 8.9 m flood event (CGVD28 datum) affecting the downtown core of Sackville, New Brunswick (reprinted with permission from Geomatica 66: 255–265, published by the Canadian Institute of Geomatics).

3. Results

3.1. Characteristics of sample groups

A total of 14 focus groups were conducted, involving 172 participants. Of the submitted questionnaires, 157 were fully completed. Only the fully completed subset was then used for the analysis. In terms of age, 38.2% were less than 25 years of age, 49.0% between 26 and 65, and 12.7% over 65. In terms of gender, 44.6% and 55.4% were females and males, respectively.

With regards to economic status, participants represented a cross section of family income and levels of home ownership: 17.8% reported an annual family income of less than $30 K (CDN); 49.7% between $30 K and $80 K; and 32.5% greater than $80 K. In terms of home ownership, 53.5% reported that they owned their own home, which is lower than the 82% average for the region as a whole (Roness and Lieske, 2012). This discrepancy is unsurprising, however, given that a significant percentage of study participants (20.4%) were secondary-school youth who defined themselves as "dependents". Of the remainder, 26.2% indicated that they rented.

From the perspective of highest levels of educational attainment, 51.6% were university educated, while 18.5% were college or trade certified. The remaining participants (29.9%) had high school education or less. As the regional average percentage university educated is 14% (Roness and Lieske, 2012), study participants could be characterized as better educated and more affluent than typical residents in the wider area. This can be attributed to the fact that the majority of participants resided in the Town of Sackville, and included a number of business leaders, university professors, and other professionals whose greater income would have upward inflated the percentages. Despite these differences, the socio-demographic characteristics of the sample group represented a sufficient cross-section of the community to characterize underlying trends.

3.2. Initial risk perception and influencing factors

Risk perceptions are summarized in Fig. 5, with initial, pre-treatment assessments represented by white bars. In response to the question: "do you feel that global climate change is a problem?", 81% felt that the problem of global climate change was either

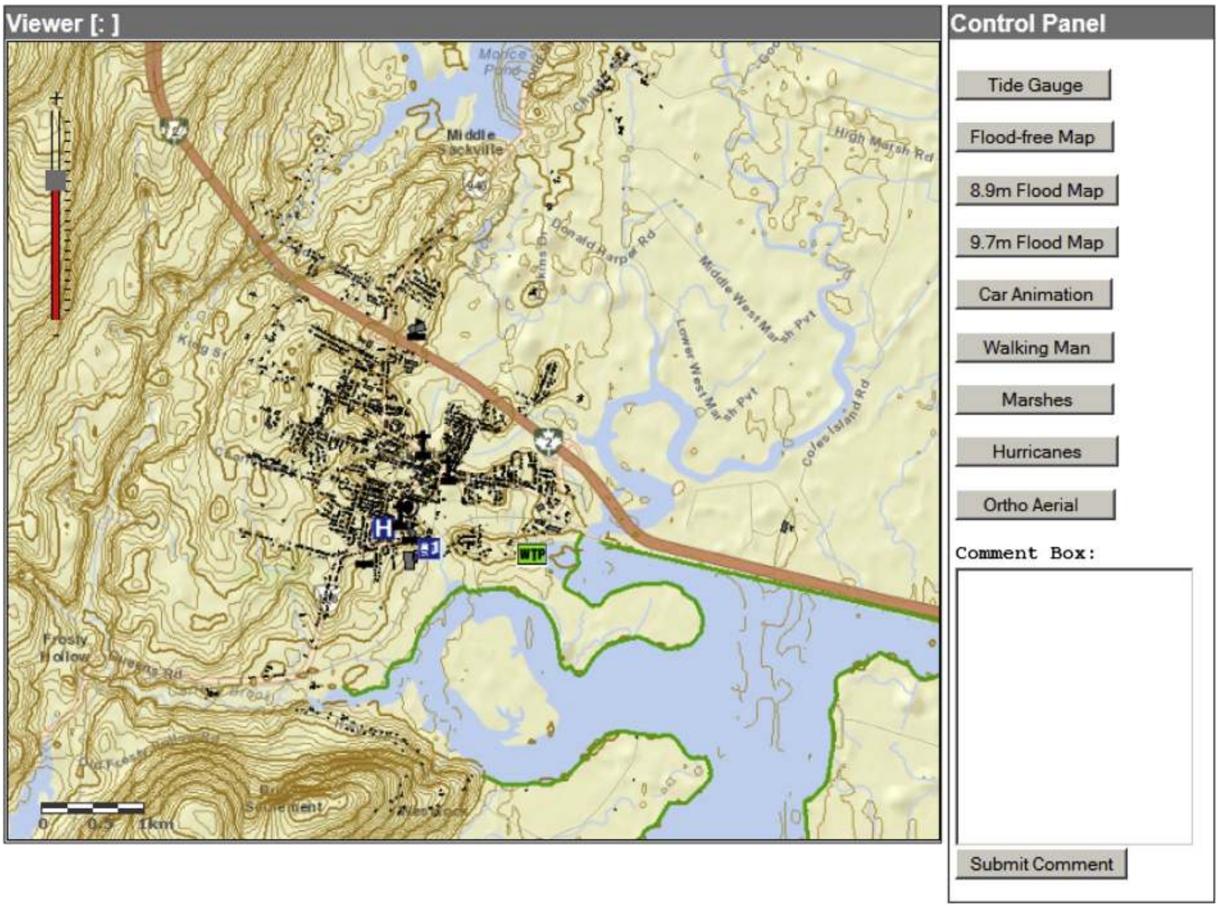

Fig. 4. Map viewer interface for dynamic display of flood risk zones and related infrastructure. The web-based viewer was implemented using the Javascript API and ArcGIS Server (Environmental Systems Research Institute, 2012).

severe (35.0%) or considerable (45.9%). When asked if they felt there was a link between climate change and the possibility of failure of the Tantramar dykes, respondents were more tentative: 70.1% considered the link to be either severe (15.3%) or considerable (54.8%). In response to the question: "how likely do you think the risk is of a dyke failure in the Tantramar?" 53.5% considered the risk to be either severe (18.5%) or considerable (35%). When asked "how vulnerable are you to the risk of a Tantramar dyke failure?", only 35.6% considered themselves to be either considerably or severely at personal risk in the event of dyke failure while 28.6% felt they were personally vulnerable to a "very small degree" or "not at all".

Fig. 6a and b illustrate the effect of factors that exerted an important influence on initial risk perception.

3.3. Quantitative change in risk perception, post-treatment

As indicated by the pre- and post-treatment distribution of risk perception scores (Fig. 5), exposure to focus group materials exerted the most impact on participants' perception of the risk of dyke failure (Fig. 5c) and the seriousness of the link between climate change and possible dyke failure (Fig. 5b). Median change (after − before) in Likert Scores was 1 for perception of the risk of dyke failure, but 0 for all other questions. Change in risk perception, as presented in Fig. 5, masks a significant effect, however: the tendency for individuals who initially ranked these risks as high to retain these views by the end of the treatment session. Clearly, prior beliefs need to be considered in order to interpret the effect of communication strategies and socio-economic covariates.

To better understand the impact of treatment and socio-economic factors we constructed proportional odds logistic regression models, except when inflation of AIC values indicated that the proportional odds assumption was too restrictive; in that case, we used a multinomial logistic regression (Section 2.5). Initial risk perception was also included as part of the set of starting variables to control for its effect. Stepwise model selection (with change in AIC as a decision rule) was used to obtain parsimonious final models for each of the four risk perception questions.

For change in the perception of the severity of global climate change, the most parsimonious model only incorporated initial risk assessment (Likelihood Ratio $\chi^2 = 11.58$, $df = 1$, $P < 0.001$). Treatment type, social, economic and demographic factors did not influence the change in opinion for this question (Table 2). For the second question, perception of the link between climate change and the risk of dyke failure, initial perception and home ownership were retained in the final model (LR $\chi^2 = 51.52$, $df = 3$, $P < 0.001$, Table 2). Renters and home owners exhibited a greater tendency towards positive changes in risk perception than participants who lived at home as dependents.

The final model for question three, change in the perception of the likelihood of dyke failure, retained initial risk assessment, age, education, and home ownership (LR $\chi^2 = 93.42$, $df = 7$, $P < 0.001$). Relative to the 26–65 age class, older individuals (66+) exhibited a greater increase (0.26 ± 0.56 SE; Table 2) while younger individuals (<25) exhibited a lesser increase (-1.16 ± 0.54 SE; Table 2). Greater educational levels led to greater increases in risk perception (Table 2); relative to college or trade certified individuals, high

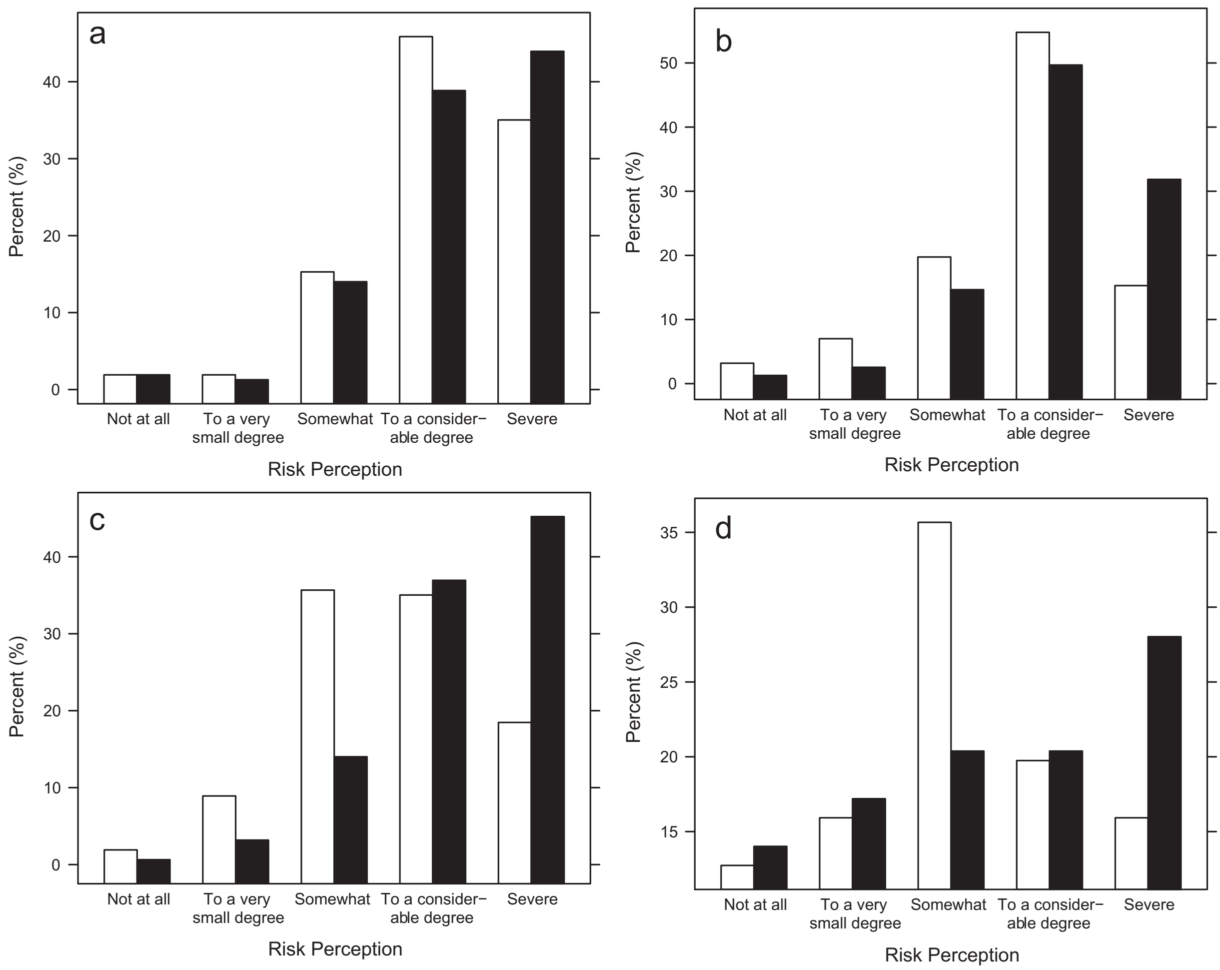

Fig. 5. Perception of risk, before (white bar) and after (black bar) participating in a risk communication focus group. Responses to the following questions were assessed: (a) "do you feel that global climate change is a problem?", (b) "do you think there is a link between a possible failure of the Tantramar dykes and climate change?", (c) "how likely do you think the risk is of a dyke failure in the Tantramar?", and (d) "how vulnerable are you to the risk of a Tantramar dyke failure?".

school educated or less exhibited a lesser increase (−0.32 ± 0.60 SE), while university educated exhibited a greater increase (0.72 ± 0.46 SE). In terms of home ownership, relative to "dependency" status, renters exhibited enhanced risk perception (1.38 ± 0.62 SE) while home owners showed a lesser change (0.28 ± 0.71 SE).

With regards to the change in the perception of personal vulnerability, initial risk assessment, age, and gender were retained in the final model (LR $\chi^2 = 31.05$, $df = 4$, $P < 0.001$). Older (66+) and younger (<25) individuals realized a lower change in the perception of personal vulnerability than middle-aged (26–65) people (−1.21 ± 0.48 SE and −0.93 ± 0.34 SE, respectively). Male participants also exhibited less change in opinion than female (−0.76 ± 0.32 SE).

3.4. Qualitative responses

Overall, 82 of the 108 responses (76%) appraising the effectiveness of communication materials identified maps and animations as a key component (Table 3a, question 4). When prompted to recommend improvements, the majority of comments pertained to the need for more information about what was being done to address the problem (8 of 30, or 27%) or more details about what an unfolding flood would be like (9 of 30, or 30%). Some requested a simplification of, for example, the information summarized in tabular format (4 of 30, or 13%), while others expressed difficulty reading text and maps (7 of 30, or 23%).

A large number of the responses regarding long-term adaptation involved moving to an alternate location (55 of 122, or 49%). Curiously, 71% (39 of 55) of the responses which singled out the moving strategy originated from participants exposed to the geovisually-augmented treatments (two and three).

Of 18 responses that indicated a desire to raise awareness, organize, or apply political pressure to advance a community adaptation strategy, 15 (83%) originated with participants exposed to geovisually-augmented treatments (two and three).

On four occasions respondents identified "shock" as their response to the event of a flood that affected them personally (question 3, Table 3a). All four were respondents exposed to treatment two (which prominently featured the 3D flood animation, Fig. 3).

4. Discussion

In summing up risk communication, Pelletier and Sharp (2008) argue that information needs to be tailored to "where people are at" in terms of readiness and intention to adapt. Grothmann and Patt (2005) point out that personal adaptation decisions are predicated on an awareness of the severity of the problem. In Grothmann and Patt's (2005) socio-cognitive model of private proactive

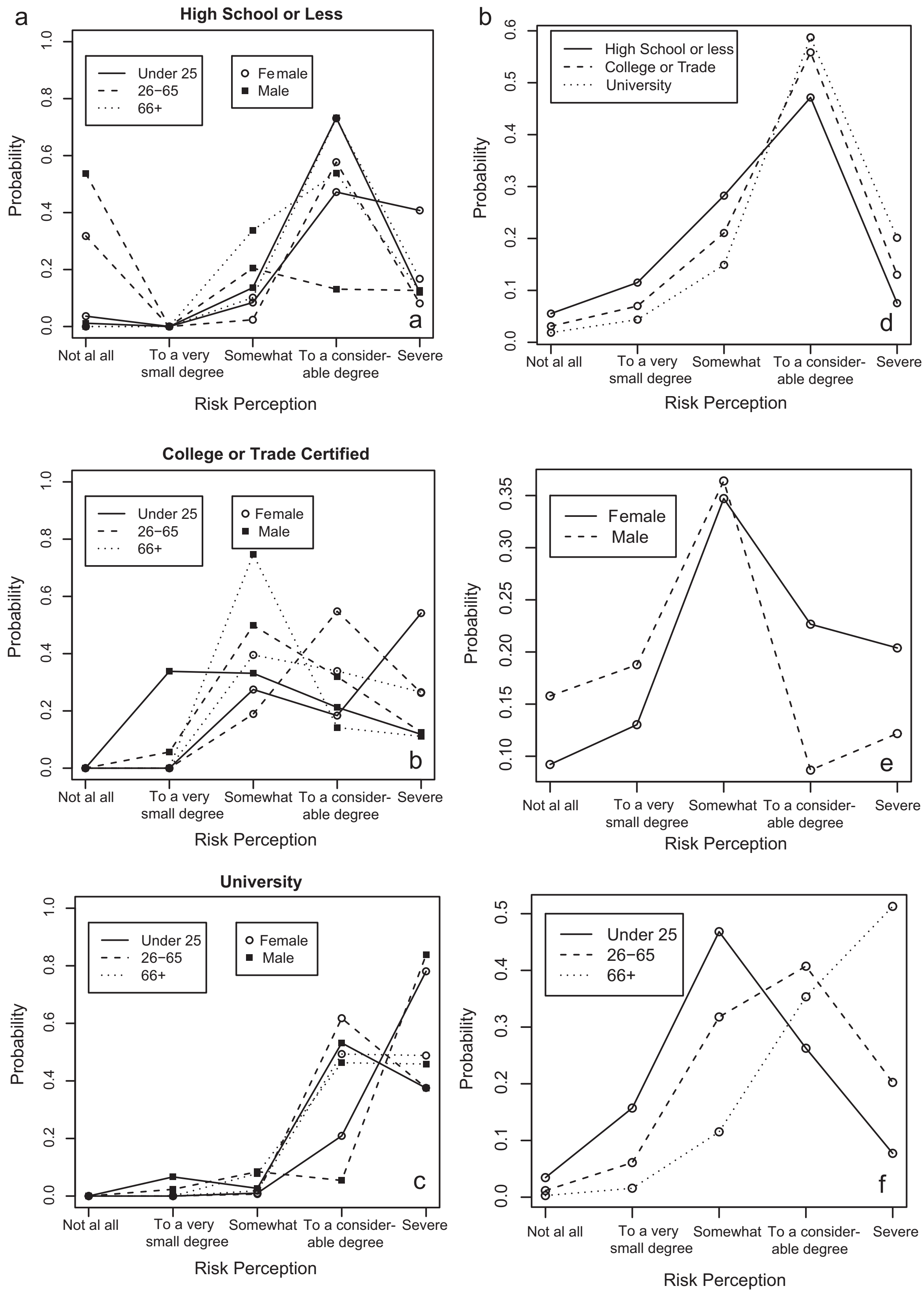

Fig. 6. 6a. Factors significantly influencing the initial perception of the threat posed by global climate change, as assessed by response to the question “do you feel that global climate change is a problem?”. Panels a through c show changes in the multinomial logistic response probabilities as a function of education, age, and gender Fig. 6b. Factors significantly influencing the initial perceptions of risk, as assessed by proportional odds logistic models of the responses to the following questions: (d) “do you think there is a link between a possible failure of the Tantramar dykes and climate change?”, (e) “how likely do you think the risk is of a dyke failure in the Tantramar?”, and (f) “how vulnerable are you to the risk of a Tantramar dyke failure?”.

Table 2
Proportional odds logistic regression coefficients (logit scale ± SE) of socio-economic and demographic variables on the change in risk perception (final score − initial score) for each of four main questions: (a) "do you feel that global climate change is a problem?", (b) "do you think there is a link between a possible failure of the Tantramar dykes and climate change?", (c) "how likely do you think the risk is of a dyke failure in the Tantramar?", and (d) "how vulnerable are you to the risk of a Tantramar dyke failure?"

Q.	Initial percep.	Age (<25 yrs)[a]	Age (≥66 yrs)[a]	Gender (male)[b]	Education (≤H.S.)[c]	Education (univ.)[c]	Own home[d]	Rent home[d]
(a)	−0.71 (0.22)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
(b)	−1.47 (0.23)	n.a.	n.a.	n.a.	n.a.	n.a.	0.91 (0.45)	1.06 (0.50)
(c)	−1.99 (0.26)	−1.16 (0.54)	0.26 (0.56)	n.a.	−0.32 (0.60)	0.72 (0.46)	0.28 (0.71)	1.38 (0.62)
(d)	−0.53 (0.13)	−0.93 (0.34)	−1.21 (0.48)	−0.76 (0.32)	n.a.	n.a.	n.a.	n.a.

[a] Relative to the age category: 26–65 years of age.
[b] Relative to the gender category: Female.
[c] Relative to the education category: Trade or College Certified.
[d] Relative to the home ownership category: Dependent.

adaptation to climate change, risk adaptation proceeds in two stages. First, exposure to communication materials prompts a process of personal "risk appraisal", moderated by cognitive biases, previous exposure to risk, and the degree of reliance on public adaptation strategies (see Tobin, 1995). The outcome is an assessment of risk probability and severity, which is immediately accompanied by a second stage: adaptation appraisal and response. At this point, communication recipients evaluate three things: (1) their perception of the overall possibility for effective adaptation (perceived adaptation efficacy), (2) their perception that it is possible for them to personally take action (perceived self efficacy), and (3) the perceived costs of adaptation (Lieske, 2012).

Participants in this study generally considered global climate change a serious threat, but this was moderated by education level and gender. The group most predisposed to assess climate change as a serious threat were university-educated females. However, despite the relatively high overall assessment of the climate change threat, fewer participants considered themselves to be personally at risk. This result was similar that of Lorenzoni and Pidgeon (2006), and illustrate Bord et al. (1998) observation that the general public tends to separate societal from personal implications. This emphasizes the need for more personalized, individually-relevant risk messaging: people need to see things of relevance to them in communication packages, e.g., potential

Table 3a
Thematic classification of responses to post-workshop qualitative questions. The number of responses within each theme are indicated in parantheses.

1. **Take home messages (385)**
(106) High risk of flooding due to climate change
(73) Dykes are at risk
(60) Planning is required for mitigation/adaptation
(27) Maps helpful in realizing flooding footprint
(22) Not concerned
(20) Education/awareness raising is required
(19) Concerned about infrastructure and buildings (transportation infrastructure, sewage lagoon, etc)
(13) Will make a personal plan
(9) Frustration
(8) Want to move
(8) Surprised
(7) Humour
(7) We should invest in boats
(6) Government should take action

2. **Have you taken any measures to lower your risk of flood damage? E.g., structural modification to house, special placement of buildings?**
(56) **Yes**
(38) High location
(18) Landscaping/Property modifications
(50) **No**
(28) None
(12) I rent
(7) I will
(3) I don't live in Sackville

3. **What would you do in the event of a flood that affected you personally (e.g., flooding a pasture, damaging a basement)? Please imagine what your immediate, as well as long term response might be.**
(15) Unsure/Nothing
(120) **Short Term**
(29) Find shelter
(23) Drain, divert, pump water
(17) Ensure protection of family, friends, and possessions
(13) Clean up
(12) Help others
(11) Insurance
(9) Salvage, sell, restore
(6) Wait for help
(112) **Long Term**
(55) Move if risk persists
(20) Reduce vulnerability
(18) Participate in political action (awareness raising, advocating for more dyke funding, etc)
(8) Boats
(7) Landscaping
(4) Sump pump

4. **Please explain how the materials worked or did not work.**
(29) Statements affirming that materials worked well.
(138) Statements suggesting why the materials worked and/or where improvements could be made.
Why they worked (108)
(82) Maps and Animations
(17) Clear explanation
(9) Graphs and Data
Improvements (30)
(8) What is being done now?
(8) What can be expected in the event of a flood?
(4) Simplify
(4) Text and maps hard to read
(3) Unclear
(1) Spelling
(1) More historical photographs
(1) More detail

Table 3b
Thematic classification of responses to post-workshop qualitative questions (continued).

5. **What resources (personal, government, or other) would you expect to be able to access in the event of a Tantramar-area flood?**
(6) All
(10) None
(4) Unsure
(2) Not applicable
Personal (30)
(18) Help from family, friends, neighbours
(5) Food and water
(5) Financial
(2) Shelter
Government (261)
(77) General Aid
(48) Food and Water
(42) Emergency Services
(29) Medical
(22) Police, RCMP, Military
(22) Transportation
(18) Shelter
(11) Financial compensation
(4) Information
Other (27)
(9) Insurance
(9) Community service groups
(5) Grocery stores
(4) Access to buildings (University, schools, banks)

impacts on locations and activities familiar and meaningful to them.

Furthermore, Lieske (2012) argues that there is a subtle difference between (1) informing people about a problem and (2) inspiring them to do something about it. Clearly, the quantitative analysis indicated that participants' perception of the seriousness of Tantramar flood risk increased regardless of treatment type. A well organized, clearly delivered presentation could raise peoples' awareness without the use of 3D animations or dynamic web maps. However, closer inspection of the qualitative responses suggests that there was an emotive component to the more elaborate geovisualizations: maps and animations were widely identified as especially effective communication materials, elicited "shock", were associated with the majority of respondents who declared an intention to move out of the risk zone, and inspired them to consider organizing to apply political pressure.

What is the potential role of visualizations in risk communication? Cleary, they can reduce some of the challenges of communication by visually demonstrating potential consequences. They can inspire interest, command attention, and possibly attract a wider and more diverse audience (Berry and Higgs, 2012). They have the potential to enable rare events to be imagined and perceived. They can quickly show the extent of climate change risks without the need for extensive verbal commentary. But research suggests that more complicated visualizations should be accompanied by background explanatory information (Appleton and Lovett, 2005; Jude, 2008). In this study the base communication materials, which were presented as part of every focus group, served this purpose. Without this support, people may fail to understand the assumptions inherent in the representation or may draw incorrect conclusions. For this reason it could be argued that while visualizations support the message, they are inadequate for standalone communication. Advanced visualizations also impose a demand for data and expertise that may render them impractical in some contexts.

This study identified an emotive component accompanying the viewing of advanced visualizations. The 3D visualization (Fig. 1), with its recognizable features (e.g., Salvation Army store) and more "human" scale, led to results that mirrored those of Nicholson-Cole (2005). In that study, local imagery "had more resonance" and was "easier to relate to and consequently more upsetting in some cases". While no data is available to assess long-term retention of the focus group materials, informal discussions with a number of participants suggested that their perception of the townscape changed from merely being a network of streets and buildings to areas with contour, i.e., high and low points of differing flood vulnerability. A related question, not pursued in this study, was the accuracy of participants' understanding of the geographic pattern of flood risk. It is possible that the "cognitive load" associated with, for instance, imagining a conventional 2D map in the 3D real world, may lead to misunderstandings (Appleton and Lovett, 2005). However, research into change detection blindness suggests that people are inevitably prone to miss many details in animations (Simons, 2000; Fish et al., 2011). Special 3D perspectives and photorealistic visualizations are only effective for displaying smaller areas (Tress and Tress, 2003). There are also unresolved issues surrounding the impact of the choice of viewpoint (Appleton and Lovett, 2005), effective level of detail (Appleton and Lovett, 2005), and the presentation of uncertainty (Roth, 2009). Clearly, more work needs to be done to improve our understanding of how people perceive, process and interpret spatial visualizations.

What has to be in place for risk communication (with or without visualization support) to be effective in inspiring pro-active change? First, there has to be trust in higher levels of government (Lorenzoni and Pidgeon, 2006) as well as the experts involved in the production of communication materials (Dransch et al., 2010). Lorenzoni and Pidgeon (2006) argue that even a well designed communication strategy, geared towards particular audiences, is unlikely to succeed in an atmosphere of distrust. Building trust should be part of all risk communication approaches, and provision made for cultivating citizen involvement. Participatory public GIS (PPGIS), intended to draw the public into discussions about spatial planning issues, could help facilitate citizen involvement (Geertman, 2002; Berry and Higgs, 2012). Ultimately, adaptation strategies (and risk communication efforts in general) are more likely to succeed when they naturally emerge from the coupling of top-down, "expert-driven" and bottom-up "grass roots" approaches (Fischhoff, 1995). Callon's (1999) "co-production" of knowledge model articulates a philosophy which involves the public in the process of knowledge creation.

Second, pro-active, risk-reducing behaviours are more likely to occur when there are adaptation strategies to choose from, they have been clearly and rationally presented, and they stand to be reasonably effective (Pelletier and Sharp, 2008). Information needs to be communicated through channels perceived to be credible, and be sustained on a regular basis (Moser and Dilling, 2004; Lorenzoni et al., 2007).

Third, enhancing the public's sense of "response-ability" (Moser and Dilling, 2004) by openly highlighting the effectiveness of recommended actions in relation to perceived costs, as well as publicly acknowledging successful case examples, is critical.

Lastly, mere possession of knowledge is not enough to motivate people to take action (McKenzie-Mohr, 2000; Lorenzoni et al., 2007). In some cases, people may be unresponsive to calls for voluntary action and may require external pressure to adapt to lower personal risk. Land use planning will be central to communities such as the Tantramar, as zoning bylaws are the one mechanism capable of prohibiting development in high-risk flood zones. As a result of participation in the project, the Tantramar community is more ready now for adaptation planning than it was three years ago. A small proportion of people, thanks to various outreach activities undertaken by partners, now have a stronger appreciation for the function of the dykes and the possible threat of flooding in the town. The Town Council has also been involved throughout the life of the project so that it can be ready to move in its decision-making on the topic. That being said, there still remain a relatively large proportion of the population who have paid no attention to the news reports on climate change impacts, or the regular updates on the project that partners provided. A targeted and wider-scale communication effort will need to be employed to provide the population with the basic information to understand why certain actions (creation of new policies and regulations) need to be made by the local Council. Stakeholders are currently in the process of creating their own public communication materials, and are relying heavily on the visualizations produced during this study. It is expected that wider dissemination of this information, tempered by a greater understanding of the communication challenges involved, will further stimulate a desire for pro-active adaptation amongst the "grass-roots" community, and lead to further discussions about acceptable and effective adaptation scenarios and strategies.

When borne out of well rationalized land use policies, zoning bylaws can help pave the way towards providing incentives for communities to adopt major adaptation initiatives. For example, freshwater flooding drove the American community of Dubuque, Iowa to devise a master plan to acquire 74 properties and open up a submerged creek (Carey, 2011). While the Dubuque planners initially encountered community resistance, a serious flood helped unite the city leaders and convince the public of the wisdom of the $21 million dollar (USD), 11-year plan. Community-based social marketing, where particular adaptation strategies are promoted as part of an adaptive campaign that addresses perceived barriers to change, may also constitute an important approach for encouraging pro-active adaptation (McKenzie-Mohr, 2000). While identification of barriers to adaptation will lengthen the time required to implement an adaptation-focused communication strategy (McKenzie-Mohr, 2000), it provides an evaluative framework (e.g., through focus groups and pilot studies) that can also be used to test the effectiveness of related communication and visualization materials.

5. Conclusions

High levels of awareness of the threat posed by global climate change do not necessarily translate into an awareness of personal flood risks at the local level. In coastal zones reliant on engineering solutions to abate flood waters, communities are commonly unaware of the risk of dyke failure. Well designed communication strategies, which address cognitive biases and present the evidence with supporting context, are capable of addressing this knowledge gap. Furthermore, the results of this study show that the type of communication strategy, whether or not it made use of special 3D and web-based geovisualizations, did not significantly differ in the way it influenced quantitative measures of risk perception. Qualitative analysis showed that advanced visualizations were accompanied by an emotive component that was absent from the baseline communication strategy. This component manifested in, for example, greater expressions of sentiment to mobilize for political and community advocacy. While no data is available to assess long-term retention of the focus group materials, informal discussions with a number of participants suggested that there may have been a persistent change in perception following exposure to geovisualizations. Translation of risk awareness to a willingness to make proactive adaptation decisions is poorly understood, but can be expected to require a supporting framework to occur. Necessary co-requisites include trust in higher levels of government and the experts involved in the production of communication materials; an accessible set of alternative adaptation strategies to choose from; appeal to personal responsibility and agency; and effective land use planning. Participatory public GIS (PPGIS) and community-based social marketing may involve the public in the process of knowledge creation and help identify impediments to adaptation.

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