Planning for Climate Change in a Flood-prone Community: Municipal Barriers to Policy Action and the Use of Visualizations as Decision-support Tools

6

Sarah Burch, Stephen R.J. Sheppard, Alison Shaw, David Flanders and Stewart J. Cohen

Abstract: Efforts are intensifying to design effective flood management strategies that account for a changing climate and that make use of the wealth of resources and latent capacities associated with action at the local level. Municipalities, however, are subject to a host of challenges and barriers to action, revealing the critical need for sophisticated participatory processes in support of municipal decision-making under conditions of considerable uncertainty. This paper examines a new process for envisioning local climate change futures, which uses an iterative, collaborative, multi-stakeholder approach to produce computer-generated 3D images of climate change futures in the flood-prone municipality of Delta, British Columbia, Canada. The process appeared to forge communicative partnerships, which may improve the legitimacy and effectiveness of the flood management and climate change response discourse in the municipality of Delta, and may lead to locally-specific and integrated flood management and climate change response strategies. We concluded that, while an enabling context and normative pressures are clearly integral to effective action, so too is the type and mode of presentation of information about climate futures.

Keywords: flood management; climate change; visualizations; municipalities, decision support; scenarios

1. Introduction

For many coastal communities, it is expected that changes in sea level and storm frequency and severity resulting from a changing climate will dramatically enhance the risk of extensive flooding in low-lying areas (Nicholls *et al.,* 2007). Perhaps as a result of these projections, efforts to localize both climate change impact assessments and response design have gained momentum (Adger *et al.,* 2005; Bai, 2007). This 'localization' of climate change response has accompanied the evaluation of successes and failures of the response effort at the global scale (Böhringer and Vogt, 2004; Buchner *et al.,* 2002). In a variety of fields, it has often been recognized that the local scale is indeed an effective realm within which to pursue collective action on environmental issues (Bulkeley and Betsill, 2003, Bulkeley and Betsill, 2005). Pragmatically, most, if not all, communities around the world will need to implement plans and response actions to address local adaptation needs and mitigation mandates. In part, because of the challenges inherent in downscaling global climate models the

study of barriers to local and regional climate change responses remains a nascent realm of investigation. It is already known that municipal governance institutions are rife with barriers to effective action on climate change (Betsill, 2001, Burch, 2010). The challenge of local climate change responses in communities across Canada requires the application and testing of methodologies that address complexities in governance structures and uncertainties in climate change impacts and responses, while simultaneously building capacity and buy-in among community members through personalization of climate change impacts and potential responses. Integrated flood risk management is an especially critical set of climate change responses in low-lying and flood-prone regions. However, implementation of risk management actions faces a host of challenges including fairness in public engagement (Johnson *et al.*, 2007), sustainable long-term coastal management in the face of climatic uncertainty (Ledoux *et al.*, 2005), and the complexity of implementing resilience-based (rather than resistance) management strategies (Klijn *et al.*, 2004).

The Local Climate Change Visioning Project in British Columbia, Canada, represents one approach that may assist local decision-making. Building on recent advances in backcasting and scenario-building to bridge the divide between predictive, quantitative approaches and narrative-based qualitative methods, the Visioning Project incorporates novel 3D visualization techniques with elements of participatory integrated assessment to explore visions of the future under climate change for the Lower Mainland community of Delta. This community is highly vulnerable to even small changes in sea level, storm surge frequency and severity, and alterations to the nearby Fraser River's spring freshet (a seasonal swelling of river water due to melting snow and ice in the nearby regions of higher elevation). Using the wealth of scholarship and current practice in community development planning (see for example: Tress and Tress, 2003, Sheppard, 2005a) the Local Climate Change Visioning Project incorporates participatory processes which introduce practical knowledge, preferences, and experiences in order to enrich the integrated assessment of the complex problem of climate change (Rotmans and Van Asselt, 1996, van Asselt and Rijkens-Klomp, 2002). While the process was not designed specifically to focus on overcoming particular barriers, it was intended to increase awareness, inform policy, and potentially motivate action on climate change. The Visioning Project's objective is consistent with other local and regional case studies in British Columbia that have used participatory approaches to link research knowledge and local (traditional, practitioner, managed system) knowledge (Walker *et al.*, 2007; Cohen and Neale, 2006; Williamson *et al.*,

2007). However, the application of 3D visualization offers a unique learning opportunity. As such, this work has the potential to enhance the capacity of this community to strengthen flood risk management practices and facilitate equitable stakeholder engagement.

The goals of this paper are threefold. First, the paper gathers insights from disparate literatures to explore a small sample of significant barriers to local action in response to flooding and other projected climate change impacts. Second, the paper presents an innovative method of participatory scenario generation, the effectiveness of which has been tested with both expert and lay groups in the Corporation of Delta, a low-lying community in Southern British Columbia. Finally, the paper explores ways in which this style of participatory integrated assessment, including the co-production of scenarios and 3D computer-generated visualizations, may help to identify and overcome barriers to climate change responses and flood risk management in serving as decision support tools. In sum, this paper aims to advance municipal best practices in flood risk management and climate change planning to incorporate more effective and equitable modes of public participation, innovative tools for the communication of complexity and uncertainty, and an appreciation of the institutional and behavioural complexities that may inhibit the development and implementation of flood management policies.

2. Background: Barriers to action on climate change at the local level

2.1 Institutional barriers to flood management responses

In the context of municipal action on climate change, the critical finding that humans often operate on the basis of routines and standard operating procedures rather than (or at least in addition to) a rational calculus of costs and benefits (Olsen and March, 1989) forces a shift in attention away from making a logical, scientific case for the avoided costs yielded by climate change actions to reduce greenhouse gas emissions. Instead a need is identified to embed new risk management norms and values associated with climate change adaptation and integrated flood risk management throughout the familiar and established practices and procedures of an institution.

Equally important are the historically-evolved and path-dependent structures that limit the options of decision-makers in municipal institutions and deeply influence the context within which responses to climate change impacts, such as flooding, are

designed and implemented. (Thelen, 2003). Once a path is taken, alternatives become increasingly difficult as time passes, learning accumulates and scarce capital is invested (Berkhout, 2002, Thelen, 2003). Flood management and climate change response policies must be developed within these highly structured organizational fields, which assist in efforts to deal rationally with uncertainty but also constrain the variety of response options available (DiMaggio and Powell, 1983). This is especially important with regard to climate change responses, because a system in which fewer path dependencies exist may be one in which the ever-evolving climate change science (such as evolving models of flood risk) may be more effectively integrated into practices and procedures (O'Riordan and Jordan, 1999).

The prevalence of path dependency reveals the importance of providing opportunities for iterative, collaborative partnerships between municipal practitioners and flood management experts.

2.2 Participatory processes and flood risk management

The study of participatory processes reveals both an additional category of barriers that originates in the socio-cultural or public realm, as well as important strategies that may be employed to help overcome these barriers. Participatory processes provide the means through which a communicative partnership can occur among a variety of state, expert, business, and civil society actors (Burgess *et al.*, 2005).

Traditional decision-making strategies tend to de-emphasize interests and values in favour of objective analysis, often leading to diminished legitimacy, irrelevant or incompetent outcomes, and a lack of popular acceptance (Renn *et al.*, 1995). As a result, it has been argued that non-traditional forms of deliberation, such as story-telling and gaming (Lewis and Sheppard, 2006; Robinson *et al.*, 2006), may obtain more meaningful and inclusive results (Dryzek, 2000). Part of the solution to these problems may be the development of consent-producing mechanisms within and among institutions and groups that help to institutionalize partnerships between decision-makers, a range of technical experts, and affected stakeholders (Renn *et al.*, 1995; Jones and Burgess, 2005). These innovative modes of decision-making and problem identification represent potentially powerful means by which barriers (such as lack of buy-in, insufficient legitimacy of decision-making procedures, and policy responses that are deficient in scientific robustness or inconsistent with public values) to policy action in response to climate change may be overcome.

The ways in which participatory processes feed into municipal decision-making and governance is of great relevance to the design and outcomes of the Local Climate Change Visioning Project. This project draws on processes used in interactive social research which "seeks to establish relationships between sponsors of research, research teams, independent organizations, and the interested public" (Robinson and Tansey, 2006). A substantial portion of the task of the Local Climate Change Visioning Project was identifying and navigating through the intricate patterns of expectations present among municipal politicians and staff. These expectations were fundamentally shaped by past and current policies, disciplinary biases, and local and regional politics, and may in themselves represent barriers to novel policy action in response to climate change.

2.3 Capacity to respond to climate change

As climate change research has shifted from a focus on modeling the potential causes and impacts of climate change to a strong focus on responses to the problem, interest in the concept of capacity has grown. Mitigative capacity is defined as "a country's ability to reduce anthropogenic greenhouse gas emissions or enhance natural sinks" (Winkler *et al.*, 2007). Adaptive capacity is defined as "the ability or potential of a system to respond successfully to climate vulnerability and change," (Adger *et al.*, 2007). They are viewed as the mirror image of each other. For instance, Yohe (2001) argued that both adaptive and mitigative capacity are comprised of resources such as financial, human, and social capital, risk-spreading mechanisms such as insurance, decision-making capacity, and availability of technological options. Psychological elements were later added to the growing list of capacity indicators, such as perceived capacity to respond (Grothmann and Patt, 2005) and the normative or motivational context of climate change responses (Haddad, 2005).

The concept of capacity reveals two issues that are especially significant to the study of local responses to climate change impacts, including flood management. The first is simply the quantity and quality of capacity. Does the jurisdiction in question possess substantial stores of financial capital, institutional capacity, and locally-specific scientific information relevant to climate change responses? Similarly, does the jurisdiction possess the legal tools (both the authority to impose regulations as well as the responsibility to do so) necessary to catalyze action? The second issue relates to the dynamic patterns of human interaction which characterize the relative success or failure of jurisdictions to mobilize capacity in response to climate change. In other

words, despite the presence of capacity, some jurisdictions may still be unable to respond to climate change. This 'gap' between capacity and action in response to climate change is only beginning to be explored by the climate change research community (Burch and Robinson, 2007; Burch, 2010; Yohe *et al.*, 2007). Innovative participatory visioning processes may be one set of tools that can help to both build capacity and to facilitate action.

2.4 Implications for policy action in response to climate change impacts and flood risk

These varied literatures lead us to the insight that the same concept or characteristic of a system can become either a barrier to, or enabler of, action on climate change (Burch, 2010). For instance, socio-cultural characteristics such as identity formation and institutional issues such as the extra-jurisdictional policy context can, in one scenario, act to inhibit the formulation and implementation of climate change policies if identities clash or provincial policies conflict directly with municipal climate change goals. In contrast, however, the development of norms and identities that support forward-looking policy action (including traditions of fruitful collaboration among scientists, policy-makers, and the lay public), complemented by policy consistency at multiple levels of government, may lead to highly effective climate change policy-making. The legal responsibility to act, and adequate tools to do so, are a critical ingredient in this process. For instance, municipalities in Canada must rely on provincial governments to raise the standards of building codes, and on the federal government to determine fuel efficiency standards. In the past, this has hampered the ability of communities to take significant action on both climate change adaptation and mitigation.

Most importantly, however, the literature presented above allows speculation about potential strategies that can be employed in order to transform barriers into enablers of action in response to climate change impacts and flood risks. For instance, the influence of habits, organizational culture, and organizational structure highlighted by new institutional theory suggests that climate change and flood management responses should be embedded, or 'institutionalized' in standard operating procedures. Iterative and collaborative partnerships paired with opportunities for institutional learning and innovation may also assist in stimulating effective flood management responses. Research into participatory processes points to the usefulness of storytelling and gaming to improve the quality of deliberation and understanding, while

enhancing value transparency and the utilization of local knowledge in planning procedures (Burgess *et al.*, 2005; Robinson and Tansey, 2006). Framing the problem as one that is embedded in the local context and local solutions represents a further opportunity to increase saliency, legitimacy, and credibility. Finally, research into capacity reveals the need to ground local responses in robust global science and provincial, national government policies and responses while building the store of local resources by sharing best practices.

3. The Influence of Landscape Visualization on Human Perception and Behaviour

An emerging approach to enhancing participation and awareness-building at the local level is the use of 3D landscape visualisation to depict alternative future community scenarios. Various forms of imagery including GIS-based tools, 3D modeling and photo-manipulation have been explored to investigate landscape change and management (Al-Kodmany, 1999; Tress and Tress, 2003; Lewis and Sheppard, 2006), including some early research on the potential to visualize climate change futures (Dockerty *et al.*, 2005; Nicholson-Cole, 2005; Sheppard and Shaw, 2007). These highlight the potential for visualization to influence individuals' perceptions of landscapes, floods, and a changing climate, which in turn may influence cognitive and affective (or emotional) understanding and influence individual and collective behaviour. Further study is required if such methods are to be used widely as a decision support tool in planning and policy. Sheppard (2005a) summarizes many of the capabilities and responses to landscape visualization that may contribute to it being an effective tool for municipalities in building their capacity to address the impacts and causes of climate change. These include:

1. Integration of the predictive and science modeling capabilities of GIS-based software, with the emotionally rich and intuitive media of photo-realistic software;
2. The potential for stronger socio-cultural content and more attractive representation may assist in engaging lay-people into public processes (Conroy and Gordon, 2004; Nicholson-Cole, 2005; Sheppard and Meitner, 2005; Lewis and Sheppard, 2006);
3. Representation of recognizable places and local information in a realistic or semi-realistic manner, increasing personal relevance as opposed to more abstract representation (Daniel and Meitner, 2001; Sheppard, 2005a);

4. Presentation of multiple alternative futures, and choices for the future to assist with decision making (Al-Kodmany, 2000; Appleton and Lovett, 2003; Steinitz *et al.*, 2003; Sheppard, 2005a);
5. Computer visualization techniques which allow for modification and user-feedback in a participatory manner for refinement and analysis (Sheppard, 2005b); and
6. Varying levels of cognitive, affective, and behavioral responses which may result from varying content, levels of realism and detail (Daniel and Meitner, 2001; MacEachren, 2001; Appleton and Lovett, 2003; Sheppard, 2005b; Lewis and Sheppard, 2006).

Potentially disadvantageous human responses to landscape visualizations, however, also exist in the context of climate change and flood risk management. Bias, advocacy, and non-neutral roles of scientific visualization (Orland *et al.*, 2001; Sheppard, 2005a) represent significant risks to the legitimacy of planning processes using visualizations. Similarly, the potential exists that highly realistic, yet inaccurate and non-transparent, imagery can generate false assumptions of authority (Sheppard, 2005a; Sheppard, 2005b). Especially relevant to the portrayal of flood risks, ineffective or inaccurate visualizations may cause disbelief, confusion, apathy or fear. Presentations must be sensitive to individual abilities to process and comprehend large amounts of imagery that represents many layers of information (Sheppard, 2005a).

4. Development of visualizations in a municipal context

This section documents the participatory scenario development process that was used to downscale, synthesize and visualize local climate change in the community of Delta. First, a description of the case study community is provided and key climate change vulnerabilities (including the potential for extensive flooding and storm damage) are identified. Then an overview of the methods used, and findings gathered, from both the 'visioning' process and the semi-structured interviews with municipal employees after being exposed to the visioning presentation are presented.

4.1 Municipal context: climate change policy in the Corporation of Delta

The corporation of Delta is one of the 21 municipalities that make up the Metro Vancouver Region in the Southwestern coastal region of British Columbia, Canada. It is home to approximately 96,000 individuals and is comprised of a blend of agricultural land, suburban residential development, and industrial operations.

Geographically, Delta is uniquely situated on the west coast of Canada, bounded by the Strait of Georgia to the west, the Canada-US border to the South, Boundary Bay to the Southeast, and the Fraser River to the North. Delta is largely comprised of the floodplain of the Fraser River, the basin of which drains 240,000 km^2 of the province of British Columbia (Fraser Basin Council, 2004). Much of Delta lies between zero and two meters above mean sea-level, and thus is protected by over 60 km of dikes.

Figure 1 | Corporation of Delta, British Columbia, Canada (Credit: David Flanders, UBC-CALP)

Delta has recently developed a climate change action plan geared towards managing both municipal emissions and facilitating adaptation to changing flood frequency and severity. At present, Delta is undertaking a revision of its flood management strategy that incorporates local climate change scenarios, and is carrying out public consultations to evaluate the desirability of a suite of flood risk responses.

Management of floods, natural areas, staff training and community education were addressed in Delta's climate change action plan, although without a high level of specificity in terms of budget and workplan. More detailed flood risk and management studies were commissioned around the same time, and Natural Resources Canada chose Delta's Roberts Bank shoreline as the focus of a detailed study of sea-level rise impacts (Hill, 2006). Delta has since placed a senior environmental officer in charge of climate change issues, and is planning on further development of both adaptation and mitigation policy.

4.2 Participatory scenario development and 3D visualizations of flooding in Delta

Approximately eight months prior to the development of the Climate Change Initiative described above, a team of researchers from the Collaborative for Advanced Landscape Planning at the University of British Columbia chose Delta to represent the first case-study in the Local Climate Change Visioning Project. This research program was designed to develop and evaluate a new prototype process for raising awareness, building capacity, increasing motivation, and supporting decision-making on both integrated food management and climate change at the local level.

The first phase was the relatively autonomous development of a conceptual framework which allowed for the organization of a plethora of qualitative and quantitative data, bridging from the global to the local level (Sheppard and Shaw, 2007). Key biophysical and socioeconomic drivers were collated from the Intergovernmental Panel on Climate Change's Special Report on Emissions Scenarios (Nakicenovic and Swart, 2000; Banuri *et al.*, 2001), the Millennium Ecosystem Assessment (Raskin, 2005), and the scenarios of the Global Scenario Group (see for example Raskin *et al.*, 2002). These scenarios were downscaled by integrating national, regional, and local impact assessment with climate-related policy information. The framework development also involved the use of a pre-existing socio-economic model, GB-QUEST (see for example: Tansey *et al.*, 2002; Robinson *et al.*, 2006), which numerically specified four

corresponding regional scenarios for the Metro Vancouver area. The coherence of the regional trends also provides the validity for the assumptions made in the four global scenarios. Regional storylines and narratives were developed which utilized the combined data provided by global models, regional assessments, local expertise, and GHG emission assumptions. These storylines were organized around four alternative scenarios, or 'worlds,' representing a continuum from no action on climate change to a 'deep sustainability approach' involving extensive greenhouse gas reductions, a shift in values, and proactive adaptation to climate change impacts (See Figure 2). Using principles of participatory scenario development, these alternative climate futures were used to stimulate dialogue with key municipal, expert, and community participants to consider what the local landscape would look like under the impact and response assumptions of each 'world.'

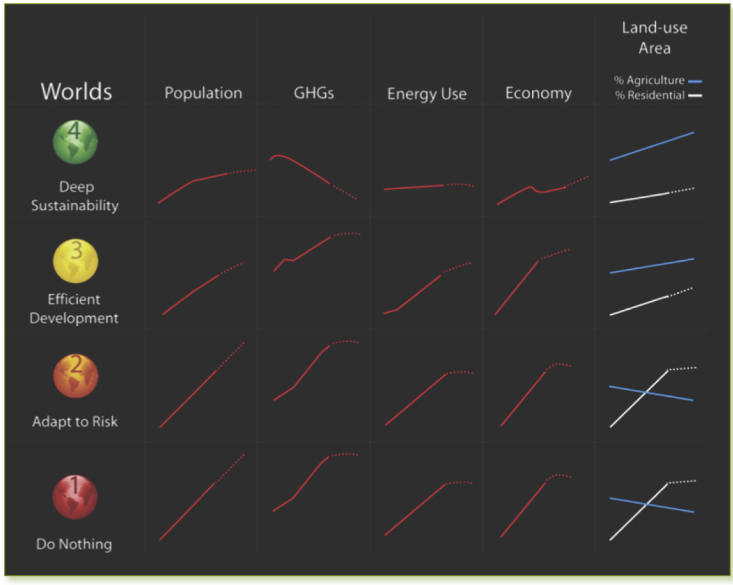

Figure 2 | Underlying socio-economic assumptions for each scenario. The GB-QUEST model provided general consistency among these main indicators. The horizontal axes represents time from 2007 to 2100; vertical axes vary by indicator. Dotted trend lines are extrapolations after 2050. GHGs stands for greenhouse gases.

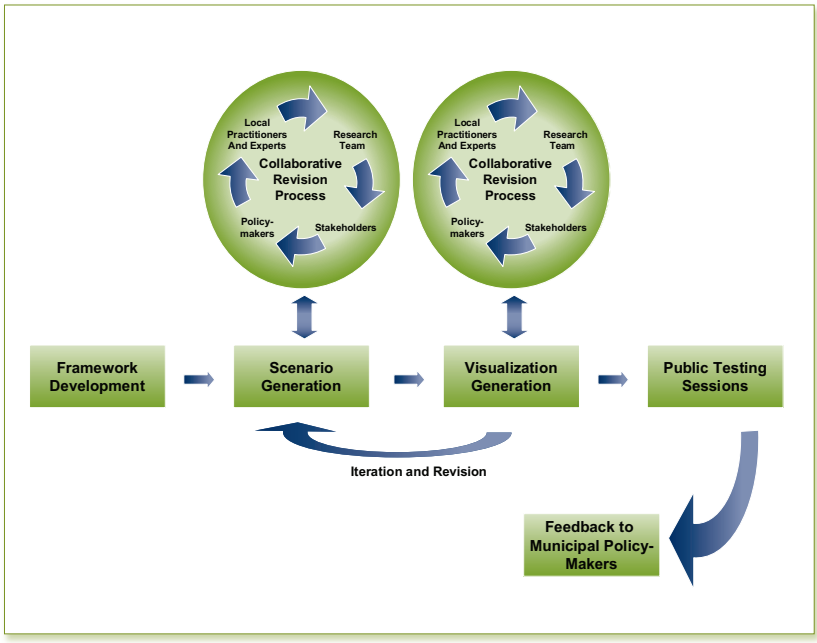

Figure 3 | The research process included opportunities for iteration, revision, and consultation with an extended team of stakeholders, local experts, and municipal decision-makers.

The output was local scenarios and projected changes in temperature, precipitation, and sea level in 2020, 2050, and 2100, which reflected the local policy context and landscapes of Delta. Using these outputs, the research team then illustrated each of these four scenarios using mapping and 3D computer-generated visualizations of key climate change impacts (such as sea-level rise or forest character and species changes) and various combinations of response options (including, for example, an adaptive response involving the raising of dikes, or a combined adaptation/mitigation strategy leading to compact mixed-use development patterns and alternative transportation choices).

The process of developing these four alternative scenarios was fundamentally shaped by a team consisting of municipal planners, engineers, environmental service providers, regional practitioners, federally-employed scientists and arms-length

University of British Columbia researchers (see Figure 3). The *core research team* (CRT) consisted of five individuals (principal investigator, co-principal investigator, two research associates, and a doctoral student) from the University of British Columbia. The *extended research group* (ERG) included fourteen university researchers and seventeen federal and provincial government researchers (with background in climate change modeling, impacts, responses), seven local and regional practitioners (planning and engineering), and five non-governmental experts. The CRT collaborated with the ERG to receive reliable inputs, to access technical data, to vet and approve the information and underlying assumptions for the global and regional scenarios (particularly for the "Deep Sustainability" scenario). The collaboration varied with respect to medium (in person, via e-mail, or telephone) and participants (plenary meetings, sub-groups) depending on availability (Shaw *et al.*, 2009).

Finally, *the local working group* (LWG) included two provincial government scientists, four practitioners from the municipality (planning and engineering), five local committees members (including agriculture and community advisory), and two private sector representatives (from the Port of Vancouver). The LWG was assembled to help contextualize the regional information by suggesting and reviewing local scenario content, advise on visualisation priorities, and review both the scenario narratives and visualizations. The participants had experiences in local climate change projects and/or were members in community groups. Three working group sessions were held in the form of workshops (Shaw *et al.*, 2009).

Final "visioning packages," referred to below as the 'treatment,' combining the visualizations and supporting information were presented to Delta decision-makers and community members. Using pre-treatment and post-treatment questionnaires (delivered to 116 individuals), the influence of the presentation and the 3-D imagery on viewers' cognitive awareness, affective response, and intended behaviour change were gatherered and evaluated. These results were a critical part of the visualization process and included enhanced levels of cognitive and affective engagement, an increased sense of urgency regarding flood management and climate change responses, improved awareness of climate change impacts, and increased behavioural intent to support or implement response options. A full examination of these results is explored elsewhere (Sheppard *et al.*, 2008; Shaw *et al.*, 2009).

4.3 Semi-structured interviews with municipal practitioners

One month following the final review of these visualizations and scenarios with municipal staff and decision-makers, interviews were held with a subset of these individuals to gather general information on barriers to action on climate change and to evaluate the impact of the visioning process[1]. In particular, the goal was to determine which images were most useful in terms of decision-making on climate change, and which images had remained in the memories of the participants. These semi-structured interviews also contained questions regarding the effect of institutional structure and culture on:

- climate change policy-making;
- past and future plans to respond to climate change through mitigation and adaptation;
- the effect of the external (and inter-jurisdictional) context on potentially reaching climate-related goals;
- various aspects of capacity (including financial, human, and technical capacity);
- external institutional factors (such as the jurisdiction at play, legislation and regulation, and external policy context);
- leadership (both political and technical); and
- issues related to the values, attitudes, and knowledge of each city's public.

The interviews provided an opportunity to gauge the usefulness of the images generated by this intensely collaborative process, and also insights into ways in which the visioning process might be improved in the future to overcome barriers. Interviews were analyzed using ATLAS TI qualitative analysis software, and responses were coded according to references to capacity, institutional structure/culture, policies and practices, external institutional context, and specific references to the visioning process (among others).

Interviewees had been presented with images of four iconic locations in Delta. The first depicted a higher-elevation residential community, the second showed a low-elevation non-residential region protected by sub-standard dikes, the third illustrated a highly-valued low-elevation habitat refuge, and the fourth showed a low-elevation neighbourhood protected by standard dikes. Images were created to depict the current

1 Sample size of semi-structured interviews: in Delta (total n=12): 3 politicians; 3 planners; 2 engineers; 4 environmental services/operations staff.

circumstances in each of these locations, followed by visions of each of the four scenarios (showing both climate change/flooding impacts and response options, depending on the scenario). In general, interviewees indicated that the images depicting the flooding of a familiar neighbourhood were the more powerful and memorable than images at the neighbourhood scale (see Figure 4).

This reaction varied somewhat, however, depending on the background and discipline of the staff member. For instance, city planners were more likely to respond to and recall images depicting dramatic changes in land use as a result of an influx of environmental refugees (see Figure 5), while engineers with the Corporation of Delta indicated that images of flooding and dikes (Figure 6a-c) were the most powerful.

All interviewees agreed that the images were highly credible, and that bringing together a variety of stakeholders and experts enriched the process considerably. Many were eager to use the process to assist in future planning and climate change policy-making, and commented on the ability of the visioning process to raise awareness about climate change impacts in local areas. It was noted, however, that climate change impacts were most clearly communicated, relative to the menu of available response options that were shown. Interviewees indicated that more information on response options (eg. cost, feasibility) was required if the process was to be truly useful as a decision support tool.

Interviewees indicated that capacity, in the form of financial capital and technical climate change expertise, was scarce in Delta, but the recent commitment of the mayor to address climate change provided much-needed political leadership and direction. Furthermore, interviewees noted that the images were both powerful illustrations of familiar places, but were also clearly rooted in science. Criticisms of the process included doubt about whether or not awareness-building tools will in fact stimulate behaviour change on the part of the public, and complaints about the absence of a straightforward list of actions that individuals can take in response to climate change. Additional analyses of the levels of capacity, barriers to climate change policymaking, and a comparison of Delta to other communities in the Lower Mainland regions, see Burch (2010).

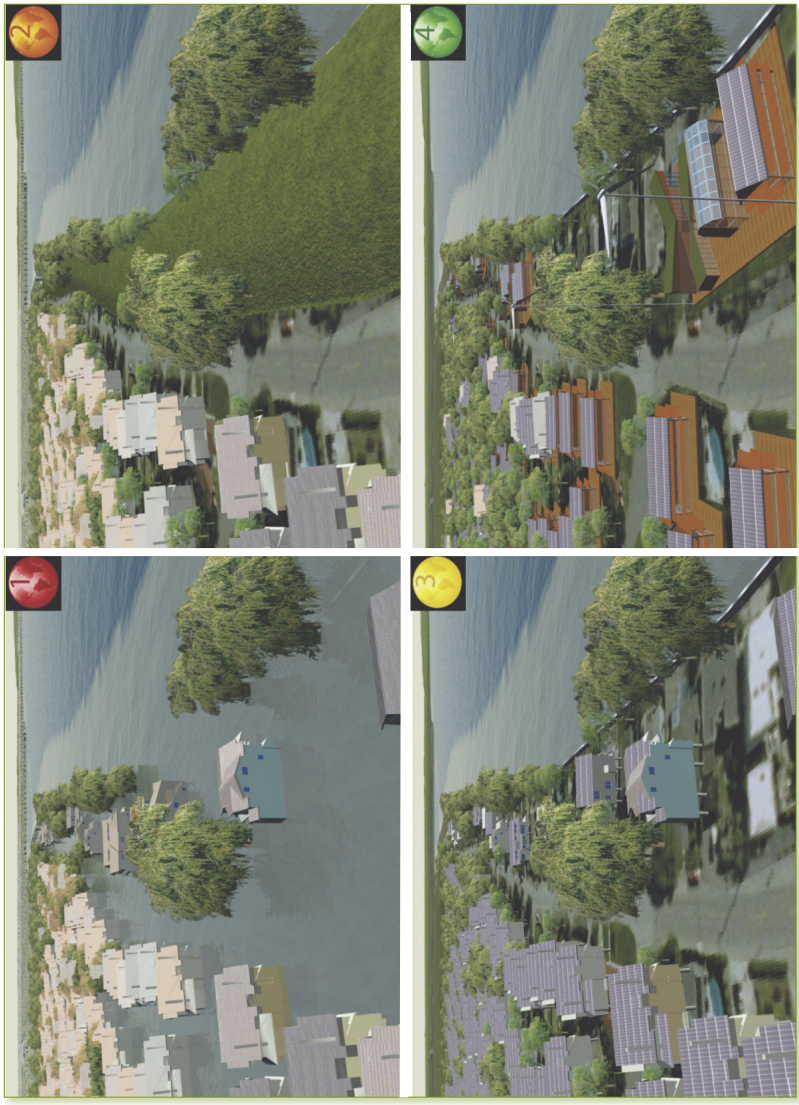

Figure 4 | Four iconic flood response and greenhouse gas mitigation scenarios for a low-lying community in Delta, British Columbia. The images shown here depict the community in 2100. (Credit: David Flanders, UBC-CALP).

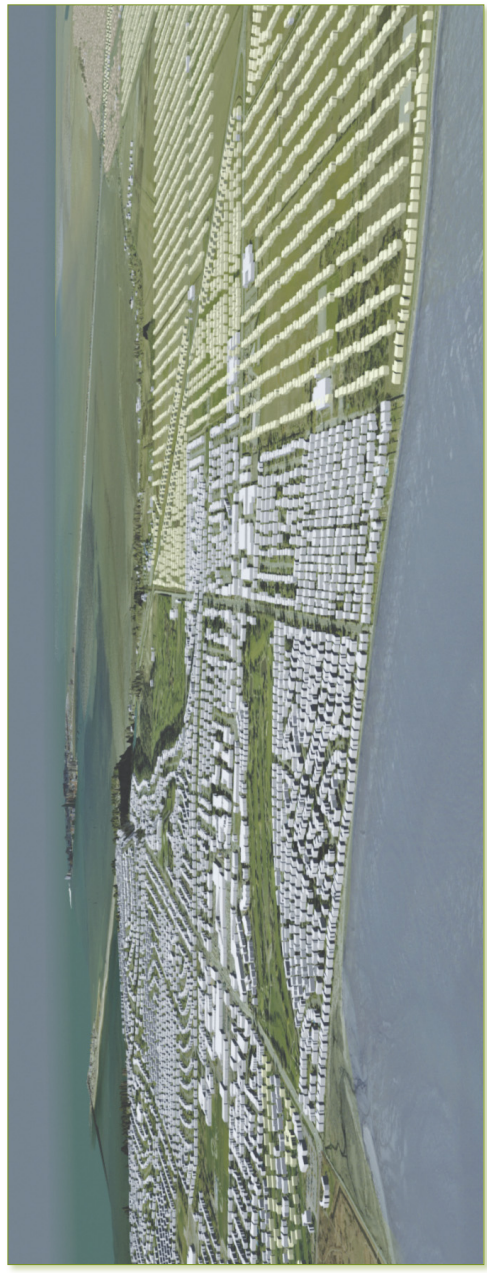

Figure 5 | Tsawwassen and surrounding area under scenario 1 "Do Nothing" by 2100. Current (white), planned (yellow), and the unplanned development of neighbourhoods due to environmental refugees (beige, top right) (Credit: David Flanders, UBC-CALP).

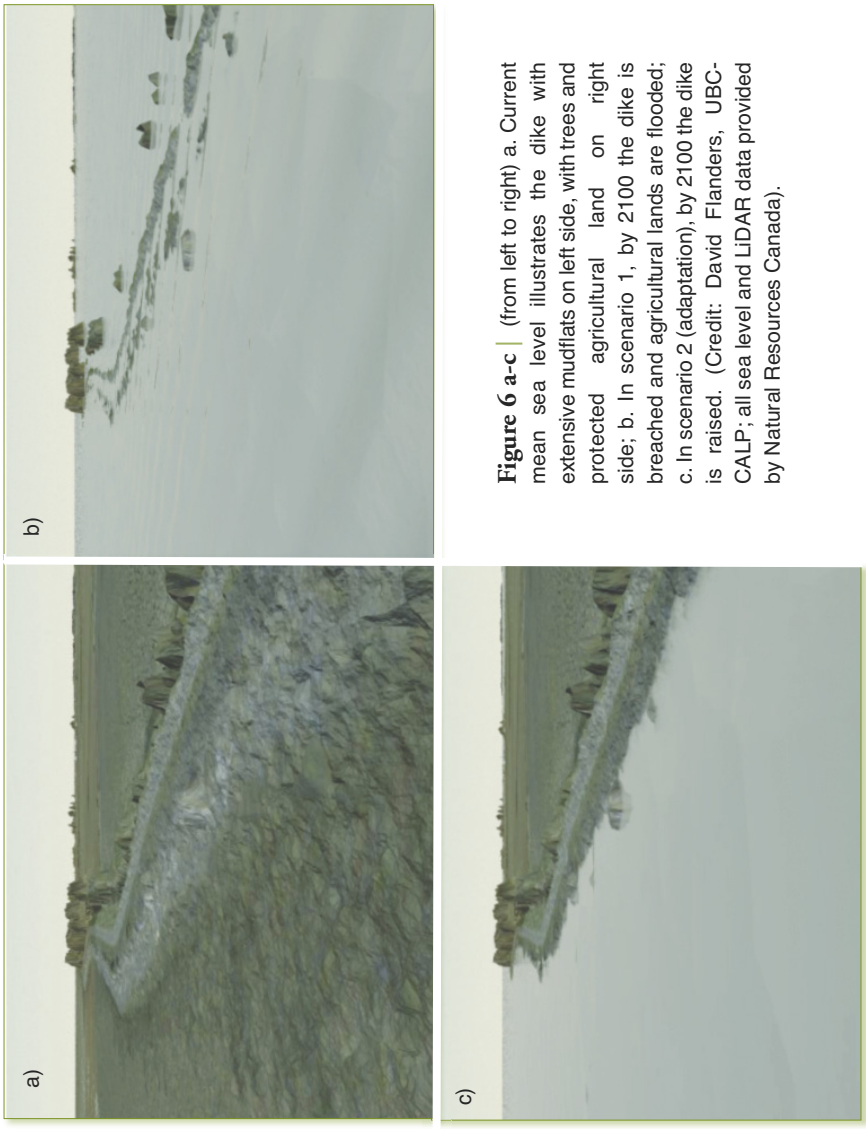

Figure 6 a-c | (from left to right) a. Current mean sea level illustrates the dike with extensive mudflats on left side, with trees and protected agricultural land on right side; b. In scenario 1, by 2100 the dike is breached and agricultural lands are flooded; c. In scenario 2 (adaptation), by 2100 the dike is raised. (Credit: David Flanders, UBC-CALP; all sea level and LiDAR data provided by Natural Resources Canada).

5. Discussion

As outlined in the brief literature review presented earlier in this paper, institutions, participatory processes, and capacity strongly influence the design, implementation, and uptake of flood risk management at the local level. The ways in which the Local Climate Change Visioning Project addressed some of these barriers are discussed below, as well as opportunities for an enhanced version of this process to overcome barriers more effectively. This discussion draws upon an interpretation of both the conceptual advantages of the process, as applied to barriers, and specific results from the interviews.

The municipal institutions which shape local responses to flood risk are subject to forces of change that have been well-documented in the field of institutional theory. Although path dependence may play a significant role in perpetuating institutional inefficiencies (Thelen, 2003) and potentially undesirable environmental outcomes, learning (whereby actors rationally identify gaps and take corrective steps) and competition (gradual refinement of institutional design resulting from competitive pressures) are forces of institutional enhancement (Pierson, 2004). The visioning process conducted in Delta represented one of the first steps toward institutional learning for the municipality in the face of a changing climate, and began to suggest ways in which both decision-making processes and the ultimate flood risk management initiatives must incorporate an integrated view of climate change impacts and responses, including both adaptation and mitigation. In particular, this process brought together engineers, planners, and policymakers in the process of generating credible images which communicated useful information about the local impacts of climate change and potential response options. Such cross-sectoral collaboration helps to overcome barriers related to limited technical capacity and the absence of best-practice information (Betsill, 2001).

The Local Climate Change Visioning Project incorporated strong elements of public participation – from the development of the images in conjunction with staff and policymakers within the municipality, revision of the images with the help of local experts and stakeholders, and testing of these images with a public audience. Even among municipal experts, the mere provision of information was deemed unlikely to address concerns regarding the uncertainty of local climate futures, the portfolio of response options available, and the effect of regional, provincial, and federal policies on local spaces and actions. As such, the project used as a general guide an 'analytic

deliberative process,' (Stern and Fineberg, 1996) which "combines sounds science and systematic uncertainty analysis with participatory deliberation by an appropriate representation of affected parties, policy-makers, and specialists" (Pidgeon *et al.*, 2005).

This deliberative process of scenario and visualization design may be an important means of overcoming barriers to effective flood risk management for three reasons. First, as mentioned above, communicative partnerships were forged between politicians, municipal staff and scientists. These partnerships may improve the legitimacy and effectiveness of the flood response discourse in the municipality of Delta, and may lead to locally-specific and integrated adaptation and mitigation policies. Second, the development of four iconic, highly localized, and meaningful scenarios aided in the explicit incorporation of values into an alternative mode of deliberation – namely storytelling using visual media. These media provide a common language with which experts from disparate disciplines may communicate and express anticipated climate change impacts and desirable responses, and thus help to overcome the barrier of miscommunication. Finally, the Local Climate Change Visioning Project, through a series of iterative consultations with various municipal groups and advisors, provided a mechanism by which the fruits of the participatory visualization development process may be fed into decision-making procedures. Collaboration with the Project was officially endorsed by the Delta City Council, and the products of the process were presented to the Council upon completion. This served the purpose of allowing Delta's political leaders to explore the implications of future climate change impacts in their region, obtain valuable technical advice from their staff in a focused and highly effective manner, and explore linkages between climate change responses, existing flood management practices, and other policy priorities.

The final realm of barriers to local action on climate change pertains to capacity to respond to climate change. Although the presence of capacity does not make responding to climate change inevitable (Burch and Robinson, 2007; Burch, 2010), capacity is nonetheless a necessary pre-condition to climate change response strategies (Adger *et al.*, 2007). The most important way in which the visioning process helped to build capacity in the community of Delta was to bring together experts, practitioners, and municipal staff to discuss feasible climate change response options and best practices. Given the small size and limited human resources of Delta, such inter-disciplinary and inter-jurisdictional discussions are not often facilitated. Interviewees indicated that the use of locally-significant 3D imagery of climate change

impacts (especially those related to flood risk) and response options added power and meaning to these discussions, and aided the exploration of desirable futures in Delta (Sheppard *et al.*, 2008). On the surface it may appear that the main goal of this study was to simply provide more information to members of the Delta community and expect this to stimulate a greater quantity and quality of action. However, the 'deficit' model of behaviour change - in which it is claimed that the behaviour will be changed simply through the provision of information - that has been roundly criticized (Irwin and Wynne, 1996; Kaiser and Wolfing, 1999; Kollmuss and Agyeman, 2002) was accounted for very early in the research design process. The unique process that the Visioning Project followed leads to the conclusion that, while an enabling context and normative pressures (Karp, 1996; Stern, 2000) are clearly integral to effective action, so too is the type and mode of presentation of information about climate futures.

Despite the usefulness of the Local Climate Change Visioning Project in bringing together a diverse group of experts and decision-makers to discuss highly localized and meaningful climate change futures for Delta, a number of gaps in the process were identified that are specific to decision-making in the realms of flood risk management and climate change responses. First, time constraints prevent the project from providing highly specific and tangible inputs into the climate change policy development process in the Corporation of Delta. A number of municipal representatives were interested in seeking advice from the research team. While this is traditionally an appropriate role for scientists and researchers it was believed that the underlying process of co-constructing the scenarios with the decision-makers and community was a way to contribute to decision-making within the local context without advising directly.

Secondly, issues also arose with regard to the allowable level of drama contained within the imagery. In order to avoid stimulating an overwhelmed or apathetic response on the part of the visualizations' audience, the researchers avoided creating images that depicted the more severe impacts of extreme climate change events (such as loss of life due to flooding). As a result, however, some members of the public testing group noted that in order to most effectively build awareness, these types of images should be included. Furthermore, a deliberate decision was made to reduce the realism of the developed areas in close-up views, to avoid possible adverse reactions from

participants and potential legal repercussions around individually recognized property in the area (Mendez, 2008). Finally, objections arose (although infrequently) in regard to the 'do nothing' scenario. One set of visualizations associated with this scenario depicted urban sprawl extending across valuable agricultural land and onto flood-prone areas. This was deemed, by a local practitioner, to be highly unrealistic and potentially misleading to the public. Nevertheless, the image remained in the visualization packages used in public testing sessions in order to explore the possibility of regressive planning practices taking over in times of extreme climatic stress and political or economic duress. This raises the question of the necessity of full participant buy-in to the visualizations, and the wisdom of using visualizations to push the boundaries of accepted planning, flood management, and urban design practices.

Requests were made by municipal staff for a concise and practical list of response priorities for the municipality, but the project team concluded that added investigations into costing and feasibility would be necessary before this could be provided. The lack of analyses that explored in detail the different costs and benefits associated with the adaptation and mitigation choices was viewed as a gap as the results relate to real-world municipal decision-making. In future iterations of this work, scenarios will be created with costs attached to the various response options in order to explore the full series of trade-offs involved in pursuing one scenario over another. It is hoped that this will more effectively feed into existing policy-making processes and facilitate integrated flood management in response to climate change. However the project provided a certain empowerment to decision-makers by generating a comprehensive understanding of key vulnerabilities and climate-related issues facing Delta and the response options available to the interests and concerns of their constituents. It would be premature, however, to judge the effect of this process on policy, as the municipality of Delta is only now beginning a critical revision of its Official Community Plan, to which the Visioning Project's results have much to contribute. Nevertheless, the team has been invited to participate in ongoing efforts to review and revise flood management policies in the community, and contribute insights into the forms that integrated adaptation and mitigation planning might take in the future. It is anticipated that more specific impacts on barriers may become clearer as policies develop. An additional effect of the visualisation work may also turn out to be via the considerable exposure in the media that the research has received, with possible 'knock-on' effects on municipal staff and policy.

6. Conclusions

Local government clearly needs more systematic research on overcoming barriers to implementing effective flood management policy given the implications of a changing climate and the host of challenges inherent in municipal institutions. This paper has explored key municipal barriers and suggested an array of possible ways to overcome such barriers. A new approach to Local Climate Change Visioning has been reviewed in the context of these municipal barriers, as a first step to more in-depth evaluation of the success of processes in overcoming barriers to municipal action. The Visioning Process provides a novel way to communicate science and uncertainty within a local context. It encourages a deliberative process that moves beyond uncertainties to craft four alternative visions of the future, which illustrate different levels of adaptation and mitigation responses (viewed to be appropriate and applicable at this scale). Visualizing these futures begins the dialogue about preferences for the future and the types of decisions that need to be made now in order to shift behaviours. It brings together a range of stakeholders without whom effective flood risk management and climate change policy-making cannot occur. This process has revealed, and in part addressed, a number of the well-established flaws in current models of flood risk management, including fairness in public engagement, uncertainty in predictive models, and lack of technical and human capacity.

Linking global science to locally significant places with visioning processes and visualisations represents a powerful tool for decision-making in the context of flood risk management. Visualization could also be applied to other types of climate change adaptation challenges, and participants in the Visioning Project have pursued applications on changing snowpack in the District of North Vancouver, and changing forest fire risk in Kimberley. In the future, providing an integrated and concise assessment of the ways in which the results of the testing sessions could be built into concrete and effective climate change response policies represents the final link in closing the loop among municipal governance, scientific expertise, and public participation. Other municipalities facing similar risks may consider existing flood risk management practices in light of the unique challenges posed by a changing climate, and the emerging public participation and scenario co-production tools explored here. With these tools in hand, municipalities and other jurisdictions may better equipped to design and implement equitable flood management responses that account for cognitive, behavioural, and institutional barriers.

Acknowledgements

The authors would like to thank GEOIDE Network of Centres of Excellence for providing funding for this project through the Strategic Investment Initiative and the following groups/individuals: John Robinson, the Corporation of Delta, Metro Vancouver, the Province of British Columbia, Natural Resources Canada, and the members of the Collaborative for Advanced Landscape Planning. This paper is an ammended version of one published in the Journal of Flood Risk Management (2010)3(2): 400-412.

References

Adger, W. N., Agrawala, S., Mirza, M. M. Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B. & Takahashi, K. (2007) Assessment of adaptation practices, options, constraints and capacity. IN PARRY, M. L., CANZIANI, O. F., PALUTIKOF, J. P., VAN DER LINDEN, P. J. & HANSON, C. E. (Eds.) *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK, Cambridge University Press.

Adger, W. N., Arnell, N. & Tompkins, E. (2005) Successful adaptation to climate change across scales. *Global Environment Change Part A*, 15, 77-86.

Al-Kodmany, K. (1999) Using visualization techniques for enhancing public participation in planning and design: process, implementation, and evaluation. *Landscape and Urban Planning,* 45, 37-45.

Al-Kodmany, K. (2000) GIS in the urban landscape: Reconfiguring neighbourhood planning and design processes. *Landscape Research,* 25, 5-28.

Appleton, K. J. & Lovett, A. A. (2003) Defining 'sufficient' realism in visualisations for rural environmental decision-making. *Landscape and Urban Planning,* 62, 117-131.

Bai, Z. (2007) Integrating global concerns into urban management: the scale and readiness arguements. *Journal of Industrial Ecology,* 11, 15-29.

Banuri, T., Barker, T., Bashmakov, I., Blok, K., Christensen, J., Davidson, O., Grubb, M., Halsnaes, K., Jepma, C., Jochem, E., Kauppi, P., Krankina, O., Krupnick, A., Kuijpers, L., Kverndokk, S., Markandya, A., Metz, B., Moomaw, W. R., Moreira, J. R., Morita, T., Pan, J., Price, L., Richels, R., Robinson, J., Sathaye, J., Swart, R., Tanaka, K., Taniguchi, T., Toth, F., Taylor, T. & Weyant, J. (2001) Technical Summary. IN METZ, B., DAVIDSON, O., SWART, R. & PAN, J. (Eds.) *Climate Change Mitigation 2001: A Report of Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge, Cambridge University Press.

Berkhout, F. (2002) Technological regimes, path dependency and the environment. *Global Environment Change,* 12, 1-4.

Betsill, M. (2001) Mitigating climate change in US cities: opportunities and obstacles. *Local Environment,* 6, 393-406.

Böhringer, C. & Vogt, C. (2004) The dismantling of a breakthrough: the Kyoto Protocol as symbolic policy. *European Journal of Political Economy,* 20, 597-617.

Buchner, B. K., Carraro, C., Cersosimo, I. & Marchiori, C. (April 2002) Back to Kyoto? US Participation and the Linkage Between R&D and Climate Cooperation. *CEPR Discussion Paper No. 3299*. Centre for Economic Policy Research.

Bulkeley, H. & Betsill, M. (2005) Rethinking sustainable cities: Multi-level governance and the 'urban' politics of climate change. *Environmental Politics,* 14, 42-63.

Bulkeley, H. & Betsill, M. M. (2003) *Cities and Climate Change: Urban Sustainability and Global Environmental Governance*, London, Routledge.

Burch, S. (2010) In pursuit of low carbon communities: An examination of barriers to action in three Canadian cities. *Energy Policy,* 38, 7575-7585.

Burch, S. & Robinson, J. (2007) A framework for explaining the links between capacity and action in response to global climate change. *Climate Policy,* 7, 304-316.

Burgess, J., Clark, J. & Chilvers, J. (2005) Going 'upstream': issues arising with UK experiments in participatory science and technology assessment. *Socilogia e Politiche Sociali,* 8, 107-136.

Cohen, S. & Neale, T. Eds. 2006. Participatory integrated assessment of water management and climate change in the Okanagan Basin, British Columbia. Environment Canada and University of British Columbia, Vancouver, 221 p.

Conroy, M. M. & Gordon, S. I. (2004) Utility of interactive computer-based materials for enhancing public participation. *Journal of Environmental Planning and Management*, 47, 19-33.

Daniel, T. C. & Meitner, M. J. (2001) Representational validity of landscape visualization: the effect of graphical realism on perceived scenic beauty of forest vistas. Journal of *Environmental Psychology,* 21, 61-72.

DiMaggio, P. J. & Powell, W. W. (1983) The iron cage revisited: Institutional isomporphism and collective rationality in organizational fields. *American Sociological Review,* 48, 147-160.

Dockerty, T., Lovett, A., Sünnenberg, G., Appleton, K. & Parry, M. (2005) Visualizing the potential impacts of climate change on rural landscapes. *Computers, Environment and Urban Systems,* 29, 297-320.

Dryzek, J. S. (2000) *Deliberative Democracy and Beyond: Liberals, Critics, and Contestations*, Oxford, Oxford University Press.

Fraser Basin Council (2004). Fraser River Basin. **http://www.fraserbasin.bc.ca/fraser_basin/index.html** [Accessed December 20, 2007]

Grothmann, T. & Patt, A. (2005) Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environment Change,* 15, 199-213.

Haddad, B. (2005) Ranking the adaptive capacity of nations to climate change when socio-political goals are explicit. *Global Environmental Change,* 15, 165-176.

Hill, P. (2006) Biophysical impacts of sea level rise and changing storm conditions on Roberts Bank. Draft Assessment Report. Geological Survey of Canada.

Irwin, A. & Wynne, B. (1996) *Misunderstanding Science? The Public Reconstruction of Science,* Cambridge, UK, Cambridge University Press.

Johnson, C., Penning-Rowsell, E. & Parker, D. (2007) Natural and imposed injustices: the challenges in implementing 'fair' flood risk management policy in England. *The Geographical Journal,* 173, 374-390.

Jones, P. J. S. & Burgess, J. (2005) Building partnership capacity for the collaborative managment of marine protected areas in the U.K.: A preliminary analysis. *Journal of Environmental Management,* 77, 227-243.

Kaiser, F. G. & Wolfing, S. (1999) Environmental attitude and ecological behaviour. *Journal of Environmental Psychology,* 19, 1-19.

Karp, D. G. (1996) Values and their effect on pro-environmental behaviour. *Environment and Behaviour,* 28, 111-133.

Klijn, F., van Buuren, M. & van Rooij, S. A. M. (2004) Flood-risk management strategies for an uncertain future: Living with Rhine River floods in the Netherlands? *Ambio,* 33, 141-147.

Kollmuss, A. & Agyeman, M. (2002) Mind the gap: Why do people act environmentally, and what are the barriers to pro-environmental behaviour. *Environmental Education Research*, 3, 239-260.

Ledoux, L., Cornell, S., O'Riordan, T., Harvey, R. & Banyard, L. (2005) Towards sustainable flood and coastal management: identifying drivers of, and obstacles to, managed realignment. *Land Use Policy,* 22, 129-144.

Lewis, J. L. & Sheppard, S. R. J. (2006) Culture and communication: Can landscape visualization improve forest management consultation with indigenous communities? *Landscape and Urban Planning,* 3, 291-313.

MacEachren, A. M. (2001) Cartography and GIS: Extending collaborative tools to support virtual teams. *Progress in Human Geography,* 25, 431-444.

Mendez, R. (2008). Immobiliarias acusan a Greenpeace de hundir los precios de La Manga. **http://www.elpais.com/articulo/espana/Inmobiliarias/acusan/Greenpeace/hundir/precios/Manga/elpepuesp/20080610elpepinac_11/Tes** [Accessed July 10, 2008]

Nakicenovic, N. & Swart, R. (Eds.) (2000) *Special Report on Emissions Scenarios. Report of the Intergovernmental Panel on Climate Change,* London, Cambridge University Press.

Nicholls, R. J., Wong, P. P., Burkett, V. R., Codignotto, J. O., Hay, J. E., McLean, R. F., Ragoonaden, S. & Woodroffe, C. D. (2007) Coastal systems and low-lying areas. IN PARRY, M. L., CANZIANI, O. F., PALUTIKOF, J. P., VAN DER LINDEN, P. J. & HANSON, C. E. (Eds.) *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK, Cambridge University Press.

Nicholson-Cole, S. (2005) Representing climate change futures: a critique on the use of images for visual communication. Computers, *Environment and Urban Systems,* 29, 255-273.

O'Riordan, T. & Jordan, A. (1999) Institutions, climate change, and cultural theory: Toward a common analytical framework. *Global Environment Change,* 9, 81-93.

Olsen, J. P. & March, J. G. (1989) *Rediscovering Institutions: The Organizational Basis of Politics*, New York, The Free Press.

Orland, B., Budthimedhee, K. & Uusitalo, J. (2001) Considering virtual worlds as representations of landscape realities and as tools for landscape planning. *Landscape and Urban Planning,* 54, 139-148.

Pidgeon, N. F., Poortinga, W., Rowe, G., Jones, T. H., Walls, J. & O'Riordan, T. (2005) Using surveys in public participation processes for risk decisionmaking: The case of the 2003 British GM Nation? public debate. *Risk Analysis,* 25, 467-479.

Pierson, P. (2000) Increasing returns, path dependence, and the study of politics. *The American Political Science Review,* 94, 251-267.

Raskin, P. (2005) Global scenarios: Background review for the Millennium Ecosystem Assessment. *Ecosystems,* 8, 133-142.

Raskin, P., Banuri, T., Gallopin, G., Gutman, P., Hammond, A., Kates, R. & Swart, R. (2002) *Great Transition: The Promise and Lure of Times Ahead*, Stockholm Environment Institute.

Renn, O., Webler, T. & Wiedemann, P. (Eds.) (1995) *Fairness and Competence in Citizen Participation: Evaluating Models for Environmental Discourse,* Dordrecht, Bostong, London, Kluwer Academic Publishers.

Robinson, J., Carmichael, J., VanWynsberghe, R., Tansey, J., Journeay, M. & Rogers, L. (2006) Sustainability as a problem of design: Interactive science in the Georgia Basin. *Integrated Assessment,* 6, 165-192.

Robinson, J. & Tansey, J. (2006) Co-production, emergent properties, and strong interactive social research: The Georgia Basin Futures Project. *Science and Public Policy,* 33, 151-160.

Rotmans, J. & Van Asselt, M. (1996) Integrated Assessment: a growing child on its way to maturity. *Climatic Change,* 34, 327-336.

Shaw, A., Sheppard, S., Burch, S., Flanders, D., Weik, A., Carmichael, J., Robinson, J. & Cohen, S. (2009) How futures matter - Synthesizing, downscaling, and visualizing climate change scenarios for participatory capacity building. *Global Environmental Change,* DOI 10.1016/j.gloenvcha.2009.04.002.

Sheppard, S. R. J. (2005a) Landscape visualization and climate change: the potential for influencing perceptions and behaviour. *Environmental Science & Policy,* 8, 637-654.

Sheppard, S. R. J. (2005b) Validity, reliability, and ethics in visualization. IN BISHOP, I. D. & LANGE, E. (Eds.) *Visualization in Landscape and Environmental Planning.* London, Taylor and Francis.

Sheppard, S. R. J. & Meitner, M. (2005) Using multi-criteria analysis and visualization for sustainable forest management planning with stakeholder groups. *Forest Ecology and Management,* 207, 171-187.

Sheppard, S. R. J. & Shaw, A. (2007) Future visioning of local climate change scenarios: Connecting the dots and painting pictures to aid earth system governance. 2007 *Amsterdam Conference of the Human Dimension of Global Environmental Change. Earth System Governance: Theories and Strategies for Sustainability.* Amsterdam: Vrije Universiteit.

Sheppard, S. R. J., Shaw, A., Flanders, D. & Burch, S. (2008) Can visualization save the world? Lessons for landscape architects from visualizing local climate change. *Digital Design in Landscape Architecture 2008; 9th International Conference on IT in Landscape Architecture.* Anhalt University of Applied Sciences, Dessau/Bernburg, Germany.

Steinitz, C., Rojo, H. M. A., Arias, H., Bassett, S., Flaxman, M., Goode, T., Maddock III, T., Mouaat, D., Peiser, R. & Shearer, A. (2003) *Alternative futures for changing landscape: The Upper San Pedro River Basin in Arizona and Sonora,* Washington, D.C., Island Press.

Stern, P. C. (2000) Toward a coherent theory of environmentally significant behaviour. *Journal of Social Issues,* 56, 407-424.

Stern, P. C. & Fineberg, H. V. (1996) *Understanding Risk: Informing Decisions in a Democratic Society,* Washington, D.C., National Research Council.

Tansey, J., Carmichael, J., VanWynsberghe, R. & Robinson, J. (2002) The future is not what it used to be: Participatory integrated assessment in the Georgia Basin. *Global Environment Change,* 12, 97-104.

Thelen, K. (2003) How institutions evolve: Insights from comparative historical analysis. IN MAHONEY, J. & RUESCHEMEYER, D. (Eds.) *Comparative Historical Analysis in the Social Sciences.* New York, Cambridge University PRess.

Tress, B. & Tress, G. (2003) Scenario visualization for participatory landscape planning - a study from Denmark. *Landscape and Urban Planning,* 64, 161-178.

van Asselt, M. & Rijkens-Klomp, N. (2002) A look in the mirror: reflection on participation in Integrated Assessment from a methodological perspective. *Global Environment Change*, 12, 167-184.

Walker, I.J., Barrie, J.V., Dolan, A.H., Gedalof, Z., Manson, G., Smith, D. & Wolfe, S. 2007. Coastal vulnerability to climate change and sea level rise, Northeast Graham Island, Haida Gwaii (Queen Charlotte Islands), British Columbia: final technical report, submitted to Climate Change Impacts and Adaptation Program, Natural Resources Canada, Ottawa, 249 p.

Williamson, T.B.; Price, D.T.; Beverly, J.L.; Bothwell, P.M.; Frenkel, B.; Park, J.; Patriquin, M.N. 2008. Assessing potential biophysical and socioeconomic impacts of climate change on forest-based communities: a methodological case study. *Natural Resources Canada, Canadian Forest Service,* Edmonton,. Inf. Rep. NOR-X-415E.

Winkler, H., Baumert, K., Blanchard, O., Burch, S. & Robinson, J. (2007) What factors influence mitigative capacity? *Energy Policy,* 35, 692-703.

Yohe, G. W. (2001) Mitigative capacity: the mirror image of adaptive capacity on the emissions side. *Climatic Change,* 49, 247-262.

Yohe, G.W., Lasco R.D. , Ahmad, Q.K., Arnell, N. , Cohen, S.J. , Hope, C. , Janetos, A.C. and Perez, R.T. 2007. Perspectives on climate change and sustainability. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 811-841.