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Understanding vulnerability of coastal communities to climate change related risks

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ABSTRACT

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This paper discusses the concept of vulnerability as characterized in the climate change literature and presents a framework for assessing adaptive capacity. The framework recognizes inherent susceptibilities of human-environment systems exposed to climate variability and change. As climate change impacts are unevenly distributed among and within nations, regions, communities and individuals due to differential exposures and vulnerabilities, the framework highlights determinants of adaptive capacity at the local scale and situates them within larger regional, national and international settings. Determinants include: access and distribution of resources, technology, information and wealth; risk perceptions; social capital and community structure; and institutional frameworks that address climate change hazards. This broader approach contrasts typical impact assessments that focus largely on reducing economic detriments of change. The framework provides a methodological starting point that, as a community-based or 'bottom-up' approach, yields important insight on local responses to climate change. It also recognizes that short-term exposure to variability is an important source of vulnerability superimposed on long-term change. At the community level, perceptions and experiences with climate extremes can identify inherent characteristics that enable or constrain a community to respond, recover and adapt. As such, local and traditional knowledge is key to climate change research and should be incorporated into research design and implementation. This approach provides locally relevant outcomes that could promote more effective decision-making, planning and management in remote areas susceptible to climate change hazards. As part of a larger study, this approach will be refined with local input to study sea-level rise impacts on one of Canada's most sensitive coastlines, northeast Graham Island, Haida Gwaii (Queen Charlotte Islands), British Columbia. Preliminary evidence of changes and responses in this area are identified as a brief case study.

ADDITIONAL INDEX WORDS: *adaptive capacity, resilience, sea-level rise, Queen Charlotte Islands*

INTRODUCTION

Global climate changes are expected to affect coastal communities around the world, many of which are already considered vulnerable to ongoing climatic variability (IPCC, 2001; MONIRUL and MIZRA, 2003). Of these changes, accelerated sea-level rise has received much attention and may entail elevated tidal inundation, increased flood frequency, accelerated erosion, rising water tables, increased saltwater intrusion, and a suite of ecological changes. These biophysical changes are expected to cause various socio-economic impacts including loss of land infrastructure and coastal resources as well as declines in associated economic, ecological, cultural and subsistence values (KLEIN and NICHOLLS, 1999). These impacts are scale-dependent however, in that they will be unevenly distributed among and within nations, regions, communities and individuals as a result of differential exposures and vulnerabilities (CLARK *et al*., 1998). In light of the rapid rate of change, widespread area and potential magnitude of these impacts, coastal vulnerability assessment has received significant international attention. However, the effects of scale on the potential inequitable distribution of climate change impacts, particularly as it frames the vulnerability of isolated island communities, has received considerably less attention.

Coastal zone impacts assessment work has been driven largely by the Intergovernmental Panel on Climate Change (IPCC) via its Coastal Zone Management Subgroup (CZMS) (IPCC-CZMS, 1992), the IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations (CARTER *et al.*, 1994), and the United Nations Environment Program (UNEP) Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies (FEENSTRA *et al.*, 1998). These documents provide frameworks and methodologies to assess impacts of climate change by identifying key vulnerabilities. Several researchers have evaluated the merit of these frameworks for assessing coastal vulnerability and have provided refined and expanded frameworks WATERMAN and KAY, 1993; YAMADA *et al.*, 1995; CLARK *et al.*, 1998; HARVEY *et al*., 1999; KLEIN and NICHOLS, 1999; WU *et al*., 2002). Concurrently, debate on how vulnerability is defined and incorporated into conventional coastal zone impacts assessments has called for a more integrated, broadened view of vulnerability. ADGER (1996) notes that much attention is given to the physical forcings and impacts of climate at the expense of examining pre-existing social vulnerability. In addition, focus on community-based research is underemphasized (RIEDLINGER and BERKES, 2001) and outcomes of climate models and scenarios are too broad for useful planning and adaptation at local scales (JONES, 2001).

Drawing on the recent climate change impacts and vulnerability literature, the purpose of this paper is twofold. First, it provides a discussion of how vulnerability has been characterized and how this has influenced current coastal vulnerability assessments. From this, a multi-scaled, integrated vulnerability framework is presented that takes a more locally relevant, community-based (bottom-up) approach. This provides a methodological starting point that will be refined and applied as part of a larger study to assess the adaptive capacity to climate change and sea-level rise impacts on one of Canada's most sensitive coastlines: northeast Graham Island, Haida Gwaii (Queen Charlotte Islands), British Columbia (Shaw *et al*., 1998). This region is located 80 km offshore from British Columbia's north coast (54°N, 132°W, Fig. 1) and was identified for its physical exposure (Shaw *et al*., 1998; Walker and Barrie, 2004), isolated setting, coastal resource dependency, indigenous peoples interests, and recent exposure to other socio-economic changes. Preliminary evidence of changes and responses in this area are identified in a brief case study.

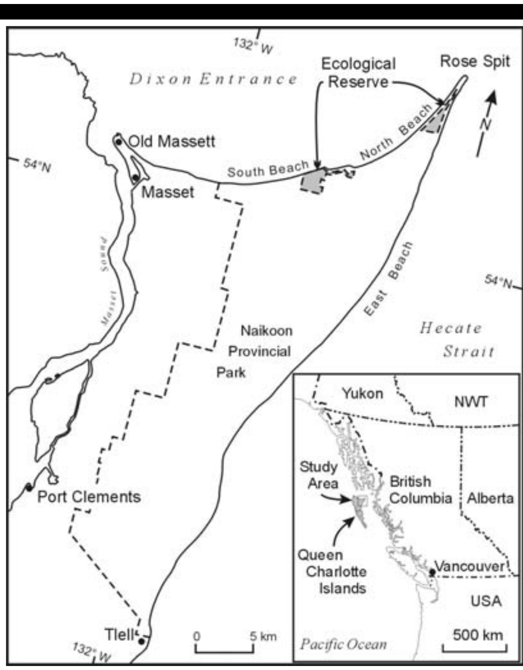

Figure 1: Study region on northeastern Graham Island, Haida Gwaii (Queen Charlotte Islands), British Columbia, Canada.

Vulnerability Assessment

The IPCC-CZMS (1992) defines vulnerability of coastal zones by their degree of incapability to cope with the impacts of climate change and accelerated sea-level rise. Vulnerability assessment includes the susceptibility of the coastal zone to physical changes resulting from climate change, the anticipated impacts on socio-economic and ecological systems, and available adaptation options (Harvey *et al*., 1999). The common methodology prepared by IPCC-CZMS (1992) to help countries identify and assess sea-level rise impacts has been applied in Canada (e.g., Shaw *et al*., 1998; Shaw *et al*., 2001). Recognizing limitations with this methodology, others have provided altered approaches (Waterman and Kay, 1993; Yamada *et al*., 1995; Clark *et al*., 1998; e.g., Harvey *et al*., 1999; Klein and Nicholls, 1999; Wu *et al*., 2002). Klein and Nicholls (1999) highlight five general limitations, three of which relate to technical and data availability constraints that limit progress on modelling and assessing quantitative (and largely physical) impacts. Such problems are especially acute in small island nations or states (Waterman and Kay, 1993; Yamada *et al*., 1995). Other limitations include the ineffectiveness of the IPCC methodology in assessing the wide range of technical, institutional, economic and cultural elements in different regions as well as the inappropriateness of applying market-evaluation frameworks in subsistence economies and traditional land-tenure systems (Yamada *et al*., 1995; Klein and Nicholls, 1999). These limitations are in part related to the broad scale of the assessment methodology and its lack of attention to distinct local- and/or community-based attributes. Furthermore, though climate change simulations and forecasts are important for predicting future changes, they are limited in their capacity to explain local and regional effects due to typically coarse spatial and temporal scales. Unless global changes are downscaled, they have little value for decision-makers who require locally relevant information that is applicable at the community scale (Jacobs and Bell, 1998). As responses to climate change impacts will consist primarily of individual responses at the local scale (Adger, 2001), this calls for a multi-scaled perspective that can be applied to assess community level adaptive capacity. Such responses may be planned adaptations (e.g., insurance to spread risk, structural shoreline protection, development setbacks) or spontaneous reactions (e.g., timing of harvest activities, alternate choice of resource) to related, though indirect impacts, of climate changes in resource sectors such as fisheries and forestry or to economic constraints (Adger, 2001). To date, most vulnerability assessments based on the common methodology do not consider scales appropriate (fine) enough to provide adequate community-level guidance regarding climate change adaptation.

Characterizing vulnerability

Limitations with existing approaches are in part a result of the 'impacts-driven' nature of conventional vulnerability assessments that adopt a narrow (and variable) definition of vulnerability. In general, vulnerability is a rhetorical warning of danger representing a potential for loss (Cutter, 1996). This view forms the basis for analysis in many disciplines (e.g., natural hazards, disasters, risk assessment, food security), including climate change research (Liverman, 1990; Blaikie *et al*., 1994; Yamada *et al*., 1995; Clark *et al*., 1998; Harvey *et al*., 1999; Cutter *et al*., 2000; Wu *et al*., 2002). To date however, there is no consistent definition used for assessing climate change impacts.

Three broad characterizations of vulnerability from climate change and natural hazards research are identified that, combined, address the dynamic and integrated nature of social and environmental vulnerability. The first characterizes vulnerability in terms of exposure to hazardous events (e.g., droughts, floods) and how this affects people and structures. As such, a physical event places people at risk and the focus is to identify vulnerable places. However, methods aimed at reducing physical risk do not necessarily reduce exposure and damages and may increase the vulnerability of populations to such events (Hewitt, 1997; Comfort *et al*., 1999; Shrubsole, 2000). For example, structural adaptations (e.g., flood protection) do not necessarily discourage people from living in high-risk areas (e.g., floodplains), but may encourage development and consequently, increase vulnerability.

A second perspective views vulnerability as a human relationship not a physical one (i.e., vulnerability is socially constructed rather than determined by the occurrence of a physical event). As such, vulnerability is a function of social conditions and historical circumstances that put people at risk to a diverse range of climate-related, political, or economic stresses (e.g., poverty, development in marginal or sensitive areas) (Watts and Bohle, 1993; Blaikie *et al*., 1994; Kelly and Adger, 2000). As such, exposure is determined by the inequitable distribution of damage and risk among groups of people (WU *et al*., 2002) and vulnerability is a result of social processes and structures that constrain access to resources (e.g., wealth and real income, formal and informal social security) that enable people to cope with impacts (BLAIKIE *et al*., 1994). Thus, protection from the social forces imposed on people that create inequitable exposure to risk is just as, or more important than protection from natural hazards (HEWITT, 1997). Social vulnerability and how it is produced, becomes the focus, regardless of the nature of the exposure.

A third perspective integrates both the physical event and the underlying causal characteristics of populations that lead to risk exposure and limited capacity of communities to respond (LIVERMAN, 1990; BURTON *et al*., 1993; ADGER, 2000; CUTTER *et al*., 2000). Vulnerability is therefore a physical risk and a social response within a defined geographic context. Several studies have integrated in some way both physical and social vulnerability perspectives (e.g., BLAIKIE and BROOKFIELD, 1987; WU *et al*., 2002). For example, WU *et al*. (2002) applied a GIS-based approach to assess physical vulnerability of a coastal region to flood hazards under varying storm intensities and projected sea-level rise. In addition, they delineated regions of social vulnerability within the community using indicators such as age, gender, race, income and housing conditions. Together, this identified the broader vulnerability of the area and its distribution within a community to flood hazard and sea-level rise.

While various approaches to an integrated definition of vulnerability to climate change-related risks have been attempted, much of this work holds a largely biophysical perspective that is pre-occupied with the outcomes of physical exposure (e.g., coastal erosion) and residual impacts. For example, many of the coastal vulnerability assessments endorsed by the IPCC are largely impacts-driven and depend on physical exposure for identifying vulnerable regions (HARVEY *et al*., 1999; KLEIN, 1999; BURTON *et al*., 2002). Though other determinants of vulnerability are examined, the assessment begins by identifying as biophysical impacts, then potential residual socio-economic impacts after adaptations. As such, understanding how to reduce vulnerability to climate change becomes an exercise in adaptation planning.

Integrated approaches have increased understanding of potential climate change impacts and of the role of adaptation options in moderating negative consequences (SMITH, 1997; TOL *et al*., 1998; KLEIN and NICHOLLS, 1999). However, this is an interventionist exercise in assessing proximate causes of vulnerability as attention is directed at identifying and evaluating the most appropriate technical, economic, institutional and/or structural means to respond to an external threat, rather than a full assessment of systemic root causes of vulnerability such as global capitalism, colonialism, and racism (HEWITT, 1983; 1997; BLAIKIE, 1985). CLARK *et al*. (1998) developed a causal hazards model that integrates indicators of social vulnerability (e.g., poverty, disability) with environmental and spatial considerations (e.g., flood risk mapping) to delineate vulnerabilities spatially within a community. Though they do not question why poverty exists in delineated areas, they state that their assessment identifies causal links between exposure and social vulnerability within the scope of existing institutional arrangements relevant to coastal policy-makers, managers and community organizers. Indeed, IPCC-directed vulnerability assessments are more interventionist and aimed at reducing the risks of potential damages by anticipating impacts and planning adaptation responses. Consequently, adaptations fall within narrow management categories that include protect, adapt, retreat and do nothing. As such, this approach perpetuates a protection-oriented response to climate change, rather than assessing a broader array of technical, institutional, economic and social elements that occur in different localities (KLEIN and NICHOLLS, 1999). Presently most coastal vulnerability assessments do not yield results sufficient for widespread, day-to-day application for coastal zone management (KLEIN and NICHOLLS, 1999). While efforts to improve vulnerability assessments via improved data and analytical techniques continue, other approaches to assist coastal communities in dealing with physical- and social vulnerabilities must be pursued.

Coastal climate change research in Canada

Despite having the longest coastline in the world and about one-third of this moderately to highly sensitive to sea-level rise impacts (SHAW *et al*., 1998), very little work has been conducted on impacts and adaptation in the coastal zone. Many coastal communities in the Canadian Arctic are experiencing climate change effects such as melting sea ice, rising sea levels, coastal erosion and permafrost thawing (WOO *et al*., 1992; SHAW *et al*., 1998; ROTHROCK *et al*., 1999). To date, however the only integrated study on sea-level rise impacts in Canada was conducted in Prince Edward Island (SHAW *et al*., 2001). The study was heavily impacts-driven and focused largely on physical impacts (e.g., storm surge flooding, shoreline erosion) and associated socio-economic costs. Though the study defined vulnerability as a function of exposure and susceptibility as well as the adaptive capacity to change, the objective was essentially to maximize ‘positive effects’ and to minimize adverse impacts, thereby reducing vulnerability. Socio-economic vulnerabilities were reduced to capital costs of: i) erosion and flooding hazards on residential, recreational, heritage and commercial properties, ii) associated tourism impacts, iii) municipal infrastructure damage, and iii) health, education and employment impacts. Environmental vulnerabilities were reduced to, “added value attributable to ecosystem services provided by the natural environment within 200m of the shoreline” (SHAW *et al*., 2001 p. 32). Among the recommendations were: i) hazard identification and monitoring, ii) managed retreat or avoidance, iii) accommodation and enhancement of natural resilience (e.g., dune rehabilitation, dyke removal, wetland renewal), iv) structural protection, v) coastal management to accommodate change (e.g., rezoning, restricted development, land swapping) and vi) increased awareness and public education. In essence, this approach was an exercise in impacts assessment, evaluation and reduction, not an integrated vulnerability assessment that incorporates risk exposure with intrinsic attributes and adaptive capacities of the local setting.

AN INTEGRATED VULNERABILITY FRAMEWORK

Given the limitations of impacts-driven coastal vulnerability assessments in considering both physical and social aspects of vulnerability and in light of the present need for community-based approaches to adapting to climate change related risks, we propose an ‘integrated’ framework (Fig. 2). This approach considers inherent susceptibilities and resiliencies of both biophysical and social environments as an interrelated and interdependent human-environment system. This compliments an emerging discourse in climate change research where vulnerability is the starting point, rather than the end point as with impacts-driven assessments (KELLY and ADGER, 2000; SMIT and PILIFOSOVA, 2003). Adaptive capacity is characterized by the ability of the system to respond and adapt, rather than in terms of what may or may not happen in the future. Current adaptive capabilities and potentials for managing changes are then linked to existing decision processes to provide a more locally relevant, community-based approach. This moves away from identifying and evaluating specific adaptation options toward promoting capacity building within communities to respond and adapt to climate change and sea-level rise risks.

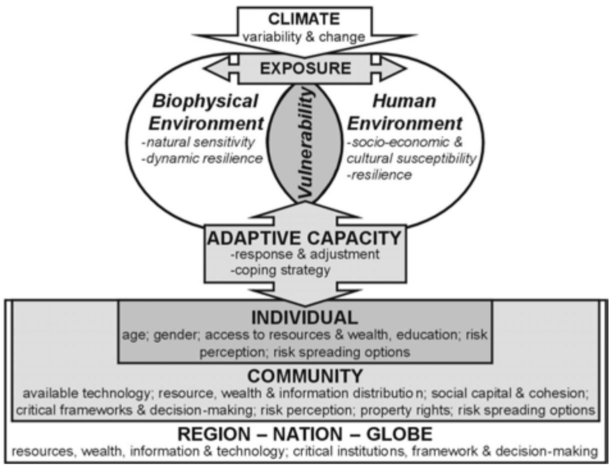

Figure 2: Integrated vulnerability framework modified from (SMIT and PILIFOSOVA, 2003; YOHE and TOL, 2002; KELLY and ADGER, 2000; BLAIKIE *et al*., 1994; WU *et al*., 2002)

Exposure to climatic variability and change

Exposure of the coastal environment can be characterized by susceptibility (or sensitivity), resilience and resistance. Susceptibility to climate change-induced sea-level rise can be defined as the potential of a coastal system to be affected by sea-level rise and could be assessed either using a simple physical sensitivity index (e.g., SHAW *et al*., 1998) or a more integrated approach (e.g., IPCC-CZMS, 1992). Resistance describes system stability to possible sea-level rise impacts (e.g., resistance of a shoreline to wave erosion), whereas resilience reflects the capacity of the system respond to and recover from impacts (e.g., dynamic dune systems that recover from storm surges). Together, these terms define natural coastal vulnerability.

Natural susceptibility is viewed as largely independent of human influence but resilience and resistance are often affected by human activities, positively or negatively (KLEIN and NICHOLLS, 1999). For example, planned adaptation (e.g., shoreline protection, dune restoration) can reduce natural vulnerability by enhancing system resistance and resilience thereby increasing the likelihood of adaptation (HARVEY *et al*., 1999). In converse, human-induced hazards (e.g., land degradation, inappropriate development and encroachment, and protection structures decrease (or temporarily increase) resistance thereby reducing resiliency of the system to respond and adapt. This underscores the view that biophysical and human systems are not isolated entities, but should be treated as a dynamically interacting and co-evolving (KLEIN and NICHOLLS, 1999) system that shares vulnerability.

While scientists project changes in climate over decades and broad spatial scales, hazards are expressed quickly at local scales. It is at this level where responses and adaptations are most important (RIEDLINGER and BERKES, 2001). The aim of coastal vulnerability approaches is to help coastal communities adapt to risks of longer-term climate change and accelerated sea-level rise. However, shorter-term impacts of climate variability including extreme storm surges, flooding and enhanced erosion are also possible risks of future climate change (CLARK *et al*., 1998; WU *et al*., 2002; MONIRUL and MIRZA, 2003). This is an important distinction in that adaptations by countries and communities will likely occur in response to changes in frequency and magnitude of short-term, variability events rather than gradual, longer-term change in average conditions such as sea-level rise (SMIT *et al*., 1999). Our framework recognizes that shorter-term exposure to variability and extreme events is an important source of vulnerability superimposed on long-term climate change. Community level perceptions of, and experiences with, climate extremes in recent and historical memory can be explored to allow examination of inherent characteristics that enable and/or constrain a particular community to respond, recover and adapt.

Adaptive Capacity

Adaptive capacity is an inherent property of the system that defines its capability to deal with exposure (SMIT and PILIFOSOVA, 2003). Here, adaptive capacity is reflective of resiliency, such that a resilient system has the capacity to prepare for, avoid, moderate and recover from climate-related risks and/or change. Building adaptive capacity helps reduce vulnerability. HOLLING (1973) posits that instead of aiming for a precise capacity to handle some future scenario, all that is required to maintain a stable system is a qualitative capacity to absorb and accommodate uncertain and unexpected changes. This idea, originally applied to ecological systems, has been applied widely to human system behaviour, particularly in natural hazards research. For instance, losses or damages to a socio-economic system after exposure indicate that the hazard exceeded the system's absorptive capacity (BURTON *et al*., 1993). This has prompted the design for resilient and hence, adaptive systems. Communities that are structurally organized to minimize the effects of hazards, whilst being able to recover quickly by restoring socio-economic vitality are thus, resistant and resilient. Communities are also considered resilient if social networks can withstand changes in both horizontal and vertical decision-making relationships. This stresses the complex and important relationship between individuals, communities and the broader political economy (TOBIN, 1999). In this sense, resilience can be referred to as an ability of human systems to learn from and reorganize to meet changed conditions, and as such will gain the inherent characteristics needed for adaptation (BARNETT, 2001).

Discussions of determinants of resilience in socio-ecological systems are long-standing (e.g., WILDAVSKY, 1988; FOLKE *et al*., 1998). In ecological systems, several system properties are indicative of resilience including: homeostasis and feedback transmission, diversification of resources and their delivery, high rate of resource movement through the system, limited hierarchical structure, and excess capacity (HOLLING, 1973; WILDAVSKY, 1988). Paralleling these in the natural hazards literature are indicators of human system resilience including: efficient transmission of knowledge across space and time, temporary and permanent diversification and sustainable intensification of resources, mobilization of social networks, mobility for relocation and access to resources, and decentralization of decision-making (HANDMER and DOVERS, 1996). In terms of climate change, the Report of Working Group II to the Third Assessment Report of the IPCC (IPCC, 2001) identifies several determinants of adaptive capacity including: available technological options, available resources and their distribution, stock of human capital including education and security, stock of social capital including property rights, structure of critical institutions, access to risk spreading processes, ability of decision-makers to manage information and validate it, and public perception (IPCC, 2001; YOHE and TOL, 2002).

The effects of interdependency within human-environmental system must also be considered in determining adaptive capacity. For example, sustainable resource management practices, decision-making processes and infrastructure can be exacerbated by climate change and sea-level rise (e.g., increased damage to critical infrastructure, declines in resource yield). This, via increased physical exposure, increases the vulnerability and, depending on frequency and magnitude of exposure, may decrease overall adaptive capacity of the human-environment system. In turn, decreased adaptive capacity of communities (e.g., reduced social capital, declines in funding to maintain infrastructure, poorly implemented resource management plans) would increase socio-economic exposure, thereby increasing the vulnerability of the system. Thus, both physical and social exposures create vulnerability and serve to decrease resilience and hence, adaptive capacity to variability and longer-term change. As such this model considers elements of the human-environment system that determine vulnerability, specifically determinants of adaptive capacity within social systems that interact and co-evolve with changes in the physical environment. This broader approach is in contrast to typical 'impacts assessment' methods that focus largely on reducing (predominantly economic) detriments of change.

Considerations of scale

While system-level determinants of adaptive capacity provide some indication of resiliency of human-environmental systems to external climate-related stresses, adaptive capacity cannot be assessed at the community scale alone. For example, economic power at the aggregate level may enhance resiliency of a nation, region or community, but at the same time may leave significant portions of the population vulnerable and different groups marginalized (HANDMER *et al*., 1999). Relationships between vulnerable populations and community social structures are complex and are best examined via specific attributes of disadvantaged populations (TOBIN, 1999). Recognizing how characteristics of vulnerability mediate risks may also increase understanding of divergent adaptive capacities in and resiliency of communities. Poverty, gender oppression, ethnic discrimination, political powerlessness, disabilities, limited employment, absence of legal rights, breakdown of interfamilial arrangements and various forms of discrimination are recognized as indicators of social vulnerability (WISNER, 1992; CANNON, 1994; HEWITT, 1997). KELLY and ADGER (2000) state that vulnerability is defined by the capacity of individuals and social groups to respond to, cope with, recover from, and adapt to external stress on their livelihoods and well-being. Their 'architecture of entitlements' focuses less on an inventory of structural conditions indicative of social resiliency and more on the socio-economic and institutional conditions that constrain (and/or enable) effective response and adaptation. They advise a multi-scale approach to understanding adaptive capacity where individuals and groups and the local, regional and global systems within which they are situated are important. Their determinants of adaptive capacity are sensitive to scale and defined as social entitlements (i.e., material sources at individual level), differentiated levels of equity and livelihood diversity (i.e., distribution at community or population level), and appropriate institutional forms (i.e., institutional context within which entitlements are formed from community to global scales)(ADGER, 2001). Thus, assessing vulnerability involves both the role of institutions and policies in mediating risk at various scales and the attributes of groups that limit their access to specific resources needed to respond and recover from external stress.

Community scale determinants

Community adaptive capacity involves complex relationships among political, socio-economic and cultural elements that vary across a range of spatial and temporal scales. Our framework recognizes that a system's ability to cope with exposures of climate change is dependent on several determinants that can be measured at the community and individual levels. For instance, *income (wealth) and its distribution* across a population is an important indicator of system-level adaptive capacity in that as wealth of a nation, region, community or individual increases, so too does the potential for preparation, recovery and adaptation (KATES, 2000). *Access to technology* (closely tied to wealth) is another system-level determinant as greater access to technology increases the potential range of adaptation options available to communities (GOKLANY, 1995). *Information and skills available* across a community and to individuals are also important (BARNETT, 2001). Recognition of the need to adapt, knowledge about available adaptation options, capacity to assess them and the ability to implement the most appropriate ones are all dependent on the availability and credibility of information and skills (FANKHAUSER and TOL, 1997). *Risk perception and awareness* are also important as individuals and institutions must perceive and understand climate change to be a present and future threat before making steps for planned adaptation (BURTON *et al*., 1993). Risk awareness is dependent on the effectiveness of social networks and infrastructure to support and facilitate the flow of information and skills. Of late, researchers have drawn relationships between community capacity to cope with hazards and their *stock of social capital*, or relationships among people based on shared values and goals involving collective action, social trust, norms and networks (COLEMAN, 1988; BUCKLAND and RAHMAN, 1999; TOBIN, 1999). Civic engagement measures social capital such that denser social support networks promote greater cooperation among community members for some mutual benefit. It follows that communities with higher stocks of social capital and stronger social networks will better deal with hazards and climate change impacts given that information and other forms of social support are more readily accessible (BUCKLAND and RAHMAN, 1999).

Critical institutional frameworks at community, regional and national levels that manage climate change risks and other hazards are important (SMITH and LENHART, 1996). If they are not present or their existence and/or credibility are tenuous, communities will be less able to adapt. For example, provision of risk spreading options (e.g., insurance) by institutions helps individuals and groups cope with physical vulnerabilities such as floods, storm surge and wind damage. At the same time, too much dependence on risk spreading may lead to long-term 'maladaptive' behaviours (SMIT, 1994) that increase vulnerability. Furthermore, if social and political institutions do not promote equitable allocation of power and access to resources, it is less likely that communities and individuals will be able to respond and adapt effectively (ADGER and KELLY, 1999; HANDMER *et al*., 1999). How property rights are defined and allocated and how land use planning processes are developed by institutions is important for community adaptive capacity as they influence access to resources, wealth, well-being and livelihood. This particularly so in remote native communities undergoing land claims and resource allocation negotiations.

Case study: Sea-level rise on Graham Island, BC

The Geological Survey of Canada (GSC) defines sensitivity as the degree to which a rise in sea level would initiate or accelerate coastal changes given local conditions (e.g., tides, waves, flooding, erosion) and other climate change effects (e.g., increased storminess). Recognizing the exposure of coastal regions to potential sea-level rise hazards, the GSC mapped a 'sensitivity index' based on geological attributes for the entire Canadian coastline (SHAW *et al*. 1998). Due to a macrotidal range, erodible sediments, frequent storm surges and an energetic wave climate, the shoreline of NE Graham Island (Fig. 1) from Tlell to Masset, ranks among the most highly sensitive in Canada. This area has undergone significant changes in sea level over the Holocene (-150 to +16 m) (JOSENHANS *et al*., 1997) and currently is rising at

+1.5 mm a-1 (BECKMANN *et al*., 1997). In response, some areas are eroding at 1-3 m a^{-1} and greater during extreme events such as the 1997-98 El Niño that caused 0.4 m of regional sea-level rise and 12 m of localized retreat (BARRIE and CONWAY 2002). Despite extreme physical sensitivity of this environment little is known about the resilience and adaptive capacity of communities on this coast to climate change and sea-level rise.

Resource-based, remote, coastal communities are increasingly affected by global trends and international markets, including shifting supply and demand of natural resources in other parts of the world. Haida Gwaii has seen significant downward trends in its natural resource-based industries as a result of changes in the global economy, environmental degradation and other national and provincial policy adjustments. The forest industry has experienced turbulent international timber markets, increasing costs of access, and changes in forest management and technology. The fishing industry has experienced variable and potentially diminishing populations of salmon, herring and clams as well as changes in allocation of fishing privileges. Downsizing of federal and provincial governments and funding cutbacks, as well as high fluctuations in tourism have also impacted these communities. These economic impacts manifest in unemployment and changes in income levels. For example, in Old Massett, a Haida native community, around 60% of the population was unemployed in 2000, down from 72% in 1995 (SNDS, 2001). In the larger region, unemployment is 16.5%, which is about twice the provincial average (8.5%)(BC-STATS, 2001). Other changes, such as closure of a Canadian Forces base in Masset, led to out-migration of about 2000 people, job losses and economic changes. Population in the larger region has declined by 12% since 1981 (BC-STATS, 2001). Coupled with these trends are national, provincial and regional contested rights of access to natural resources for local livelihoods, both subsistence and commercial.

The communities of Graham Island are potentially vulnerable to climate change given their isolated and sensitive landscape, extreme climate variability (WALKER and BARRIE, 2004), and their economic dependence on variable and increasingly restricted natural resources for subsistence and jobs. Social and biophysical resilience are closely tied in resource-dependent communities and climate changes may increase uncertainty of resource availability and access. Past coping experiences and perceptions of change reveal insight into future adaptive capacity (RIEDLINGER and BERKES, 2001). This requires that researchers work with local people to identify coping and adaptation strategies to current and future risks. As discussed, contested property rights, land claims, and land use planning processes both complicate and compromise adaptive capacity of communities in the area. Such issues are embedded in historical and cultural circumstances and must be considered as they directly influence the livelihoods and well-being of a significant proportion of the population.

On the other hand, these same communities may be especially resilient given their past experiences with and adjustments to environmental and socio-economic changes, coupled with their rich social and cultural fabric and enduring community attachment. Assessment of adaptive capacity of individuals and communities in Haida Gwaii must take into account not only inherent resiliencies, but also differential rights, discrimination and other social processes that limit access to resources, power and decision-making. In other words, the socio-cultural context in which community activities and livelihoods are situated is important. In addition, dependence on critical infrastructure (e.g., diesel electricity generation, roads and power lines on eroding coasts, supplies delivered by ferries) susceptible to sea-level rise impacts may increase vulnerability. This, despite an inherent social resilience and ability to deal with inconvenience. The next stage of this research will explore these attributes to reveal determinants of community adaptive capacity to deal with current and future climate change and sea-level rise hazards.

The role of community-based research

Assessing vulnerability requires contributions from a variety of disciplines, institutions, local decision-makers, resource users and residents. The contribution of local and traditional knowledge to understanding climate change in remote regions is well-documented (BIELAWSKI, 1995; COHEN, 1997; FAST and BERKES, 1998). Our framework focuses on local-level capacities to deal with change and the institutional frameworks that govern decisions at different scales. This requires that research be grounded at the community-level and involve local knowledge systems (including traditional ecological knowledge) as well as cultural interpretations of the environment. This allows scientific views of changes to be framed in a local context. For example, traditional knowledge can 'ground truth' scientific research and allows for better examination of how global changes will be expressed and interpreted locally (USHER, 2000; RIEDLINGER and BERKES, 2001). In turn, this provides improved foundations for decision-making and adaptive capacity building.

CONCLUSIONS

This paper discusses the concept of vulnerability as it has been characterized in the climate change literature and presents a multi-scaled, integrated framework for assessing vulnerabilities and adaptive capacity. The framework stems from a recent discourse in climate change research that recognizes inherent vulnerabilities of human-environment systems as interdependent entities exposed climate variability and longer-term change. Determinants of adaptive capacity include: access to and distribution of wealth, technology, and information; risk perception and awareness; social capital; and critical institutional frameworks to address climate change hazards. These are identified at the individual and community level and situated within larger regional, national and international settings. Local and traditional knowledge is key to research design and implementation and allows for locally relevant outcomes that could aid in more effective decision-making, planning and management in remote coastal regions. As such, this integrated vulnerability approach contrasts typical coastal impact assessments that focus largely on reducing the economic detriments of change. As part of a larger study, this approach will be refined with local input from communities and regional institutions and applied to study sea-level rise hazards and adaptations on one of Canada's most sensitive coastlines.

LITERATURE CITED

ADGER, N.W., 2001. Scales of governance and environmental justice for adaptation and mitigation of climate change. *Journal of International Development*, 13, 921-931.

ADGER, N.W. and KELLY, M.P., 1999. Social vulnerability to climate change and the architecture of entitlements. *Mitigation and Adaptation Strategies for Global Change*, 4, 253-266.

ADGER, W.N., 2000. Institutional adaptation to environmental risk under the transition in Vietnam. *Annals of the Association of American Geographers*, 90(4), 738-758.

BARNETT, J., 2001. Adapting to climate change in Pacific Island countries: The problem of uncertainty. *World Development*, 29(6), 977-993.

BARRIE, J.V. and CONWAY, K.W., 2002. Rapid sea-level change and coastal evolution on the Pacific margin of Canada. *Sedimentary Geology*, 150(1-2), 171-183.

BC-STATS, 2001. *2001 Census Profile of British Columbia's Regions, Skeena-Queen Charlotte Regional District*. BC Stats, Victoria. 18 p.

BECKMANN, L.; DUNN, M. and MOORE, K., 1997. Effects of climate change on coastal systems in British Columbia and Yukon. In: TAYLOR, E. and TAYLOR, B. (eds.), *Canada Country Study: Climate Impacts and Adaptation. Responding to Global Climate Change in British Columbia and Yukon*. Environment Canada and British Columbia Ministry of Environment, Lands and Parks, pp. 8-1 to 8-19.

BIELAWSKI, E., 1995. Inuit indigenous knowledge and science in the Arctic. In: PETERSON, D.L. (ed.), *Human ecology and climate change: People and resources in the far north*. Taylor and Francis, Washington, DC, pp. 219-228.

BLAIKIE, P.M., 1985. *The Political Economy of Soil Erosion in Developing Countries*. Longman, London. 188 p.

BLAIKIE, P.M. and BROOKFIELD, H., 1987. *Land degradation and society*. Methuen, London. 296 p.

BLAIKIE, P.M.; CANNON, R.; DAVIES, I. and WISNER, B., 1994. *At Risk: Natural Hazards, People's Vulnerability, and Disasters*. Routledge, New York. 284 p.

BUCKLAND, J. and RAHMAN, M., 1999. Community-based disaster management during the 1997 Red River Flood in Canada. *Disasters*, 23(3), 174-191.

BURTON, I.; HUQ, S.; LIM, B.; PILIFOSOVA, O. and SCHIPPER, E.L., 2002. From impacts assessment to adaptation priorities: the shaping of adaptation policy. *Climate Policy*, 2, 145-159.

BURTON, I.; KATES, R. and WHITE, G., 1993. *The Environment as Hazard*. Guilford Press, New York. 290 p.

CANNON, T., 1994. Vulnerability Analysis and the Explanation of Natural Disasters. In: VARLEY, A. (ed.), *Disasters, Development and Environment*. Wiley, London, 167 p.

CARTER, T.R.; PARRY, M.C.; NISHIOKA, S. and HARASAWA, H., 1994. *Technical Guidelines for Assessing Climate Change Impacts and Adaptations*. University College London, England and Centre for Global Environmental Research, Tsukuba, Japan, 59 pp.

CLARK, G.E.; MOSER, S.C.; RATICK, S.J.; DOW, K.; MEYER, W.B.; EMANI, S.; JIN, W.; KASPERSON, J.X.; KASPERSON, R.E. and SCHWARZ, H.E., 1998. Assessing the Vulnerability of Coastal Communities to Extreme Storms: The Case of Revere, MA., USA. *Mitigation and Adaptation Strategies for Global Change*, 3, 59-82.

COHEN, S.J., 1997. What if and so what in northwest Canada: Could climate change make a difference to the future of the Mackenzie Basin? *Arctic*, 50(4), 293-307.

COLEMAN, J.S., 1988. Social capital in the creation of human capital. *American Journal of Sociology*, 94, S95-S121.

COMFORT, L.; WISNER, B.; CUTTER, S.; PULWARTY, R.; HEWITT, K.; OLIVER-SMITH, A.; WIENER, J.; FORDHAM, M.; PEACOCK, W. and KRIMGOLD, F., 1999. Reframing disaster policy: the global evolution of vulnerable communities. *Environmental Hazards*, 1, 39-44.

CUTTER, S., 1996. Vulnerability to environmental hazards. *Progress in Human Geography*, 20(4), 529-539.

CUTTER, S.; MITCHELL, J.T. and SCOTT, M.S., 2000. Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina. *Annals of the Association of American Geographers*, 90(4), 713-737.

FANKHAUSER, S. and TOL, R.S.J., 1997. The social costs of climate change: The IPCC second assessment report and beyond. *Mitigation and Adaptation Strategies for Global Change*, 1, 385-403.

FAST, H. and BERKES, F., 1998. Climate change, northern subsistence and land-based economies. In: AVIS, W. (ed.), *Canada country study: Climate impacts and adaptation.* Environment Canada, Ottawa, pp. 206-226.

FEENSTRA, J.G.; BURTON, I.; SMITH, J.B. and TOL, R.S.J., 1998. *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*. United Nations Environment Program, Nairobi and Institute for Environmental Studies, Free University, Amsterdam.

FOLKE, C.; BERKES, F. and COLDING, J., 1998. Ecological practices and social mechanisms for building resilience and sustainability. In: BERKES, F. and FOLKE, C. (eds.), *Linking social and ecological systems: Management practices and social mechanisms for building resilience*. Cambridge University Press, Cambridge, pp. 414-436.

GOKLANY, I.M., 1995. Strategies to enhance adaptability: Technological change, sustainable growth and free trade. *Climatic Change*, 30, 427-449.

HANDMER, J.W. and DOVERS, S., 1996. A typology of resilience:Rethinking institutions for sustainable development. *Industrial and Environmental Crisis Quarterly*, 9(4), 482-511.

HANDMER, J.W.; DOVERS, S. and DOWNING, T.E., 1999. Societal Vulnerability to Climate Change and Variability. *Mitigation and Adaptation Strategies for Global Change*, 4, 267-281.

HARVEY, N.; CLOUSTON, B. and CARVALHO, P., 1999. Improving coastal vulnerability assessment methodologies for integrated coastal zone management: An approach from South Australia. *Australian Geographical Studies*, 37(1), 50-69.

HEWITT, K., 1983. The idea of calamity in a technocratic age. In: HEWITT, K. (ed.), *Interpretations of Calamity*. Allen and Unwin, Boston, pp. 3-30.

HEWITT, K., 1997. *Regions of Risk: A Geographical Introduction to Disaster*. Longman, England. 389 p.

HOLLING, C., 1973. Resilience and stability in ecological systems. *Annual Review of Ecology and Systematics*, 4, 1-23.

IPCC-CZMS, 1992. *Global Climate Change and the Rising Challenge of the Sea*. Report of the Coastal Zone Management Subgroup, Intergovernmental Panel on Climate Change. Ministry of Transport, Public Works and Water Management, The Hague, Netherlands,

IPCC, 2001. *Climate change 2001: impacts, adaptation, and vulnerability. Contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, New York. 1032 p.

JACOBS, J.D. and BELL, T.J., 1998. Regional perspectives on 20th century environmental change: Introduction and examples from northern Canada. *The Canadian Geographer*, 42(4), 314-318.

JONES, R.N., 2001. An Environmental Risk Assessment Management Framework for Climate Change Impact. *Natural Hazards*, 23, 197-230.

JOSENHANS, H.; FEDJE, D.; PIENITZ, R. and SOUTHON, J., 1997. Early Humans and Rapidly Changing Holocene Sea Levels in the Queen Charlotte Islands - Hecate Strait British Columbia, Canada. *Science*, 277, 71-74.

KATES, R.W., 2000. Cautionary tales: Adaptation and the global poor. *Climatic Change*, 45, 5-17.

KELLY, M.P. and ADGER, N.W., 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change*, 47, 325-352.

KLEIN, R.J.T. and NICHOLLS, R.J., 1999. Assessment of coastal vulnerability to climate change. *Ambio*, 28(2), 182-187.

LIVERMAN, D.M., 1990. Vulnerability to global environmental change. In: CUTTER, S. (ed.), *Environmental Risks and Hazards*. Prentice-Hall, Englewood Cliffs, pp. 326-342.

MONIRUL, M. and MIRZA, Q., 2003. Climate change and extreme weather events: Can developing countries adapt? *Climate Policy*, 3, 233-248.

RIEDLINGER, D. and BERKES, F., 2001. Contributions of traditional knowledge to understanding climate change in the Canadian Arctic. *Polar Record*, 37(203), 315-328.

ROTHROCK, D.A.; YU, Y. and MAYKUT, G.Q., 1999. Thinning of the Arctic sea-ice cover. *Geophysical Research Letters*, 26(23), 3469-3472.

SHAW, J.; TAYLOR, R.B.; FORBES, D.L.; RUZ, M.H. and SOLOMON, S., 1998. *Sensitivity of the coasts of Canada to sea-level rise*. Geological Survey of Canada, Report No. 505, Ottawa. 79 p.

SHAW, R.W. and CCAF Project A041 Team, 2001. Coastal Impacts of Climate Change and Sea-Level Rise on Prince Edward Island. Environment Canada, Natural Resources Canada, Fisheries & Oceans Canada, Dartmouth. 80 p.

SHRUBSOLE, D., 2000. Flood management in Canada at a crossroads. Environmental Hazards, 2, 63-75.

SMIT, B., 1994. Climate, Compensation and Adaptation. In: MCCULLOCH, J. and ETKIN, D. (ed.), *Improving Responses to Atmospheric Extremes: The role of insurance and compensation*. Environment Canada, Toronto, pp. 2.29-2.37.

SMIT, B.; BURTON, I.; KLEIN, R.J.T. and STREET, R., 1999. The Science of Adaptation: A Framework for Assessment. *Mitigation and Adaptation Strategies for Global Change*, 4, 199-213.

SMIT, B. and PILIFOSOVA, O., 2003. From adaptation to adaptive capacity and vulnerability reduction. In: SMITH, J.B.; KLEIN, R.J.T. and HUQ, S. (eds.), *Climate change, adaptive capacity and development*. World Scientific, River Edge, NJ, pp. 1-20.

SMITH, J.B., 1997. Setting priorities for adaptation to climate change. *Global Environmental Change*, 7, 251-264.

SMITH, J.B. and LENHART, S.S., 1996. Climate change adaptation policy options. *Climate Research*, 6, 193-201.

SNDS, 2001. Online Labour Market Census Report. Skeena Native Development Society. http://www.snds.bc.ca/Census%20Online/index.htm

TOBIN, G.A., 1999. Sustainability and community resilience: The Holy Grail of hazards planning? *Environmental Hazards*,1, 13-25.

TOL, R.S.J.; FANKHAUSER, S. and SMITH, J.B., 1998. The scope for adaptation to climate change: what can we learn from the impact literature. *Global Environmental Change*, 8(2), 109-123.

USHER, P.J., 2000. Traditional ecological knowledge in environmental assessment and management. *Arctic*, 53(2), 183-193.

WALKER, I.J. and BARRIE, J.V., 2004. Geomorphology and sea-level rise on one of Canada's most 'sensitive' coasts: Northeast Graham Island, British Columbia. *Journal of Coastal Research*, SI 39: this volume.

WATERMAN, P. and KAY, R.C., 1993. Review of the applicability of the 'Common Methodology for Assessment of Vulnerability to Sea-Level Rise' to the Australian Coastal Zone. In: MCLEAN, R. and MIMURA N. (eds.). *Vulnerability Assessment to Sea-Level Rise and Coastal Zone Management*. Proceedings of IPCC Eastern Hemisphere Workshop, Tsukuba, Japan, 3-6 August 1993, pp. 237-248.

WATTS, M.J. and BOHLE, H.G., 1993. The space of vulnerability: The causal structure of hunger and famine. *Progress in Human Geography*, 17(1), 43-67.

WILDAVSKY, A., 1988. *Searching for Safety*. Transaction Books, New Brunswick. 253 p.

WISNER, B., 1992. Disaster vulnerability. In: BOHLE, H.G. (ed.), *Worlds of Pain and Hunger: Geographical Perspectives on Disaster Vulnerability and Food Security*. Saarbrucken, Verlag Breitenbach, pp. 13-52.

WOO, M.K.; LEWKOWICZ, A.G. and ROUSE, W.R., 1992. Response of the Canadian permafrost environment to climatic change. *Physical Geography*, 13, 287-317.

WU, S.Y.; YARNAL, B. and FISHER, A., 2002. Vulnerability of coastal communities to sea-level rise: A case study of Cape May County, New Jersey, USA. *Climate Research*, 22(4), 255-270.

YAMADA, K.; NUNN, P.D.; MIMUA, N.; MACHIDA, S. and YAMAMOTO, M., 1995. Methodology for the assessment of vulnerability of South Pacific Island countries to sea-level rise and climate change. *Journal of Global Environmental Engineering*, 1, 101-125.

YOHE, G. and TOL, R.S.J., 2002. Indicators for social and economic coping capacity - moving toward a working definition of adaptive capacity. *Global Environmental Change*, 12, 25-40.

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