

## Research on the Human Dimensions of Climate Change in Nunavut, Nunavik, and Nunatsiavut: A Literature Review and Gap Analysis

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**ABSTRACT.** Research on the human dimensions of climate change (HDCC) in the Canadian Arctic has expanded so rapidly over the past decade that we do not have a clear grasp of the current state of knowledge or research gaps. This lack of clarity has implications for duplication of climate policy and research, and it has been identified as a problem by communities, scientists, policy makers, and northern organizations. Our review of current knowledge about the HDCC in Nunavut, Nunavik, and Nunatsiavut indicates that the effects of climate change on subsistence harvesting and other land-based activities and the determinants of vulnerability and adaptation to such changes are well understood. However, the effects of climate change on health are less known. In the nascent research on this topic, studies on food security and personal safety dominate, and little peer-reviewed scholarship focuses on the business and economic sector. Published research shows a strong bias toward case studies in smaller communities, especially communities in Nunavut. Such studies have focused primarily on negative impacts of climate change, present-day vulnerabilities, and adaptive capacity, but studies proposing opportunities for adaptation intervention are beginning to emerge. While documenting the serious risks posed by climate change, they also highlight the adaptability of northern populations and the effects of economic-political stresses on vulnerability to changing climate. We note the absence of studies that examine how Northerners can benefit from new opportunities that may arise from climate change, or assess how the interaction of future climatic and socio-economic changes (specifically, resource development and enhanced shipping) will affect their experience of and response to climate change, or discuss the broader determinants of vulnerability and adaptation.

**Key words:** climate change, Arctic, Canada, Inuit, systematic review, Nunavut, Nunavik, Nunatsiavut, research needs assessment

**RÉSUMÉ.** L'étude des dimensions humaines du changement climatique (DHCC) dans l'Arctique canadien a pris de l'ampleur ces dix dernières années au point où nous n'avons pas une idée claire de l'état actuel des connaissances ou des lacunes en matière de recherche. Cette absence de précision a des incidences sur le plan du dédoublement des politiques et des études sur le climat, ce qui est considéré comme problématique par les collectivités, les scientifiques, les décideurs et les organisations se trouvant dans le Nord. Nous avons passé en revue les connaissances actuelles en matière de DHCC au Nunavut, au Nunavik et au Nunatsiavut, ce qui nous a permis de constater que les effets du changement climatique sur les récoltes de subsistance et sur d'autres activités rattachées aux ressources naturelles sont bien compris, tout comme le sont les déterminants de la vulnérabilité et de l'adaptation à ces changements. Cela dit, les effets du changement climatique sur la santé sont moins bien connus. Dans le cadre des recherches à l'état naissant à ce sujet, les études portant sur l'innocuité alimentaire et la sécurité personnelle dominant, et peu d'études évaluées par les pairs sont axées sur le secteur commercial et économique. Les travaux de recherche dont les résultats ont été publiés indiquent un fort penchant pour des études de cas visant de plus petites collectivités, surtout les collectivités du Nunavut. Ces études portent principalement sur les incidences négatives du changement climatique, sur les vulnérabilités actuelles et sur la capacité d'adaptation, quoi que des études proposant des possibilités d'intervention adaptative commencent à faire surface. Bien que des études se trouvent à documenter les risques sérieux que pose le changement climatique, elles font également ressortir l'adaptabilité des populations nordiques et les effets des stress politiques et économiques sur la vulnérabilité au climat changeant. Nous avons aussi remarqué l'absence d'études qui examinent comment les gens du Nord peuvent bénéficier des retombées du changement climatique, d'études qui évaluent comment l'interaction des changements climatiques et socioéconomiques futurs (plus précisément en ce qui a trait à la mise en valeur des ressources et à l'amélioration des voies d'expédition) toucheront leur expérience du changement climatique et leur réaction à celui-ci, ou d'études qui discutent des plus grands déterminants de la vulnérabilité et de l'adaptation.

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Mots clés : changement climatique, Arctique, Canada, Inuit, revue systématique, Nunavut, Nunavik, Nunatsiavut, évaluation des besoins en recherche

Traduit pour la revue *Arctic* par Nicole Giguère.

My worry now is not that too little is known [about Arctic change], but that so much is known which has not been synthesized. (Anderson, 2009:9)

Nunavik, and Nunatsiavut. The paper builds on a bibliometric analysis of Arctic publishing trends by Bolton et al. (2011) and a comparable review for the Inuvialuit Settlement Region by Pearce et al. (2011b).

## INTRODUCTION

Climate change research focusing on impacts, adaptation, and vulnerability has expanded exponentially over the last decade (Aspinall, 2010; Berrang-Ford et al., 2011; Ford et al., 2011a; Grieneisen and Zhang, 2011). Keeping track of publishing trends and the current state of knowledge has therefore become increasingly problematic, particularly in the Arctic, a “hot spot” for climate change research (ACIA, 2005; IPCC, 2007; Lemmen et al., 2008). In Canada, for instance, large multi-year research programs focusing on Arctic climate change have been initiated through ArcticNet (2003–18), the International Polar Year (2007–11), the Nasivvik Centre for Inuit Health and Changing Environments (2003–13), and the Northern Ecosystem Initiative (1998–2008). Federal departments, including Aboriginal Affairs and Northern Development Canada and Health Canada, have also supported numerous projects through their climate change programs (Health Canada, 2009; INAC, 2010; Ford et al., 2011b). This expansion of funding has been a major development given the neglect of northern research in the 1990s, but it also presents challenges. As these programs have progressed, the proliferation of studies has raised concerns that research is being duplicated and policy links are being overlooked (Duerden, 2004; Ford and Pearce, 2010; Bolton et al., 2011; Pearce et al., 2011b). This situation has implications for strategic planning of research and policy priorities by the scientific community, funding agencies, and stakeholders. The need for studies that characterize current understanding and identify research gaps is therefore increasingly recognized.

A number of literature reviews, including the Arctic Climate Impact Assessment (ACIA, 2005), Canadian national assessment (Lemmen et al., 2008; Prowse and Furgal, 2009), and sector-specific studies (Furgal and Seguin, 2006; Seguin, 2008; Bell et al., 2009; Forbes, 2011), have attempted to identify and characterize current understanding on Arctic climate change. These are comprehensive reviews. However, we also need regional assessments that focus specifically on human dimensions and use transparent and replicable methods for searching, selecting, and synthesizing knowledge (Ford and Pearce, 2010; Petticrew and McCartney, 2011). This paper complements previous assessments by developing and applying a systematic review method to characterize current understanding of the human dimensions of climate change (HDCC) in Nunavut,

## METHODS

A systematic review approach was developed to search, select, and examine peer-reviewed literature on the HDCC. The review involved close collaboration between a university-based research team that included a librarian with expertise in literature searching and analysis; knowledge users, including Aboriginal Affairs and Northern Development Canada; Inuit Tapiriit Kanatami; and northern science bodies such as the Nunavut Research Institute. The study was commissioned by knowledge users who were concerned that duplication of research was contributing to research fatigue in communities and needed to know where to prioritize future efforts. All team members were actively engaged in the project, from research design to analysis and interpretation of results.

The review focuses on identifying and characterizing current understanding of the human dimensions of climate change in Nunavut, Nunavik, and Nunatsiavut. This region, which covers an area of ~ 2.5 m km<sup>2</sup> and has a predominantly Inuit population of ~ 43 000, is undergoing some of the most rapid and pronounced changes in climate in the world (Barber et al., 2008; Lemmen et al., 2008; Prowse et al., 2009). We selected articles for their focus on the HDCC. Here “climate change” refers to any change in climate over time, whether it is due to natural variability or results from human activity (IPCC, 2007). HDCC scholarship covers research that examines how human systems (such as communities, businesses, regions, and states) are affected by and respond to climate change now and will do so in the future. The selected articles include impact, adaptation, and vulnerability studies, but exclude mitigation studies. Studies primarily biophysical in nature were also included if they focus on biophysical system attributes important to humans, include this importance in the rationale for the study, and examine human implications. The review included only peer-reviewed articles published after 2000 in English or French. Full inclusion and exclusion criteria are provided in Table 1.

We identified three databases in which to search for published research: the ISI Web of Knowledge (WOK), PubMed, and GeoBase. A search phrase consisting of geographic place names (English and French), ranging from community names to geophysical features within our area of interest, was used to select relevant literature (Table 2).

TABLE 1. Inclusion and exclusion criteria.

Inclusion	Exclusion
Written in English or French	Written in other languages
Published between 1 January 2000 and 30 July 2010	Not published within this date range
Indexed in Web-of-Knowledge, GeoBase, or PubMed	Not indexed in these databases
Peer-reviewed	Non peer-reviewed
Reviews, articles, editorials	Book reviews, conference proceedings
Explicit focus on climate change	No climate-change focus
Studies of impacts, adaptation, and vulnerability	Mitigation, biophysical focus only
Reference to Nunavut, Nunavik, or Nunatsiavut	Western Arctic focus, no reference to Nunavut, Nunavik, or Nunatsiavut

TABLE 2. Search terms applied to each database.

Geographic terms	(Nunavut OR Baffin OR Kivalliq OR Kitikmeot OR “Arctic Bay” OR Arviat OR “Baker Lake” OR “Bathurst Inlet” OR “Cambridge Bay” OR “Cape Dorset” OR “Chesterfield Inlet” OR “Clyde River” OR “Coral Harbour” OR “Gjoa Haven” OR “Grise Ford” OR “Hall Beach” OR “Iglulik” OR Iqaluit OR Kimmirut OR Kugluktuk OR Pangnirtung OR Kugaaruk OR “Pond Inlet” OR Qikiqtaaluk OR “Rankin Inlet” OR “Repulse Bay” OR Resolute OR Sanikiluaq OR Taloyoak OR “Whale Cove”) OR (Nunavik OR Akulivik OR Aupaluk OR Inukjuak OR Ivujivik OR Kangiqsualujuaq OR Kangiqsujuaq OR Kangirsuk OR Kuujuaq OR Kuujuarapik OR Puvirnituq OR Quaqtaq OR Salluit OR Tasiujaq OR Umiujaq OR Whapmagoostui) OR (Nunatsiavut OR Labrador OR Nain OR Hopedale OR “Northwest River” OR Rigolet OR Makkovik OR Postville OR “Happy Valley—Goose Bay” OR “Mud Lake”) OR (“Ungava Basin” OR “Hudson Bay” OR “Davis Strait” OR “James Bay” OR “Foxe Basin” OR “Hudson Strait” OR “Gulf Of Boothia” OR “Frobisher Bay”) OR (“Bassin De La Baie D’ungava” OR “Baie D’hudson” OR “Déroit De Davis” OR “Arctique” OR “Régions Circumpolaires” OR Inuit)
AND	
Qualifier	Arctic OR “Indigenous Knowledge” OR “Traditional Knowledge” OR “Traditional Ecological Knowledge” OR “Connaissances Indigènes” OR “Savoirs Indigènes” OR “Connaissances Autochtones” OR “Savoirs Autochtones” OR “Connaissances Traditionnelles” OR “Savoirs Traditionnels” OR “Connaissances Écologiques Traditionnelles” OR “Savoirs Écologiques Traditionnels”

A two-stage process was then used to screen articles identified by the search. In the first stage, the primary researcher read the title and abstract of each document and assessed them according to the inclusion criteria. Of 2082 non-duplicate articles identified in the database searches, 1863 were excluded at this stage. To validate the screening process, a second researcher independently screened the same list of documents. The agreement between the two researchers on which articles to include was greater than would be expected by chance (measured using the Kappa Statistic,  $K = 0.41$ ). Of the remaining 219 documents, another 115 were excluded after a full read-through, leaving 104 included articles. A snowball search of citations in the 104 included journal articles identified 13 additional documents, increasing the literature review sample to 117 articles.

We used two methods to review the 117 selected articles. First, we developed a questionnaire to document and characterize publishing trends, enabling standardized analysis using descriptive statistics. This quantitative analysis of research trends is reported in Bolton et al. (2011). Second, we reviewed each article in depth to identify and characterize current understanding on the human dimensions of climate change in the Arctic, and we report those results here. The review was structured using a vulnerability framework, in which vulnerability is conceptualized as a function of exposure and sensitivity to climate-related risks and the adaptive capacity to deal with those risks (Smit and Pili-fosova, 2003; Ford and Smit, 2004; Adger, 2006; Fussel and Klein, 2006; Smit and Wandel, 2006; Ford et al., 2010c). “Exposure” refers to the nature of climate-related risks; “sensitivity,” to the organization and structure of human

systems, which determine the pathways through which exposure is manifest; and “adaptive capacity,” to the ability of individuals, households, communities, and institutions to address, plan for, or adapt to these risks. When reviewing articles, therefore, we paid attention to the documentation of risks and opportunities associated with the impacts of present and future climate change at local to regional levels, the adaptations that are being undertaken, and the factors identified as determining adaptive capacity (and resilience). We also noted differences between communities or regions in vulnerability and adaptation and identification of priorities for future research and adaptation actions. In the analysis, studies were also divided into those that focus on current vulnerability, examining how changes in climatic conditions currently affect human systems, and those that focus on future vulnerability in light of projected or expected future changes. This is a common structure used in the general literature (Burton et al., 2002; Burton and Lim, 2005).

The vulnerability framework allows us to integrate diverse scholarship from the biophysical and social sciences and humanities to broaden understanding of how human systems experience and respond to stress. While some scholars have critiqued the use of “vulnerability” terminology, which has been argued to portray climate change in negative terms, “vulnerability” here refers to the approach and concepts, not the outcome (Ford et al., 2010c). The examination of adaptive capacity is central in vulnerability research and captures the significant potential of human systems to respond to climate change.

## THE STATUS OF CURRENT KNOWLEDGE

Scientific publishing on HDCC in Nunavut, Nunavik, and Nunatsiavut has expanded rapidly over the last decade, making this region one of the most intensively studied in the world. In this section we synthesize current understanding using a vulnerability framework, and focus on the five socio-economic sectors (Table 3) identified by Pearce et al. (2011b) in their review of HDCC scholarship in the Inuvialuit Settlement Region. Noting that there is overlap between sectors, the structure nevertheless offers a practical way of integrating and organizing the findings of a diversity of studies.

### *Infrastructure and Transportation*

**Current Vulnerability:** Scholarship in this sector is dominated by studies examining the safety of using semi-permanent trails for hunting and recreational travel, particularly how changing snow and ice regimes, less-predictable weather, and changing wind patterns are an increasing danger, making routes less dependable and compromising the ability to engage in harvesting activities (Aporta, 2002, 2009; Aporta and Higgs, 2005; Ford et al., 2006a, b, 2008a, b, 2009; Tremblay et al., 2006, 2008; Ford, 2009; Laidler et al., 2009; Prno et al., 2011). Fall freeze-up is commonly described as a time of acute danger and constrained access, with warming and more variable temperatures prolonging the period of ice instability. A hot spot for such research is the community of Igloodik, Nunavut, whose location on a small island and high dependence on sea-ice routes make it particularly sensitive to such changes (Ford et al., 2006b; Laidler and Ikummaq, 2008; Laidler et al., 2009). Land-based trails offer alternative access to hunting areas for some communities, thereby buffering the impacts of changing ice regimes, although changing snow conditions have been reported to make these routes difficult to use. For communities that engage in narwhal hunting at the floe edge in late spring to early summer (e.g., Pond Inlet, Arctic Bay) or use floating pack-ice as a hunting platform (e.g., Igloodik), more dynamic ice conditions have made these already hazardous activities particularly problematic.

While the climate of the eastern Arctic is changing rapidly, communities are also adapting. Commonly reported adaptations include changing the timing and location of harvesting activities, switching species, using new travel routes, and avoiding travel at certain times and locations (Furgal and Seguin, 2006; Gearheard et al., 2006; Ford et al., 2008b; Tremblay et al., 2008). The traditional knowledge of hunters underpins many of these responses, embodying a detailed knowledge of the local environment, land skills, and a code of behavior based on time-honoured values and practices (Aporta and Higgs, 2005; Ford et al., 2006b; Gearheard et al., 2006). This collective social memory has evolved to manage changing environmental conditions that define the Arctic and is drawn upon to deal with routine events and respond creatively to novel events.

Hunters thus manage risks by understanding the dangers of hunting and taking precautions, knowing precursors to certain hazardous conditions and how to survive if they are caught in bad weather, knowing what equipment to take along and what preparations to make, and, especially for the more experienced hunters, knowing how to navigate using traditional means (Ford et al., 2006a; Gearheard et al., 2006; Wenzel, 2009). Moreover, traditional knowledge continually evolves through observation, trial-and-error experience, and the incorporation of non-traditional knowledge alongside the traditional. For instance, Ford et al. (2009) document the experiential learning that allowed Igloodik hunters to manage changes in climate that had caused significant disruption in the late 1990s and early 2000s. They describe the important role of elders and experienced individuals in this learning as the ones observing, experiencing, responding to, and communicating this information to others through informal social networks.

Technology is also playing a crucial role in facilitating adaptation. Aporta (2003) documents the integration of geo-coded Inuit place names and trails using GPS in Igloodik and demonstrates that such technologies are quickly embraced for their ease of use and marriage of cultural value with modern tools. Ford et al. (2006a), Laidler et al. (2009), and Meier et al. (2006) document the use of GPS and other technologies such as satellite phones, VHF radios, and distress beacons as adaptive strategies for travel conditions that are no longer easily predicted using traditional methods. Climate change is not the only or even the primary motivator behind these developments, but is nevertheless commonly cited as providing impetus for their adoption and use. These responses have been aided in some instances by the establishment of community-based observation and monitoring networks, which provide location-specific data on trail conditions (Tremblay et al., 2006, 2008).

That Inuit are highly adaptable is not a new insight, but has long been illustrated by scholars in anthropology and archaeology (Wenzel, 1991, 2009; McGhee, 1996, 2005); yet research indicates that adaptive capacity should not be taken for granted and will not be uniform. A significant body of scholarship examines how societal and economic changes of the last half-century are affecting the ways in which Inuit interact with a changing climate, demonstrating that these human changes are as important as climate change per se, if not more important, in affecting vulnerability and adaptation (Ford et al., 2010a). A widely expressed concern is the weakening of land skills and traditional knowledge among younger generations, who have fewer opportunities to engage in harvesting activities (MacDonald, 1998; Takano, 2004a, b; Ford et al., 2008b). This trend is compounding the dangers posed by changing environmental conditions, increasing sensitivity, and compromising adaptive capacity. Technology is also emerging as a double-edged sword: while enabling adaptation, it is also increasing risk-taking behavior (and hence sensitivity) and can be problematic if it substitutes for a detailed

TABLE 3. Sector definitions (after Ford and Pearce, 2010).

Sector	Focus of studies in sector
Subsistence hunting and harvesting	Ability to engage in local hunting, trapping, and fishing activities and procure traditional foods
Health and well-being	Health of individuals and communities, including physical and mental well-being
Infrastructure and transportation	Semi-permanent hunting trails on sea ice, lake ice, and land; permanent and seasonal roads; shipping access; air access; building stability
Culture and education	Formal school system, traditional learning, cultural promotion and preservation, cultural sites
Business and economy	Formal economic sector, including resource development and tourism

knowledge of traditional navigation and understanding of environmental conditions (Aporta and Higgs, 2005; Aporta, 2009). In addition to these socio-cultural conditions, the literature has also identified barriers to adaptation. The cost of adapting is widely noted, particularly the price of gasoline, which is limiting the ability to adapt by using new and longer transportation routes and purchase new hunting equipment to take advantage of new opportunities (e.g., the longer open-water period) (Laidler et al., 2009). Cost pressures are particularly problematic in light of the high poverty and unemployment rates characteristics of many hunting households.

**Future Vulnerabilities:** Studies examining future vulnerability largely examine projected changes in exposure, are conducted by researchers in the biophysical sciences, and focus at a regional scale. For communities surrounding Hudson Bay, research has examined the implications of warming temperature for permafrost thaw (Laidler and Gough, 2003), and one study predicts a reduction of 50% by 2100, with associated infrastructural impacts (Gough and Wolfe, 2001). An intensifying hydrological cycle (i.e., increased streamflow) is expected to continue across northern regions (Barber et al., 2008). According to Dery et al. (2009), hydroelectric dams and mining operations will be affected by the increasing variability of streamflow in addition to its ecological and social impacts. Climate change may result in a northward shift of storm tracks, which implies stronger temperature advection, stronger updrafts, and more moisture, leading to the increased probability of freezing precipitation and stronger storms (Roberts and Stewart, 2008; Roberts et al., 2008). This change could affect surface infrastructure, including electrical wires; there is concern about the thickness of wires compared to those in the south and potential susceptibility to ice storms (Roberts and Stewart, 2008).

With regard to the use of hunting trails, a number of studies extrapolate current trends to the future. Thus current dangers and access challenges associated with changing ice and weather conditions are expected to persist into the future, and there is concern about emerging vulnerabilities (e.g., weakening of land skills) and barriers to adaptation (Ford et al., 2008b). Novel and unknown risks are reported to be more problematic, although a number of studies also note significant potential for adaptive learning. Two studies identify the importance of government-level adaptation interventions to address barriers to adaptation and drivers of emerging vulnerabilities, arguing that

impacts of climate change can be managed with appropriate intervention and support mechanisms (Ford et al., 2007, 2010a). Other projects have sought to build adaptive capacity through actively engaging communities in research, which includes integrated community-based monitoring networks to facilitate greater sharing between communities regarding travel conditions (Gearheard et al., 2006; Tremblay et al., 2006, 2008; Huntington et al., 2009; Mahoney et al., 2009; Weatherhead et al., 2010), environmental change monitoring (Dyck, 2007), and open houses to increase understanding of scientific research and findings (Hanesiak et al., 2010).

**Research Gaps:** There is a well-developed understanding of risks of using semi-permanent trails in a changing climate, determinants of vulnerability, and opportunities for adaptation. This research is dominated by studies in Nunavut and Nunavik, with a focus on smaller communities (Fig. 1) and a preference for examining risks related to sea ice. Social science research employing community-based approaches is widely used in this work. However, broader vulnerabilities in the infrastructure and transportation sector have been neglected. Only limited published research exists on the vulnerability of municipal infrastructure (e.g., community drinking water, waste management, buildings); industry-related infrastructure, including mine sites, ice roads, and shipping access; permafrost thaw and other landscape hazards; and extreme weather (with the exception of southern Baffin). Studies that examine sensitivity and capacity to adapt to future climate change are typically speculative in nature, and these topics are not the primary focus of the research being reported on. Moreover, as recently noted by Cameron (2012), shipping and resource development are likely to be major factors affecting vulnerability and adaptation in Arctic communities, affecting socio-economic systems and livelihoods, yet they have been largely excluded in community-based studies.

### *Health and Well-Being*

**Current Vulnerability:** One quarter of studies reviewed here examine health and well-being in the context of a changing climate. This is a recent development in the literature and builds upon a considerable body of research on Inuit health in general (Young, 2003; Wilson and Young, 2008). The majority of health studies focus on food security, which concerns the ability of individuals and households to have reliable access to food of an acceptable

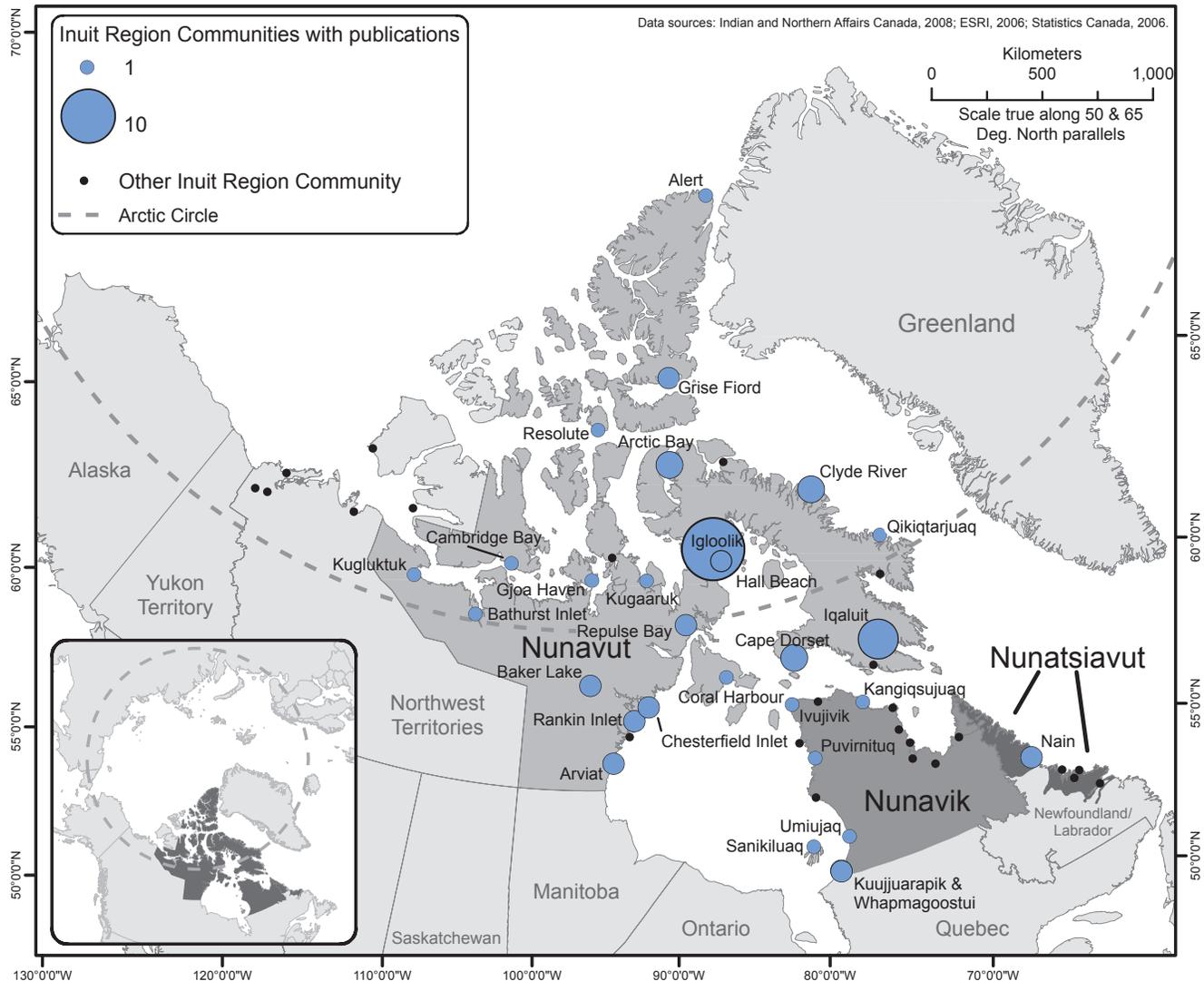


FIG. 1. Communities that are a focus of HDCC research in the literature reviewed here, identified through proportionally sized circles.

quality (FAO, 2002). Three components of food security—access, availability, and quality—are sensitive to climatic conditions, particularly given traditional food cultures that are undergoing rapid change. Research, predominantly conducted in small Nunavut and Nunavik communities, highlights changing climatic conditions that are already affecting food security (Furgal and Seguin, 2006). This link in some cases is direct, with studies documenting changes in the abundance of certain species and changing weather patterns affecting food quality (e.g., meat fermentation for specialist dishes) (Lambden et al., 2007; Nancarrow and Chan, 2010). More commonly, however, the link described is indirect; food security is affected by the increased economic burden of harvesting imposed by changing conditions (i.e., food access), disruption to transportation networks (i.e., food availability), or community or household characteristics that determine the ability to produce, process, and share harvested food successfully and efficiently (food access and availability) (Chan et al., 2006; Furgal and Seguin, 2006; Beaumier and Ford, 2010;

Ford and Beaumier, 2010). In recent years, research has also begun to examine how climate change might affect exposure and sensitivity to contaminants, building upon a long history of research on contaminants in northern Canada (Kraemer, 2005; McKinney et al., 2009; Donaldson et al., 2010). Studies have stressed that snowmelt, a major source of mercury contamination in Arctic freshwater systems, could increase with climate change (Dommergue et al., 2003; Gantner et al., 2010). Other researchers have found that climate change may lead to increased bioaccumulation of contaminants in the food chain (Hare et al., 2008; Kuzyk et al., 2010; Macdonald and Loseto, 2010), although these studies are in their infancy.

Sharing networks, widely described as helping communities to manage variations in food access and availability, are effective for managing temporally discrete stresses, such as a late freeze-up or successive days of fog or high winds (Chan et al., 2006; Ford and Beaumier, 2010). Yet as Inuit society is changing, sharing networks are coming under increased stress, compounded by climate change,

rising costs of hunting, and regulations (Wenzel, 1995a, 2009). Recent studies have reported some hunters asking for cash payment for traditional foods, with community members expressing concern over the sustainability of food sharing (Beaumier and Ford, 2010). Increased reliance on store foods has also been documented, particularly at key times of the year (e.g., freeze-up) when traditional foods are difficult to obtain. Food switching, however, is not always an option for some households; it is a function of high rates of poverty, unemployment, costs of store food, addiction, and lack of knowledge on store foods (Ford and Beaumier, 2010). In such instances, meals may be skipped and consumption directed towards food that is low in nutrition, the health consequences of which are widely noted (Egeland et al., 2010; Johnson-Down and Egeland, 2010). Not all communities or community members are equally at risk, however. Vulnerable groups identified in the literature include females, particularly single mothers living alone; households without an active hunter; and households engaged in the harvesting sector, but with limited access to cash resources (Chabot, 2003; Beaumier and Ford, 2010; Healey et al., 2011; Lardeau et al., 2011).

**Future Vulnerability:** Climate change has been identified as one of the biggest health threats of the 21st century (Costello et al., 2009), yet there is little published research examining future health vulnerabilities. Some studies have extrapolated current food insecurity trends to hypothesize that food insecurity will increase in the future as climate change further constrains access to and availability of traditional foods. Not all communities or regions will be equally affected, yet only a few are studied thoroughly. Furthermore, opportunities may also develop as new species move north and the open-water hunting and fishing season expands (Meier et al., 2006; Wenzel, 2009), but these have not been examined. An emerging scholarship is identifying how food systems can be strengthened in light of projected climate change and other stresses: suggestions include investing in and enhancing harvester support programs, community freezers and food banks, youth hunting programs, and meat sharing initiatives (Myers et al., 2004, 2005; Chan et al., 2006; Furgal and Seguin, 2006; Ford et al., 2007, 2010a; Damman et al., 2008; Lardeau et al., 2011). There is concern, however, that while institutional support may increase adaptive capacity, it may not provide an equivalent substitute for traditional sharing networks (Ford et al., 2006a; Lardeau et al., 2011). Some studies have also examined how the northward shift in ecosystems may increase the release of contaminants into food and water sources of northern communities (Constant et al., 2007), as well as within ecosystems upon which Northerners depend (McKinney et al., 2009).

**Research Gaps:** Climate change impacts on health and well-being in the eastern and central Canadian Arctic are a relatively new focus, with a number of studies integrating a climate change component into long-standing issues, particularly food systems and nutrition, and to a lesser extent, contaminants. This interest reflects concerns that

Inuit populations are likely to suffer disproportionately from negative health outcomes relative to other Canadians. Notwithstanding these developments, there are significant gaps in understanding.

First, only a few health risks have been examined. Mental health, for instance, is largely neglected in the scholarship, despite the disproportionate rates of suicide and other mental health issues in the North and rapid acculturation that is likely to increase sensitivity to such impacts (Lehti et al., 2009; Cunsolo Willox et al., 2011; Healey et al., 2011). Vector-, food- and water-borne diseases (e.g., E-coli, salmonella, trichinella, brucellosis) that could become more problematic with climate change have been largely overlooked (Martin et al., 2007; Gauthier et al., 2010). This oversight perhaps reflects the fact that the published research reviewed here is primarily authored by scholars from geography and environmental sciences, who focus on the social determinants of health as opposed to clinical and epidemiological analyses (Lehti et al., 2009). Second, studies have focused primarily on present-day vulnerabilities and adaptation. Thus while there is an emerging scholarship in the biophysical sciences examining changes in the abundance, health, and migration timing of wildlife species, few food security projects have examined potential risks or opportunities associated with these changes. Similarly, little research has examined how changing species availability might affect future food-sharing networks that structure who gets what and when. For contaminants scholarship, as Macdonald et al. (2010) argue, there is a dearth of studies examining exposure and sensitivity under conditions of future climate change.

### *Business and Economy*

**Current and Future Vulnerability:** Most inhabitants of the eastern and central Arctic live in small remote communities that are accessible by air year-round and by boat in the ice-free period of summer. The wage economy comprises mainly public administration, resource extraction, arts and crafts, and in some regions, tourism. The literature emphasizes that climate change presents both risks and opportunities to northern economies. Mining development is expanding rapidly in all regions, particularly in Nunavut, aided by reduced sea-ice cover in summer months, which is improving shipping access and is expected to be beneficial for future expansion (Nuttall, 2008; Pearce et al., 2011a; Stephenson et al., 2011; Ford et al., 2011c). Concerns have been noted regarding the continued viability of ice roads (Atkinson et al., 2005); however, eastern Arctic mines are more ship-dependent than those in the western Arctic and could thus benefit from reduced ice extent (Ford and Pearce, 2010). Changing sea-ice regimes are increasing the opportunities for cruise boat tourism, with potential employment and income-generating opportunities (Stewart et al., 2007, 2010). Nunavik's Makivik Corporation is exploring partnering with Nunavut and Nunatsiavut to promote the emerging cruise industry (Fugmann, 2009), although

not all communities are expected to benefit. Cruise activity in Hudson Bay is predicted to decline eventually as species such as the polar bear shift northward (Stewart et al., 2010). The literature also documents potential opportunities for new commercial fisheries as certain species such as cod shift northward and as the retreat of sea ice improves boat access in other regions (Drinkwater, 2005; Barber et al., 2008). Yet for economic activities surrounding the subsistence economy, climate change is likely to present a number of challenges. For example, the listing of polar bears as a “vulnerable species” under the U.S. Endangered Species Act in 2008 and the subsequent ban on importation of polar bear trophies to the United States are expected to have significant economic implications (McLoughlin et al., 2008; Dowsley, 2009a; Schmidt and Dowsley, 2010). Between 1995 and 2008, trophy hunters from the United States represented 70% of all sport hunters in Nunavut (Dowsley, 2009a), providing important income to hunters (Wenzel, 2009)—income that could also be used to enable climate adaptation.

The characteristics of northern economies and nature of economic development will also determine sensitivity and adaptive capacity to climate change. Research consistently identifies low socio-economic status, disenfranchisement, high unemployment, and crowded and poor-quality housing as contributors to pronounced local and regional-level vulnerability and adaptation constraints in the North (Furgal and Seguin, 2006; Ford et al., 2010b). Therefore, new opportunities for economic development hold promise for providing access to cash resources and reducing poverty, which lies at the heart of vulnerability to climate-related risks. Nevertheless, economic development could also undermine characteristics of Inuit society that have historically underpinned adaptive capacity, including sharing networks, social capital, flexibility in resource use, and traditional knowledge systems, and further stress wildlife resources already being affected by climate change (Wenzel, 1995a, 2005, 2009; Ford et al., 2006a, b).

**Research Gaps:** Only 11% of the articles reviewed here focus on the business and economy sector, and while these publications raise a number of key issues, many gaps in understanding remain. First, while there is potential for significant economic benefits with climate change as reduced ice extent opens up opportunities for shipping (Stephenson et al., 2011), few studies have examined these opportunities and how they should be managed. While it is commonly assumed that the private sector will autonomously take advantage of new opportunities, the Arctic presents logistical, regulatory, and financial barriers, many which have not been examined, along with unique environmental challenges. Secondly, mining operations are rapidly expanding in the region and are expected to play a growing role in northern economies (Atkinson et al., 2005). Aside from industry environmental assessments, however, few independent studies in the peer-reviewed scholarship have tried to determine the socio-economic and environmental impacts of mineral extraction on surrounding communities

and their implications (positive or negative) for climate vulnerability and adaptation. Third, economic development trajectories in the North are highly uncertain, influenced by external conditions (e.g., market conditions, transportation access, government policy, international regulations). Few studies examine how these broader influences will affect vulnerability and adaptation in the eastern and central Canadian Arctic, although research from Scandinavia indicates the often limited power of local and regional governments to influence these trends (Keskitalo, 2008, 2009; Keskitalo and Kulyasova, 2009). Fourth, the exchange of traditional foods for money has been noted in some projects as an adaptation to the costs of hunting and a way to provide resources for adapting to changing environmental conditions (Gombay, 2005, 2006; Ford et al., 2009; Laidler et al., 2009). While cultural tradition disfavours the selling or buying of traditional foods, it is potentially a viable way to create economic opportunity and reinvestment for supporting traditional ways. Climate change will likely be an important determinant of future developments in this area, yet no projects that we reviewed examined opportunities and challenges in detail.

### *Culture and Education*

**Current and Future Vulnerability:** The land and land-based activities are considered to be integral to Inuit identity, culture, and spirituality (Cunsolo Willox et al., 2011). Research documents the effects of changing ice and weather conditions on people’s ability to take part in these activities and their implications for interpersonal and environmental relationships, stewardship, and oral history, all of which are intimately tied to culture (Nickels et al., 2005; Furgal and Seguin, 2006; Gearheard et al., 2006; Ford et al., 2010b; Cunsolo Willox et al., 2011). Yet the link between climate and culture is not linear, and it is affected by longer-term societal trends. Thus Inuit of the younger generations, who have less knowledge of weather patterns, ice conditions, survival skills, and navigational cues, are described as being more at risk because of changing conditions, and they are increasingly less inclined to hunt and travel, particularly during dangerous times of the year (Aporta, 2002; Aporta and Higgs, 2005; Bravo, 2009; Ford et al., 2009). Reduced opportunity to engage in land-based activities with climate change is described as potentially reinforcing the weakening of land skills among younger generations, limiting the availability of harvested animals and associated processing tasks, and reducing contact between youth and elders, potentially further reducing opportunities for knowledge sharing (Chan et al., 2006; Laidler et al., 2009). A significant body of research has focused on cultural change and its causes and consequences in Arctic communities, with climate change adding a new dimension. The literature identifies and examines programs that have been developed to provide cultural education and training, which are also identified as central to climate change adaptation (Takano, 2004a, b; Chan et al., 2006; Ford et al., 2007,

2010a; Pearce et al., 2011c). The effectiveness of such programs in a climate change context has not been studied.

Sharing networks involving the customary distribution to relatives and those in need are also being affected by reduced availability of and access to animals, and these effects are compounded by broader changes in Inuit society associated with modernization and the development of a wage economy (Wenzel, 1995b, 2009). In some communities, this situation has contributed towards the selling of country foods by hunters although it is unknown to what extent this is a long-term adaptation or what the broader implications would be for the social economy of sharing. Other cultural impacts on practices may stem from the potential for increased risk of contaminants in traditional foods due to climate change as noted above (Donaldson et al., 2010). The perception of foods as less safe and desirable may affect consumption practices or create anxiety about consumption patterns, or both. Climate change is also affecting sense of place and historical attachment through damage to the physical fabric of communities and cultural sites (e.g., graveyards, hunting camps), challenging traditional ways of knowing, and changing features of the land and ice that are important to Inuit toponymy (Laidler and Elee, 2008; Laidler and Ikummaq, 2008; Bravo, 2009; Forbes, 2011). Apart from Henshaw (2006), few studies have focused on cultural sites in terms of the risks posed by climate change and potential interventions.

**Research Gaps:** Research on the significant and wide-ranging cultural implications of climate change for Inuit has focused primarily on examining harvesting-related vulnerabilities (such as food security and land use) in smaller communities (Fig. 1). A key gap, however, is the potential mental health ramifications of cultural impacts of climate change. Research in the general scholarship has illustrated links between environment and psychological health and well-being, with a positive correlation between environmental degradation and human distress and anxiety (Cook et al., 2008; Sartore et al., 2008; Speldewinde et al., 2009). Similar concerns have been expressed for the Arctic, but not analyzed in detail (Furgal and Seguin, 2006). Also pertinent is an absence of scholarship comprehensively examining how the cultural dimensions of climate change might evolve in the future in light of climate projections and socio-economic change. Inuit society is likely to undergo significant change in the 21<sup>st</sup> century, as it has in the past 50 years, and these changes will determine the cultural implications of climate change. Many questions remain unanswered: will larger regional communities with their strong and growing wage-based economies be as vulnerable as smaller communities to the cultural implications of climate change? Are non-Inuit residents susceptible to similar cultural effects? Would reduced reliance on subsistence hunting reduce sensitivity to potential cultural impacts? As northern self-determination proceeds, will communities feel better prepared to address the cultural effects of climate change?

### *Hunting and Subsistence Harvesting*

**Current Vulnerability:** Direct and indirect climate change impacts on hunting and subsistence harvesting are the most prominent subjects studied in the literature sample, with 44% of publications treating this topic. This focus is not surprising, as harvesting activities are closely dependent on environmental conditions. There is a high participation rate in hunting and associated consumption of traditional foods (Poppel et al., 2007), and therefore multiple pathways through which climate change can have an impact. Indeed, in many of the sectors above, the implications of climate change are propagated through harvesting. A key focus of much of the early peer-reviewed work on this sector was to interview elders and experienced hunters and document their observations of changing conditions and associated impacts; more recently, such research has compared indigenous observations with instrumental data (Gearheard et al., 2006, 2010; Laidler and Elee, 2008; Laidler and Ikummaq, 2008; Weatherhead et al., 2010). Recorded changes in the health and availability of key species hunted are possibly linked to climate change (Regehr et al., 2007; Nancarrow and Chan, 2010). Such research has focused on polar bears and ringed seals because changing ice regimes threaten their population stability (Ferguson and Messier, 2000; Ferguson et al., 2005; Laidre and Heide-Jørgensen, 2005; Stirling and Parkinson, 2006; O'Neill et al., 2008). In addition to research focusing on the dangers of trail use, cultural impacts, and food security implications that are addressed in the above sections, scholarship in this sector has also noted increasing social inequalities as hunting has become more difficult in light of climate change and economic stresses. Thus households that have skilled hunters and access to cash resources and hunting equipment can take advantage of new conditions and adapt to challenges in ways less capitalized households cannot (Ford et al., 2008b).

Management of wildlife resources, one of the most important issues facing the hunting sector, is the focus of an expanding body of scholarship. Early research identified existing management frameworks as ill-prepared to cope with the rapidly changing environmental conditions, reducing the flexibility with which Inuit historically managed fluctuations in wildlife access and availability (Berkes, 1999; Berkes and Jolly, 2002; Berkes et al., 2003; Armitage, 2005a, b). Indeed, co-management structures have come under increasing pressure from Inuit, who have voiced dissatisfaction with quota allocations that are viewed as inconsistent with traditional knowledge on wildlife stocks; from international NGOs concerned about the long-term viability of animal populations in light of climate change and hunting pressures; and from scientists in both camps, those who support more hunting and those who wish to restrict it. Recognizing these challenges, research has examined opportunities to improve management regimes, with particular focus on polar bears and narwhals, and bridge the current polarization in viewpoints (Armitage, 2005b; Clark

et al., 2008; Dowsley and Wenzel, 2008; Dowsley, 2009b). Such studies form part of the broader literature in the hunting sector, which has used understanding of determinants of vulnerability to identify opportunities for institutional support to facilitate adaptation. Some of these studies indicate the potential to enhance existing policies by integrating a climate-change lens, including hunter support mechanisms, disaster compensation, and community freezers; the creation of new programs designed specifically to address climate change, including community-based monitoring programs; and the creation of institutions and decision-making processes that are diverse and flexible and better able to cope with change (Armitage et al., 2008; NTK, 2008; Tremblay et al., 2008; Dowsley, 2009b; Ford et al., 2010a).

**Future Vulnerability:** Climate change is expected to result in shifts in biodiversity as well as in the ranges of animal and plant species important to northern people in the eastern Canadian Arctic (Laidler and Gough, 2003; Tews et al., 2007a; White et al., 2007; Eberle et al., 2009; Hobson et al., 2009). Ecosystems may be altered by species such as killer whales, which are found in increasingly high numbers in eastern waters, resulting in a top-down transformation of the food web with unknown consequences (Higdon and Ferguson, 2009). Ecosystems may also be affected by increased resource development and shipping (Cameron, 2012). Marine mammal species such as polar bear, hooded seal, and narwhal have been identified as highly sensitive to climate change, particularly in the southern part of their range, because they depend on sea ice (Stirling and Parkinson, 2006; Crompton et al., 2008; Laidre et al., 2008; Durner et al., 2009). Studies are beginning to examine how climate change might affect caribou in northern Nunavut (Tews et al., 2007a, b), and Quebec and Labrador (Payette et al., 2004; Sharma et al., 2009). Although these future changes are expected to have significant implications for harvesting activities, they are the explicit focus of only a few studies, most of which examine resource management. Thus with regard to polar bears, Clark et al. (2008) argue for the strengthening of knowledge transmission networks through means such as intelligence-focused venues that build relationships across disciplines and backgrounds (e.g., science-IQ workshops), knowledge co-production projects or community-based monitoring programs, and arbitration frameworks. These suggestions are similar to Dowsley's (2009b) call for community clusters for resource management and Armitage's (2005b) recommendation for community-based narwhal management.

**Research Gaps:** These studies represent a strong understanding of current exposure, sensitivity, and adaptive capacity. Peer-reviewed research demonstrates that while the underlying determinants of vulnerability and adaptation are likely to be generalizable across the region, the nature of risks posed will be place-specific, depending on the human ecology of harvesting, local socio-economic conditions, and community history (Ford et al., 2010a). Yet the majority of published research has been conducted in

small communities in Nunavut (Fig. 1), although there are a number of unpublished studies from Nunavik and Nunatsiavut. As with the other sectors, future dimensions of vulnerability have been less examined, despite ample evidence for substantial disruption with changing ice regimes and animal populations. The wildlife management literature has been the most forward looking, although future social-economic trends have not been comprehensively assessed. Thus, as participation in the wage-based economy increases, individual harvest incentives may conflict with collective decision making in community-based resource management, and this conflict will have broad implications (Armitage, 2005b). Resource development in particular could have significant implications for wildlife management, through its effects on populations, by altering socio-economic characteristics of communities, and in other ways that have not been examined.

## DISCUSSION

This paper identifies and synthesizes current understanding of the human dimensions of climate change in Nunavut, Nunavik, and Nunatsiavut. The regionally focused analysis complements other Arctic-focused reviews, characterizing the state of current knowledge, identifying priorities for future research, and involving policy makers and northern organizations in the review process and gap identification. Moreover, the methods offer significant promise for other Arctic regions (e.g., Yukon, Northwest Territories) where a need has been identified but literature reviews have not been conducted. While the review procedures are rigorous and comprehensive, the limitation to peer-reviewed scholarship has likely overlooked relevant contributions in the grey literature, particularly consulting reports, technical papers, and policy documents. However, such a limitation is a common procedure for quality control in systematic reviews; it keeps the review process manageable and allows for rapid assessment of the evolution of knowledge over time.

As shown in this study and elsewhere, HDCC research is a rapidly expanding field. The growth in regional interest in the Arctic is an important development and holds potential to inform communities and policy makers about the risks posed by climate change and the prospects for intervention to reduce its negative effects and take advantage of new opportunities. The Arctic, as a "miner's canary" of climate change, is also an early warning opportunity to increase our understanding of how climate change will play out in other regions. Indeed, temperatures in recent decades have already increased beyond the 2°C threshold believed to be indicative of "dangerous" interference in the climate system, allowing empirical analysis of resultant impacts and adaptations. Yet the increase in interest also carries with it the potential for conflict between southern researchers and communities, with concerns expressed over research fatigue and duplication. These concerns stem in part from the increasing volume of studies being conducted, but also

reflect how research has been traditionally conducted in the North, with communities typically engaged as subjects of research as opposed to partners, as described by Castleden et al. (2008). Action-oriented HDCC projects have been important in developing and promoting community-based participatory research approaches in which communities are equal partners and help direct the research, but it is evident that more needs to be done (Collings, 2011). Literature reviews of this nature can help direct research to questions that have not already been asked and thus avoid duplication. In addition to the specific gaps noted for each sector, a number of overarching research needs are also evident; it is noteworthy that these are similar to those noted by Pearce et al. (2011b) in the Inuvialuit Settlement Region. Here we formulate these overarching needs as questions to provide a starting point for researchers, policy makers, and communities to develop priorities for future research:

- How can we capitalize on new opportunities posed by climate change?
- How will future social, economic, and political changes interact to affect how Northerners experience and respond to climate change? Specifically, what will be the roles of resource development, shipping, and increased geopolitical focus on the North?
- How will broader non-local determinants of vulnerability and adaptation enhance or moderate vulnerability and affect adaptation at a local to regional level?
- How will vulnerability and adaptation differ according to the magnitude and nature of climate change?
- Can humans adapt to any amount of climate change, or is there a limit to our adaptive capacity?
- Will enhanced devolution to the North provide a basis for addressing the disenfranchisement and colonial legacy that underpins many of the drivers of vulnerability and constraints to adaptation?
- What adaptations offer the most promise of reducing climate change impacts and how can we implement them effectively?
- Who should assess such adaptations, and by what criteria?
- What roles do various levels of government (municipal to federal) play in supporting adaptation? Do their jurisdictions overlap?

It is particularly important to develop a broader and more diverse geographic and sectoral knowledge base, since current understanding is derived largely from local studies in small communities that focus on traditional activities. The larger regional centres are emerging as hubs of economic development and population growth in which an “urban” Inuit identity is emerging (Searles, 2010). This new identity will have important implications for susceptibility to climate change that have not been examined. It is noteworthy that these overarching needs and specific gaps reflect our own perceptions based on the literature review. They should not be viewed as prescriptive, but more as a chance

for scientists, communities, and decision makers to reflect on where we have been, where we are going, and where we need to go.

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