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ORIGINAL ARTICLE

Vulnerability of Inuit food systems to food insecurity as a consequence of climate change: a case study from Igloolik, Nunavut

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Abstract This paper develops a conceptual model to examine the vulnerability of Inuit food systems to food insecurity as a consequence of climate change. The model illustrates that food system vulnerability is determined by the exposure and sensitivity of the food system to climate-related risks and its adaptive capacity to deal with those risks. The model is empirically applied using a case study from Igloolik, Nunavut. Specifically, the paper focuses on how extreme climate-related conditions in 2006 interacted with the food system to affect food security, using 2006 as a lens to identify and characterize some of the processes and conditions shaping vulnerability, and establishing a baseline for identifying and characterizing processes that are likely to shape future vulnerability. There is a high level of adaptive capacity among Igloolik Inuit, with food sharing mechanisms, hunting flexibility, and store-food access moderating the impact of climatic-risks on food security. However, high fuel and commodity prices, the increasing economic burden of adapting to back-to-back years with unfavorable climatic conditions, underlying community vulnerabilities, and the nature to the climate extremes in 2006, overwhelmed the adaptive capacity of many community members. Those dependent on traditional foods and having limited access to financial resources were particularly vulnerable.

Keywords Food security · Climate change · Inuit · Canada · Vulnerability science · Adaptive capacity · Traditional foods

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Introduction

To be food secure, individuals and households must be able to reliably access food, the availability of nutritious food must be sufficient, and it must be of an acceptable quality (FAO 1999). Food security and health are closely linked, with those who are food insecure more likely to suffer from compromised health status (UNWFP 2007). Food access, availability, and quality are sensitive to climatic conditions, and it is believed that food systems are susceptible to climate change (IPCC 2007). The relationship between climate change and food security has been addressed in the context of agriculture-based food systems, including links to health outcomes (Scmidhuber and Tubiello 2007; Brown and Funk 2008; Lobell et al. 2008). There have been few studies, however, which have explored potential implications of climate change for the security of food systems that are dependent on hunting and fishing (Chan 2006; Furgal and Seguin 2006).

In the Canadian Arctic, Inuit live in isolated off-grid settlements accessible only by air, winter roads, and boat in the summer (Fig. 1) (Ford 2008a). Inuit communities range in size from fewer than 100 people to as many as 7,000, with the majority characterized as having economies composed of waged employment and subsistence-based resource harvesting. The waged economy is largely based on public administration and resource extraction, with tourism also important in some regions. The consumption and procurement of locally harvested traditional foods plays an important role in supporting Inuit livelihoods and diet, with limited opportunities for agricultural production in Arctic regions (Furgal and Seguin 2006; Poppel et al. 2007). On account of the sensitivity of hunting and fishing to climatic conditions, there is concern that Inuit food systems are particularly vulnerable to climate change (Paci

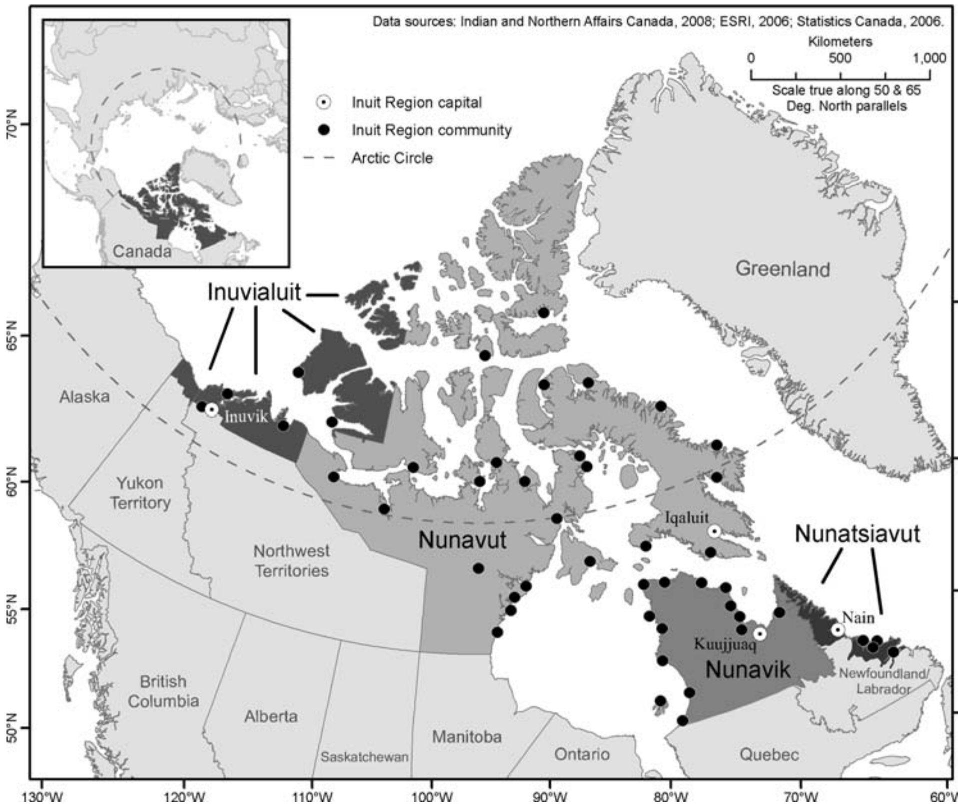

Fig. 1 Canada's Inuit regions—comprising the settlement areas of Nunavik, Nunatsiavut, and Inuvialuit, and the Territory of Nunavut—cover 30% of the Canadian land mass. The area is sparsely populated with an average population density of 0.014 people per km^2, and approximately 51 permanently settled communities

2004; ACIA 2005; Newton et al. 2005; Furgal and Prowse 2008). Moreover, Inuit food systems are struggling to meet everyday nutritional needs due to socio-economic stresses including limited and unreliable access to cash income, high prices for nutritional store foods, and—in some instances—shifting food preferences away from traditional foods. Indicators of food insecurity, for example, greatly exceed the Canadian average (Lawn and Harvey 2003; Ledrou and Gervais 2005). High baseline food insecurity may make Inuit particularly susceptible to climate change, with potentially-serious health-implications (Power 2008).

This paper examines how climate change might affect the food security of small Inuit communities in Canada. The paper begins by providing an overview of Inuit food systems; a necessary first step to understanding the potential effects of climate change. It then reviews the concept of food security, assesses how it has been applied in Inuit contexts, and identifies determinants of food security documented in the literature. The paper then develops a conceptual model to examine the vulnerability of Inuit food systems to food insecurity as a consequence of climate change which is applied in a case study from the Inuit community of Igloolik. The paper finishes by using the case study to provide insights into the food security implications of climate change for Canadian Inuit in general.

The Inuit food system in Canada

A food system comprises "dynamic interactions between and within biophysical and human environments which result in the production, processing, distribution, preparation and consumption of food," (Gregory et al. 2005, p. 2141). Traditional foods and store-bought are important components of the contemporary Inuit food system (Fig. 2), the contribution of each varying through the year and by community, household, and individual.

Traditional foods

Traditional foods comprise a variety of locally harvested non-domesticated wildlife species, the most common including ringed seal, caribou, Arctic char, beluga whale, and narwhal, and a variety of wild berries (IHS 2003; NWMB 2004). Despite decreasing consumption of traditional foods in recent decades, especially among younger generations, they remain social, culturally, and economically important in the contemporary Inuit food system. Food surveys by Poppel et al. (2007) in Nunavut, for example, identified that 41% of respondents obtained more than half of the meat and fish they consume from traditional sources. Likewise, nutrition research by Kuhnlein and Receveur (2007) reveals that Canadian Inuit obtain

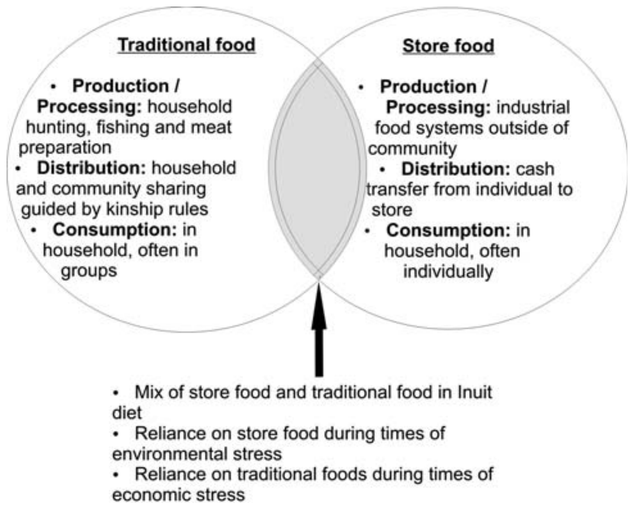

Fig. 2 The traditional and store-food components of the Inuit food system

between 6 and 40% of their daily energy requirements from traditional foods. The social and cultural importance of traditional foods to Inuit communities is also noted in the literature (Wenzel 1995; Furgal and Seguin 2006; Nickels et al. 2006).

> "Traditional foods and traditional means of obtaining and preparing them are part of a cultural heritage. Thus, [traditional] food is holistically entwined with culture and personal identity, as well as with physical health." The Royal Commission on Aboriginal Peoples (1996, p. 194)

The benefits of traditional foods to health—including nutritional status and psychological well-being—is widely acknowledged (Myers et al. 2004; Van Oostdam et al. 2005; Chan et al. 2006; Furgal and Seguin 2006; Kuhnlein and Receveur 2007; White et al. 2007).

The production, processing, distribution, and consumption of traditional foods differ significantly from store-bought food. The extended household unit forms the primary unit of the traditional food system (Wenzel 1995; Usher et al. 2003; Kishigami 2004; Poppel et al. 2007). Wildlife is often harvested by household members on a daily, weekly, or monthly basis, with equipment owned individually or pooled within the household. Harvesting may take place in close proximity to communities or may involve extended overnight trips to distant hunting areas depending on the time of year, species being harvested, level of success, time availability, and level of skill of the hunter(s). Regulations set by the territorial and federal government also affect harvesting behavior, determining what animals can be harvested, how many, and at what time of the year. Commonly-regulated hunts include polar bear, walrus, and all whales, with the nature of the regulation differing over space and time according to animal population status (Ford et al. 2007; Dowsley and Wenzel 2008; McLoughlin et al. 2008). The physical act of harvesting is largely a male activity, with the meat from harvested animals processed by female household members. Traditional foods procured and processed by the household unit are distributed within the household, and occasionally with others in the community. Food-sharing practices differ across Inuit regions in Canada and between communities, the nature and extent of which is contingent on ecological conditions, personal circumstances, and societal directives, often following complex rules (see Wenzel 1995; Damas 2002; Usher et al. 2003; Duhaime et al. 2004; Kishigami 2004). Common across Inuit regions in Canada, however, is the reluctance to exchange traditional foods directly for money (Gombay 2007).

Store-bought foods

Over the past 50 years, store-bought or 'southern foods' have played an increasingly important role in the diet of Canadian Inuit at the expense of traditional foods. For younger generations, the store often represents their main source of food—part of the 'nutritional transition' documented among Canadian Inuit communities in the last few decades (Kuhnlein et al. 2004; Kuhnlein and Receveur 2007; Poppel et al. 2007). This trend—combined with youth preference for nutrient poor, high sugar and fatty store produce, and high prices for fresh fruit and vegetables in the North—has had far reaching health implications with rising levels of obesity and diabetes reported in northern communities (Young 1996; Kuhnlein et al. 2004; Kuhnlein and Receveur 2007).

Communities usually have at least two small stores which stock a variety of fresh and processed foods that can be found in southern Canada, with store food having to be brought in by scheduled air service or, for non-perishables, on the sea-lift once a year during the summer ice free period. These activities are susceptible to environmental conditions. Depending on the frequency of the connection, shortages of certain products may ensue at certain times of the year. Bulk non-perishables that are brought in by boat once or twice a year often run-out in late spring before the sea-lift re-supply in July and August. Moreover, the sea-lift itself is susceptible to sea ice and weather conditions, with delays in re-supply not uncommon; although earlier sea ice break up in fall and later freeze up is extending the shipping season and reducing delays due to ice conditions. Fresh produce brought in by air is also susceptible to delays due to bad weather (e.g. fog, high wind, blizzard, and whiteout)—a common feature of Arctic environments at all times of the year. A delay in transporting fresh produce is particularly problematic in the Arctic with produce already close to (and in some cases exceeding) expiry dates on arrival in communities.

The food system surrounding store food reflects industrial/agriculture based food systems in southern Canada. Food production, processing, distribution and consumption are discrete activities involving many actors, often in different countries; availability is shaped by the decisions made by the store about what food to stock; and store food is rarely shared with access governed through the cash economy.

Interdependence in the Inuit food system

As illustrated in Fig. 2, the production, processing, consumption, and distribution of traditional and store food do not exist in isolation in the Inuit food system, interacting in often complex ways. For example, studies have documented that at times of environmental stress when wildlife are not accessible, available, and/or are of poor quality, people rely more on store food (Nickels et al. 2006; Ford et al. 2007). Moreover, many Inuit report relying on store food when their equipment has broken down and they can not afford the high capital outlay for repairs. At other times, when access to money is limited or prices high, reliance on traditional foods may increase. This is particularly pertinent in the context of the rising food prices, with the cost of store food in the north (especially nutritious food) significantly exceeding prices down south. Equally, with rising price of gasoline making hunting expensive, individuals may be forced to consume out of necessity cheap nutrient poor store-food or eat less. This interdependence has important ramifications for how climate change might affect Inuit food systems and is discussed in greater detail in Sect. "Conceptual model".

Food security in Inuit communities

Food security exists "when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1999). To be food secure, individuals and households must be able to reliably access food, the availability of nutritious food must be sufficient, and it must be of an acceptable quality (Myers et al. 2004; Gregory et al. 2005) (Fig. 3). Food *availability* refers to the availability of sufficient food (Scmidhuber and Tubiello 2007), i.e., the overall ability of the store and traditional food components of the food system to meet demand. Food *access* covers the ability of households and individuals to access adequate resources to acquire store and traditional foods for a nutritious diet. Food *quality* concerns the ability to obtain safe food of sufficient nutritional and cultural

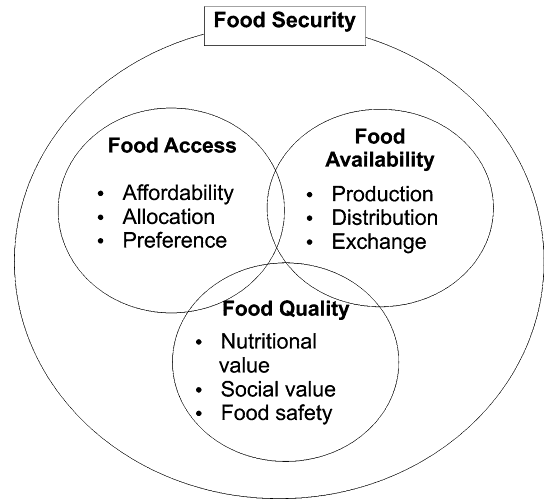

Fig. 3 Dimensions of food security (building on Gregory et al. 2005)

value (Fig. 3). Food *insecurity* occurs when food systems are stressed so that food is not accessible, available, and/or of sufficient quality. In the Canadian Arctic, and elsewhere, food insecurity has been linked to negative health outcomes, with those who are food insecure more likely to feel unhealthy, be prone to infection, have chronic health problems, and experience psychological stress (including feelings of inadequacy, attention disorders, irritability, anger, distorted family dynamics etc.) (Hamelin et al. 1999, 2002; McIntyre and Tarasuk 2002; Lambden et al. 2006; UNWFP 2007).

Food security emerged as a focus of research in Arctic Canada in the 1990s in response to concern over the impact of contaminants on food systems and the implications of changing dietary patterns. This research has documented a high prevalence of food insecurity among Inuit communities, significantly exceeding the Canadian average (Lawn and Harvey 2003; Myers et al. 2004; Ledrou and Gervais 2005; Chan 2006). Various factors that influence the security of Inuit food systems have been identified and are summarized in Fig. 4. Of these determinants, lack of income, cost of hunting and purchasing store food, lack of active hunters in the household, and changes at the societal level including decreased transfer of hunting skills and traditional knowledge to younger Inuit, reduced sharing of food, shifting food preferences, and limited government involvement/support have been identified as creating food insecurity (Chabot 2003; Myers et al. 2004; Pratley 2005; Chan 2006; Chan et al. 2006; Lambden et al. 2006; Kuhnlein and Receveur 2007; Power 2008). It is also likely that climate change, in the context of non-climatic conditions and change, is affecting food security. Climate-related conditions are particularly important in affecting Inuit food security in Nunavut. With few permanent roads, the frozen ocean and land provides an important

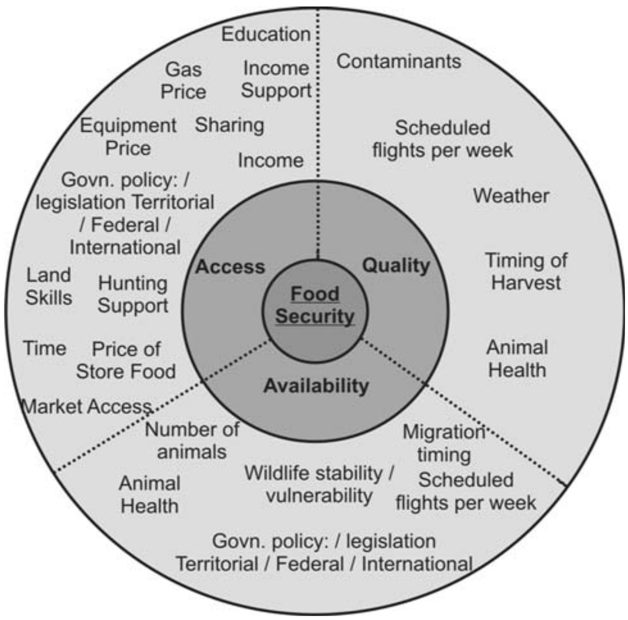

Fig. 4 Food security determinants (traditional and store food) for Canadian Inuit communities

transportation link to hunting grounds and are susceptible to changing ice and snow conditions due to warming temperatures and shifting precipitation regimes (Ford et al. 2008a). When the ice is unsuitable or the land lacks an adequate snow cover, it is often not possible to hunt (Furgal and Prowse 2008). Moreover, the very animals that make up traditional foods are sensitive to climate-related conditions, specifically the presence or absence of ice, snow, and precipitation regime which determine migration timing, abundance, and health (ACIA 2005; Furgal and Prowse 2008; Ford et al. 2008b). The role of climate-related conditions in affecting food security in the Canadian North, however, remain largely unexamined (Chan 2006). The impacts of current climate change and prognosis of accelerating change have increased the need to understand links between climate and food security (Patz et al. 2005; Furgal and Seguin 2006; McMichael 2006; McMichael et al. 2008).

Conceptualizing climate change and food security outcomes

Climate change–food security literature

The relationship between climate change and food security has been examined in agricultural-based food systems. This research is largely based on quantitative-modeling approaches, where climate-prediction scenarios are used to model the impacts of climate change on crop productivity and production (i.e., food availability) (Rosenzweig and Parry 1994; Scmidhuber and Tubiello 2007). Food security outcomes are treated synonymously with predictions of altered production, reflecting an extension of production focused approaches common in the literature (Gregory et al. 2005; Scmidhuber and Tubiello 2007; Lobell et al. 2008). In the Arctic too, the output from climate scenarios have been used to evaluate the potential implications of changing biophysical conditions (ACIA 2005). This research has provided information on the potential impacts of climate change on food systems and sensitivity of food production to changing biophysical conditions. However, social science research has demonstrated that food security is also concerned with access and quality of food alongside availability, and the economic, political, and social conditions that influence the ability to manage stresses to the food system (Sen 1981; Watts 1983; Chambers 1989; Watts and Bohle 1993; Yaro 2004; Eakin and Luers 2006). This research focuses on the resources available to people to secure their livelihoods, and the political, social, economic, institutional and biophysical processes that make some livelihoods more vulnerable than others, and how stresses emanating at multiple scales affect food security.

In recent years, scholarship in vulnerability science has advanced understanding of the possible implications of climate change on human well-being, including food systems (Cutter 2003; Schröter et al. 2005; Adger et al. 2006; Ebi et al. 2006; Polsky et al. 2007; Ford 2008b). Vulnerability has often been described as the ‘capacity to be wounded.’ It is a measure of the susceptibility to harm in a system in response to a stimulus or stimuli, and is related to both exposure and sensitivity to climatic risks and adaptive capacity to deal with those risks (IPCC 2007). Vulnerability science seeks to characterize the determinants of exposure, sensitivity, and adaptive capacity, and how they interact together, to create dimensions of vulnerability (Turner et al. 2003a; Ford and Smit 2004; Keskitalo 2004; Ebi et al. 2006; Smit and Wandel 2006; Liu et al. 2007; Nelson et al. 2007; O’Brien et al. 2007; Keskitalo 2008).

Conceptual model

A conceptual model illustrating how climatic conditions interact with Inuit food systems to create conditions of food security *and* insecurity is presented in Fig. 5. The model draws upon scholarship in vulnerability science and structures the identification and characterization of the human and non-human processes shaping food system vulnerability to climate-related conditions, traces the pathways through which these processes affect food systems, and locates and explains the presence of vulnerable groups. Such understanding is essential for identifying entry points for policy to strengthen food systems in the context of a changing climate (Schröter et al. 2005;

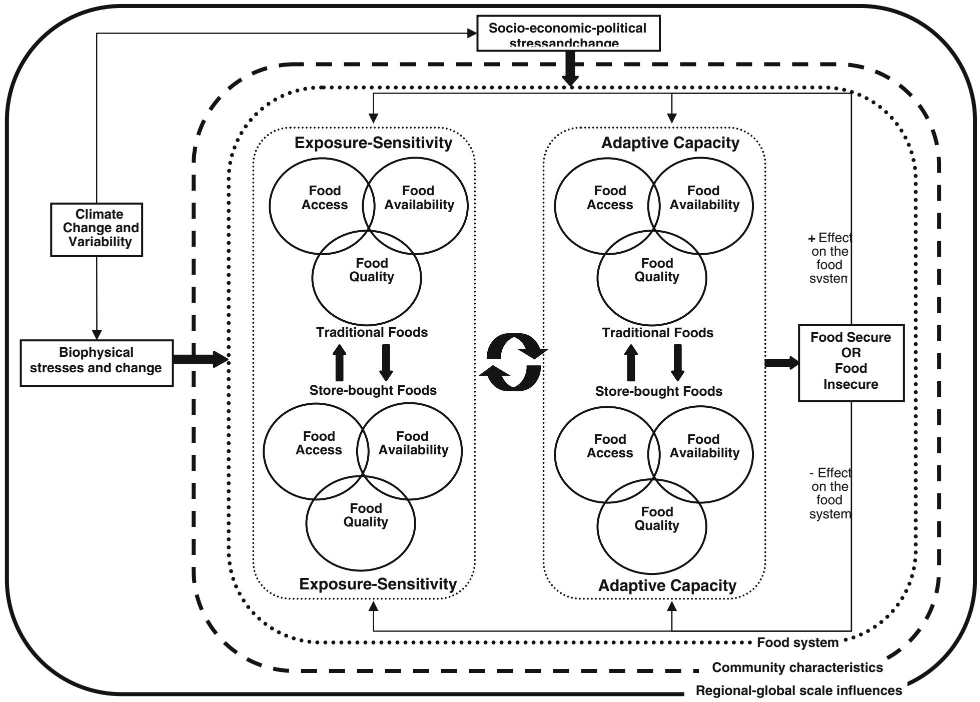

Fig. 5 A vulnerability-based model for assessing potential implications of climate change for food security for Inuit communities in Canada

O'Brien et al. 2007; Scmidhuber and Tubiello 2007). Specifically, it builds on the general vulnerability model of Ford et al. (2006b) and Smit and Wandel (2006) for food security application in northern Canada. Here, vulnerability refers to the susceptibility of the food system to food insecurity as a consequence of climatic variability, extremes, and change, and implies the potential for negative health outcomes (where health is viewed as encompassing physical, mental and social well-being). The model illustrates that food-system vulnerability is determined by the exposure and sensitivity of the food system to climate-related risks and its adaptive capacity to deal with those risks.

The first element in the model, *exposure-sensitivity*, reflects the susceptibility of the food system to climate-related conditions that represent risks—including those associated with climate change—manifesting itself in the form of constrained food access, availability, and quality of store-bought and/or traditional foods. Exposure-sensitivity is dependant upon both the characteristics of climatic conditions *and* nature of the food system in question. The characteristics of climate-related conditions concern the magnitude, frequency, spatial dispersion, duration, speed of onset, timing, and temporal spacing of conditions which affect the food system. The nature of the food system concerns how food is produced, processed, distributed, prepared and consumed and is influenced by the extent to which individuals or communities rely upon traditional and store foods in their diet, the human ecology of harvesting, local biophysical conditions, community and household social relations, livelihood status, and community location relative to wildlife and transportation access. The model also highlights the interdependence of dimensions of food security. Constrained access to traditional or store foods, for instance, can also affect the availability and quality of food, and vice versa.

Climate change has the potential to affect exposure-sensitivity by altering the nature of climate-related conditions, and/or affecting the nature of the food system. This link might be direct whereby decreasing wildlife population or altered migration-timing due to changing conditions constrain harvesting success (i.e., food availability), or rising temperatures increase the frequency of food poisoning by altering meat fermentation for specialist dishes (i.e., food quality) (Furgal et al. 2002). More likely, the consequences will be indirect. For example, changing climatic conditions may affect trail networks used to access hunting grounds reducing the ability to hunt at certain times of the year (i.e., food availability), increase the economic burden on harvesting (i.e., food access), disrupt store-food transportation networks (i.e., food availability), or affect community/household characteristics that determine the ability to produce, process, and share harvested food successfully and efficiently (i.e., food availability and access). There are also important temporal dimensions to climate change effects on exposure-sensitivity. The impact may involve sudden shocks. For example, a climate-related event such as a late ocean freeze-up might prevent access to hunting grounds, or successive days of fog or high winds might reduce aircraft access, with the impact being discrete in time. Equally, it may involve gradual change in climate-related conditions which slowly increase exposure-sensitivity over-time.

The second element in the model, *adaptive capacity*, can be defined as: "The ability of a system to adjust to *climate change* (including *climate variability* and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC 2007, p. 869). In the context of this research, the system of interest is the Inuit food system and those adjusting are households and individuals. People have learned to modify their behavior and their environment to manage and take advantage of their local climatic conditions. Therefore, most communities are adaptable to normal climatic conditions and a range of deviations around norms (Ford and Smit 2004). For example, a number of strategies are utilized by Inuit to enhance and maintain food access, availability, and quality of traditional and store-foods during times of stress, helping reduce vulnerability (Nickels et al. 2006). These strategies may target one dimension of food security, for example maintaining food availability through flexible hunting strategies, or they may target multiple dimensions including food access, availability and quality. Strategies may also be characterized by purpose, temporal scope, spatial scope timing, and form (Smit et al. 1999) and may target different functions of the food system (i.e., production, processing, etc.). The dimensions of food security are also interdependent so that strategies aimed at enhancing food availability, may concurrently enhance other aspects of food security. Adaptive capacity of the food system at an individual and household level is determined by a number of factors including economic wealth, social capital, infrastructure, social institutions, experience with previous risk, capacity to learn, the range of technologies available for adaptation, and equality; characteristics and structure of the food system; and the nature of exposure-sensitivity (Chapin 2006; Smit and Wandel 2006; Nelson et al. 2007; Ford et al. 2008b).

A number of important processes and conditions that shape the outcome of climate change for food security are illustrated in the model and merit further discussion. Firstly, the model directs attention to coupled human–environment systems, where environmental and social processes are viewed as co-evolving and joined, not distinct and separate. It is interaction between human and environment components of the food system which determine the effects of climate change on food security, with exposure-sensitivity and adaptive capacity interacting in often complex ways. Exposure to repeated climate-related conditions, for instance, can facilitate active experimentation in management and governance thereby providing opportunities for social learning to adjust to change, and can also increase awareness of climate and perception of risk, thus increasing the adaptive capacity of the food system (Chapin et al. 2004, 2006; Armitage et al. 2008; Huntington et al. 2007). Equally, such experience can reduce the resources a group or individual has to manage climatic stresses and can exacerbate existing system-weaknesses. Likewise, adaptive strategies can affect community and individual behavior to make the food system more or less sensitive to climatic conditions.

Secondly, the model highlights how food security is influenced by many factors, including government policies and contextual factors in which community processes are shaped by larger-scale and ultimately global-scale processes (Liu et al. 2007; Huntington et al. 2007; Keskitalo 2008). Territorial, federal, and international controls on hunting and importation of animal skins, for example, influence the flexibility with which hunters can adapt to change and access economic resources to do so. Rising commodity and food prices meanwhile, can increase the cost of adaptation to climatic stress and reduce available resources to adapt.

Thirdly, the traditional and store components of the Inuit food system are not mutually exclusive, with interaction between the two potentially exacerbating or moderating exposure-sensitivity and/or adaptive capacity. For example, increased harvesting-costs due to climate change may reduce household resources necessary to purchase store food, decreasing both access to store foods and/or the quality of food that can be afforded. In this case, the store food component of the Inuit food system is affected without a direct link to climatic conditions. Vulnerability may be exacerbated if both traditional and store components of the food system are stressed so that they compound each other.

Fourthly, the outcome in the model, food security or insecurity, has important temporal dimensions. Food insecurity can be temporally discrete (transitory) being experienced by households or individuals for a short period of time (weekly, monthly, year): a consequence of a specific event or sequence of events exceeding adaptive capacity at a specific point in time. Transitory food insecurity was first noted in the literature in the 1980s—particularly with regards food crises in sub-Saharan Africa (World Bank. 1986; De Waart et al. 1988; Lavy 1992; FAO 2003)—and in a northern context is typically caused by year-to-year variations in food prices and household incomes, and/or the occurrence of biophysical conditions which reduce wildlife availability, access, and quality. Food insecurity may also be a chronic condition stemming from underlying vulnerabilities that render the food system persistently unable to meet basic needs and susceptible to external stresses (World Bank 1986; FAO 2003). Importantly, the food-security outcome itself is not an endpoint but feeds-back (directly or indirectly) into the food system to affect exposure-sensitivity and adaptive capacity. Transitory food-insecurity as a result of a single event or sequence of events over many years can deplete resources available to access food of acceptable socio-nutritional value and reduce the ability to avoid, resist, and recover from climatic and non-climatic stresses, thereby increasing vulnerability and increasing the likelihood of chronic food insecurity. System response to discrete episodes of food insecurity may also change the nature of food system making it more or less vulnerable to change. Similarly, chronic food insecurity might result in re-organization or transformation of the food system to better fulfill socio-nutritional needs or may involve intervention to reduce exposure-sensitivity and increase adaptability.

Finally, and a corollary of the above points, vulnerability to food insecurity as a consequence of climate change will be inherently dynamic, changing as the community changes its characteristics relative to the climatic conditions, changing as the stimuli themselves change, and changing on account of internal feedbacks which can reinforce or counterbalance vulnerability trends (Nelson et al. 2007; O'Brien et al. 2007). On account of these dynamics, the emergence of food insecurity as a consequence of changing climatic conditions may not be immediately observable in the food system because of time lags between human–environment interactions, thresholds, and non-linearity of system response.

Methods

Nunavut case study

Community case studies are central for understanding the vulnerability of food systems to climate change permitting in-depth analysis of human–environment interactions which determine food-security outcomes (Turner et al. 2003b; Chapin et al. 2004; Guyot et al. 2006; Morton 2007; Huntington et al. 2007). Particularly in instances where we know very little about system response to climate change (i.e. Inuit food systems in Canada), case studies can quickly identify drivers of vulnerability and adaptive capacity, and can inform the development of larger frameworks for diagnosing change in socio-ecological systems (Loring et al. 2007). This paper illustrates the application of the vulnerability model with a case study from the community of Igloolik, Nunavut.

Igloolik is a coastal Inuit community of approximately 1,500 people (95% Inuit) located on Igloolik Island in the Canadian High Arctic territory of Nunavut (Fig. 6). Community characteristics and social-economic indicators are provided in Table 1. Igloolik, like all Nunavut communities, has been characterized as having an economy composed of waged employment and subsistence harvesting (Ford et al. 2006a). The waged economy is largely based on public administration and tourism, including the production of traditional Inuit art and the guiding of southern sports hunters. Igloolik is also the base for the film company ISUMA productions, and local guides are occasionally employed in the production of feature films and documentaries. In recent years, mine companies have begun to explore iron ore and diamond deposits in the region, providing well-paying seasonal-jobs in mining camps in summer months. Earning a cash income and procuring traditional food are not separate activities for many locals: especially for seasonal and occasional jobs, cash income is used to support part- and full-hunting activities, and when local guides take sports hunters to harvest polar bear or walrus, the meat is often kept for local consumption (sports hunters usually take the skin of polar bear and walrus ivory).

The harvesting of marine and terrestrial mammals is widely practiced in the community, with traditional foods

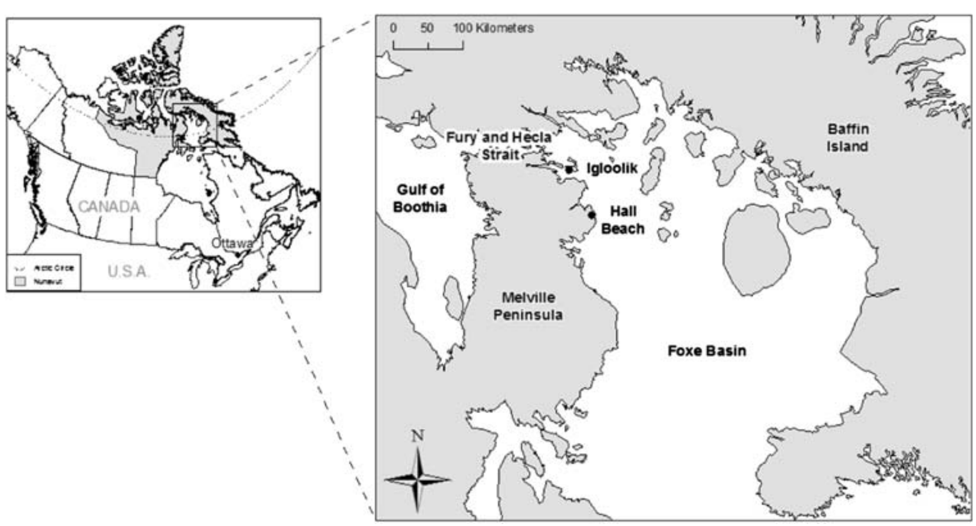

Fig. 6 Igloolik, Nunavut

Table 1 Socio-economic characteristics of Igloolik, Nunavut and Canada in general

Characteristics	Igloolik	Canada
Employment rate (%)[a]	43.6	62.4
Unemployment rate (%)[a]	16.1	6.6
Median age[a]	18.9	39.5
Average household size[a]	4.7	2.5
Average per capita earnings (Canadian $)[b]	20,156	31,757
Life expectancy[c]	67.2 (males)	77.2
	69.6 (females)	82.1
Human development index[d]	0.75 (Nunavut)	0.88

[a] 2006 Canadian census

[b] 2001 Canadian census

[c]2002 data from http://www.statcan.ca/english/freepub/84F0211XIE/2002/tables/html/t027_en.htm. Note these data are the average for Nunavut as a whole

[d] Data from Wilkins et al. (2008). Human development index calculated based on life expectancy (health), education (literacy/knowledge), income per capita (access to goods and services). Note these data are the average for Nunavut as a whole

forming an important part of the community's nutritional intake. The conditions of the ice are particularly important for traditional food procurement, acting as an essential hunting platform from which walrus (*Odobenus rosmarus*), ringed seal (*Phoca hispida*), and polar bear (*Ursus maritimus*) are harvested (Laidler et al. 2008). The frozen ocean surface also provides an important transportation medium, allowing access to the mainland to the South (Melville Peninsula) and Baffin Island to the North, which comprise important caribou (*Rangifer tarandus*) hunting grounds, and Arctic char (*Salvelinus alpinus*) fishing lakes. Given the absence of roads in the Igloolik region, the conditions of land trails are also important in determining accessibility and safety of harvesting, particularly snow depth and the thickness of ice on river crossings (Furgal and Seguin 2006; Nickels et al. 2006; Ford et al. 2008b). The procurement of traditional food is also sensitive to other climate-related conditions including wind, precipitation, and temperature. Store food is also important in the diet of Igloolik Inuit, with two stores stocking 'southern foods' and supplied by scheduled air service from the territorial capital, Iqaluit, six times a week and by ship during re-supply once a year. Food delivery is susceptible to inclement weather including blizzard, high winds, snow, and fog, which can cause shortages of food items.

Qualitative methods

The vulnerability model is applied to analyze links between climate-related conditions and food security by examining how community members experienced and responded to climatic extremes during 2006. 2006 was in many ways an anomalous year for sea ice and other climate-related conditions, and representative of changes predicted for the Igloolik region—and the Canadian North in general—by global climate models (Dumas et al. 2006; Ford et al. 2008b; Laidler et al. 2008). The case study therefore offers a lens to identify and characterize some of the processes and conditions shaping vulnerability, allowing identification of determinants of adaptive capacity and sources of exposure-sensitivity. Using temporal analogs to explore climate change vulnerability is a well recognized approach in vulnerability research, improving our understanding of the implications of future climate change, illustrating important lessons for decision makers concerned with vulnerability reduction, and establishing a baseline for identifying and characterizing processes that are likely to shape future vulnerability (Glantz 1996; Smit et al. 2000; Duerden 2004; Ebi et al. 2006; McLeman et al. 2008; Huntington et al. 2007; Keskitalo 2008; Leary et al. 2008).

Focus groups and semi-structured interviews with Igloolik Inuit, local health representatives, and resource managers were conducted to document Inuit and institutional knowledge on the nature of exposure-sensitivities in the food system in 2006, identify adaptive mechanisms, and characterize conditions facilitating and constraining adaptability. A guide identifying key themes was used to direct the interviews and focus groups. This allowed for flexibility in the interview: participants were guided by the interviewer's questions, but the direction and scope of the discussion followed the associations they identified (Ford et al. 2006a). This allowed participants to identify and specify conditions and processes they found important, with openness allowing for new and unexpected relationships to be conveyed (Ford 2008b). Data collection was conducted with local Inuit collaborators and following procedures for ethical research. To provide a baseline from which to assess climatic exposure-sensitivities and adaptive capacity in 2006, interviews contained in the Igloolik Oral History Project (IOHP) were reviewed using systematic content analysis (see Ford 2006). The IOHP is a database containing over 500 interviews with local residents on a variety of topics that was started in 1986 and captures lived experience and oral history spanning the twentieth century. Previous retrospective analyses of climate vulnerability in Igloolik are also reviewed to situate vulnerability processes observed in 2006 in a broader temporal context (Ford et al. 2006a, 2008b). Where available, census and official statistical data (e.g., consumer price index, food surveys) are utilized to compliment key arguments. However, as a new territory, data availability is limited in Nunavut.

Results

Exposure-sensitivity in the food system in 2006

Sea ice abnormalities in 2006

Air and ocean temperature and wind influence the nature of the sea ice in terms of break up and freeze up timing, and ice thickness and stability. Ice conditions in the Igloolik region departed from the long term norm in 2006 in two key respects. Firstly, ice charts from the Canadian Ice Service (CIS) indicate almost complete absence of summer floating ice in Foxe Basin, especially regions to the northeast and southeast of Igloolik (Ford et al. 2008a; Laidler et al. 2008). Floating ice comprises ice that is not attached to the land and is constantly moved by ocean currents and the wind. It forms walrus habitat during summer months from August until late September, and a preferred location for walrus hunting (Anderson and Garlich-Miller 1994). Ice chart data going back to 1982 (the available record) reveals extensive areas of northern Foxe Basin covered with floating ice, especially in August. 2006 is the first year in the dataset that large areas of the Basin are completely ice free. In focus group discussion, Inuit elders likewise characterized the summer ice conditions as being unprecedented in living memory, with negative impacts on the walrus hunt. Indeed, in 65 interviews conducted in previous research in Igloolik and in interviews analyzed in the Igloolik Oral History project, there is no indication of abnormalities of this magnitude in ice presence during summer (Ford et al. 2008a).

Secondly, in the Igloolik region, the ocean normally freezes and becomes usable for hunting activities and transportation in mid- to late October. CIS records document the average freeze up date to be the 26th October from 1969 to 2005 (Ford et al. 2008a; Laidler et al. 2008). If one observes the trend from 1969 to 2000 the freeze up date is significantly earlier, with later freeze-up particularly pronounced since 2000 (Laidler et al. 2008). In 2006, according to Inuit elders, the freeze-up was one of the latest in living memory. After initially freezing and becoming usable on the 5th November in 2006, warming temperatures resulted in the ice breaking up until late November delaying usage by 3–4 weeks later than normal. Ice chart data is largely consistent with Inuit description (Ford et al. 2008a; Laidler et al. 2008). The late freeze up in 2006 is also consistent with a progression of later freeze up documented in the ice chart data from the late 1960s (Laidler et al. 2008).

Sea ice conditions in 2006 were described locally as significantly constraining the ability to harvest.

As illustrated in Fig. 7, the lack of floating sea ice in the summer significantly reduced the ability to harvest walrus in northern Foxe Basin. Inuit described walrus migrating further south beyond the range of local hunters due to a lack of ice. Walrus remaining in northern Foxe Basin congregated along the shoreline: Inuit prefer harvesting walrus on ice as the animals are easier to approach, offer a clear stationary target, are less likely to be lost, and do not have to be hauled out of the water for butchering. This had a direct impact on food security, compromising traditional food availability.

> "This year we have no aged walrus. We go out hunting but come back without walrus because there (is) no ice … because the hunt has been bad we have only been able to hunt just for today. We haven't done any caching of walrus meat. This is the first time in my life that I have gone without aged walrus meat." Abraham Ulayuruluk
>
> "There's hardly been any Igloolik people hunting walrus this year [in the summer] because there has been no ice at all." Herve Paniaq

The lack of walrus meat in summer affected community elders and more mature residents for whom walrus is an important food source in summer and into fall, providing a well-balanced source of nutrients, vitamin A, and protein. Fermented and aged-walrus meat (*Igunak*) meanwhile is considered a local delicacy. This likely had economic ramifications. Anderson and Garlich-Miller (1994) in the early 1990s estimate the net economic-value of each harvested walrus (an average walrus provides 460 kg of meat) between $1,692 and $2,960 depending on whether walrus meat is replaced by meat from other animals or by store food (more recent economic analysis is not available). In 2006, given limited access to other animals, substitution mostly involved switching to store food. Young Inuit in this study and in previous research openly admitted to a disinclination to eat walrus due its strong and acquired taste and hard work required to harvest the animal. Decreased walrus access and availability had limited impact on their food security.

During fall, the sea ice is widely used for travel to caribou hunting grounds and char fishing lakes on the mainland (Melville Peninsula), and is used as a platform for hunting ringed seals. Ringed seals are hunted at small pockets of open water that remain as the ice is freezing and also in bays and points of land where cracks open up (Laidler and Ikummaq 2008). Participants articulated that the late freeze up in 2006 constrained the ability to travel to the mainland because the ice was too thin and dangerous to use until mid- to late November. According to local Inuit, this significantly reduced the ability to hunt seals on the ice and travel to hunt caribou and char, with implications for traditional food availability. The widespread appeal and importance of these animals in the local diet magnified the implications for food security in the community.

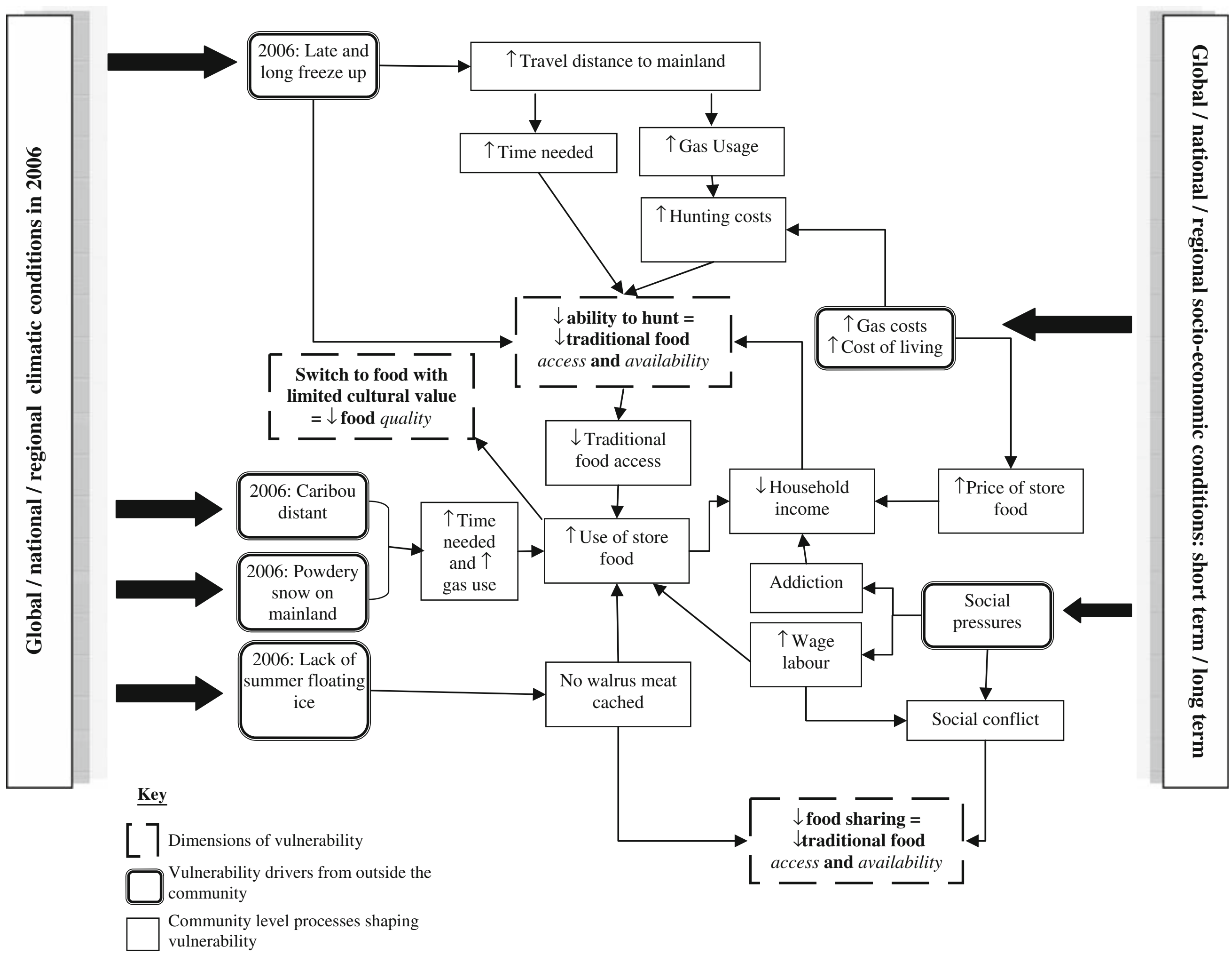

Fig. 7 Global influences, local vulnerability: multiple stresses and dimensions of food insecurity in Igloolik in 2006

> "This fall has been long because we spend a lot of time on [Igloolik] island. Usually we go out hunting earlier in the fall but we haven't been able to go to the mainland for a while. We have not been able to get new meat because of this [late freeze up]…. So there has been hardly any new meat over fall." Nathan Qamaniq
> "[I have been] eat[ing] more store food …. [It] seems like we have to buy more from the store this year [because of the late freeze up]" Tarcissus Tagugak

Even when the ice did become safe to use in mid- to late November, it was not until early December that the ice reached a thickness capable of supporting direct travel to the mainland. These routes normally start being used for travel to char fishing lakes and for caribou hunting between late October and early November. The resulting detours required in fall 2006 added travel time and distance to hunting trips—and hence cost—thereby limiting access to those with time and/or sufficient financial resources to afford the increased fuel costs.

Other climatic-risks in 2006

Other climatic conditions were identified as magnifying the impacts of sea ice conditions on food security in 2006, including a lack of snowfall in early fall which limited the ability to travel on the land using snowmobiles to access caribou hunting grounds (Fig. 7). During November, heavy powdery snow on the mainland, believed locally to be due to warm temperatures, continued to make caribou difficult to hunt. Powdery snow makes it hard to use snowmobiles, especially when towing animal carcasses, and uses a lot of gas. Recent years have also witnessed the caribou migrate away from the Igloolik region (they could be found approximately 130 km to the southwest of Igloolik in 2006). Described as part of natural migration patterns, the location of the caribou exacerbated difficulties posed by sea ice conditions.

Adaptive capacity of the food system

In light of compromised access and availability of traditional foods in summer and fall 2006, participants in the study identified having to purchase more store food to meet their dietary needs (Fig. 7). For elders, mature hunters and those with a strong connection to the land-based economy, switching to store-bought foods was not considered an equal trade-off. Traditional foods are preferred because they are believed to better tasting and have cultural significance. Moreover, the health and nutritional benefits of consuming traditional foods are widely noted (Van Oostdam et al. 2005). Shortages of traditional foods were identified as being less of a concern for many youth in the community who already rely on store food for a large portion of their dietary intake; a trend documented in small Inuit communities across the Canadian north and in previous research in Igloolik (Ford et al. 2006b; Kuhnlein and Receveur 2007).

Moreover, for those who eat traditional foods and have limited access to financial means, switching to store-foods is often not an option due their cost. The cost of basket of food in Igloolik for family of four per week in 2005, for example, was $286 or twice the cost of Ottawa (INAC 2006), and average income during the 2001 census was less than two-thirds the Canadian average (Table 1, 2). Using data from Anderson and Garlich-Miller (1994), to substitute 1 kg of walrus meat with store food would cost approximately ten dollars in 1994 prices. Participants described those who did not have enough money to purchase food having to rely on family members to share store food, use the food-bank, purchase poor-quality store-food, and some reported going without food for a couple of days. Even for those who could afford store food, the stress placed on household income of relying on purchased food reduced financial resources available to support hunting activities, reinforcing the negative impacts of ice conditions (Fig. 7). Having to utilize more store food also had implications for the quality dimension of food, compromising access to food with cultural value.

In previous years, the sharing of traditional foods has maintained food security in light of environmental stress (Ford et al. 2006a). It was noted that sharing was also important in 2006, supplementing the diet of those who were not able to hunt or successful in procuring traditional food. For example, even though the summer walrus hunt was limited, those who were successful described sharing the meat with those who 'craved walrus meat' but had none, and those who had traditional foods stored during fall reported sharing with others. Sharing was described as mostly occurring in the extended family unit but also with friends. Compared to previous years, however, the extent to which sharing was able to offset traditional-food shortages for those without access was limited. Particularly for walrus in summer and caribou in fall, many community members were affected equally hard with little meat to be re-distributed through sharing networks.

Multiple stresses and vulnerability in 2006

Non-climatic stresses, exposure-sensitivity, and adaptive capacity

Climate-related conditions are only one factor affecting food security (Fig. 7). Non-climatic stresses exacerbated the implication of climatic extremes for food security in 2006. As previously noted, access to financial resources is a major determinant of the ability to hunt, procure

Table 2 Price and income trends for the period 1991–2006

Item	% increase 1991–2001	Average increase per year 1991–2001	% increase 2001–2006	Average increase per year 2001–2006
Gasoline[a]	11	1.1	35	7
Food[a]	15	1.5	10	2
Shelter[a]	11	1.1	18	3.6
Household heating fuel[a]	22	2.2	50	10
Average per capita earnings[b]	20	2	n/a	n/a
Median income[c]	n/a	n/a	26	4.3

[a] Price data for 1991–2006 are from Yellowknife, Northwest Territories, and can be assumed to be broadly representative of prices in Nunavut. Systematic price data in these categories are not published for Nunavut. Data from Statistics Canada

[b] Average earning data are specific to Igloolik and are taken from the 1991, 1996, and 2001. The 2006 census switched to measuring median income and is not reporting average earnings

[c] Median income was measured in the census only in 2001 and 2006

traditional foods, and cope with environmental variability and change. In 2006, participants identified increasing gas and commodity prices as one of main external conditions affecting household finances, a trend that has affected communities in Northern Canada particularly hard since the early twenty-first century (Table 2). It is largely in the context of climatic stresses, particularly the need for increased travel to access hunting areas and locate locally-important wildlife-species, that increasing prices have had their largest effect on the food system. In summer 2006, hunters used extra gasoline searching (largely unsuccessfully) for walrus along the coastline of northern Foxe Basin at the same time that gasoline prices were high. The impacts on food security were described as being particularly pronounced for hunting households with limited access to financial resources. They had difficulties affording gas to go hunting and had limited ability to buffer reduced traditional-food consumption by purchasing store food. Those who had financial means to afford the extra costs of hunting, the stress on financial resources reduced the ability to purchase store food.

> "The high cost of gas has really affected the people of Igloolik. Some people go without food for days … it really takes its toll when you can not buy gas to get the [traditional] food which to us is cheaper than [the] store [food]." Abraham Ulayuruluk

Compounding non-climatic stresses, the economic burden imposed by ongoing exposure to climate change has added additional strain. Ford et al. (2006a) and Laidler et al. (2008) for example, report loss and damage to hunting equipment in Igloolik since the impacts of climate change were first observed in the mid- to late 1990s. Commercial insurance is difficult to obtain and costly for hunting equipment and the loss and/or damage of major capital investments (snowmobiles cost in the range of $10,000) has strained household finances, reducing the resources available to resist and recover from climatic events. It is within this context that Igloolik households experienced the sea ice conditions and economic stresses in 2006.

Increasing prices and the economic impacts of adapting to climate change have been particularly problematic for Inuit in northern Canada. Food in the North is expensive, with high levels of poverty, unemployment, and a large number of community members dependent on welfare (Myers et al. 2004) (Table 1). Households in Nunavut, for example, spend twice as much of total household expenditures on food compared to the rest of Canada and households spend approximately double what Canadians do on heating (Rogan 2003). Moreover, the income of many community members has failed to keep pace with rising costs (Rogan 2003) (Table 2).

Underlying vulnerabilities

The implications of climatic extremes in 2006 also have to be situated in the context of changes at the societal level which have been occurring over the last half century in northern Canada—what Chapin et al. (2006) term 'slow variables' and Liu et al. (2007) 'legacy effects.' The general trend in Igloolik, and across Nunavut, is one of changing community dynamics: fewer young people are hunting, the population of settlements is rapidly expanding, traditional land and food preparation skills are being transferred less, sharing relationships are under strain, there is a high prevalence of social problems including addiction and suicide, and community members are increasingly dependant upon the formal economic sector (Wenzel 1995; Damas 2002; Henshaw 2007). The last point is particularly salient. Time availability is an important determinant of adaptability to environmental stress in Igloolik. Adaptations documented in 2006 and in other years involved traveling longer distances to access caribou hunting areas and char fishing lakes, waiting until ice conditions improved, and searching along the coastline for walrus. Those with full or part time jobs described not have the time to respond in this manner, thereby reducing the ability to hunt and procure traditional foods. The erosion of land skills among younger Inuit was also an important factor in 2006, with young participants describing lacking the skills to safely use the ice until it had fully formed in early December. And while sharing-food remains important, many participants voiced their concerns that they can no longer rely on the nuclear or extended family for adequate sharing of traditional food during periods of stress. Not all these trends are increasing vulnerability however. Increased reliance on store food, for instance, has decreased food system exposure-sensitivity to changing climatic-conditions, especially among younger Inuit.

Discussion

The year 2006 stands out in the instrumental record and in the traditional knowledge of Igloolik Inuit as a year of extreme climate-related conditions. Climate-change scenarios indicate that such extremes will become the norm in Igloolik and the Canadian North in general with climate change (Ford et al. 2008b). Simulations of ice-response to rising temperature in northern Foxe Basin by Dumas et al. (2006), for example, indicate that by mid-century ice duration will decrease by approximately 49 days compared to the 1970–1989 mean, with freeze up projected to occur in mid- to late November. It is also reasonable to assume that snowfall will increase in a warming climate, and higher temperatures in fall will increase the occurrence of 'powdery snow' similar to what Igloolik caribou hunters noted in 2006 (Walsh and Chapman 2007). By examining how community members experienced and responded to climate-related conditions in 2006, and identifying the actual processes shaping vulnerability, this case study provides real-time insights into how climate change might affect food security, establishing a baseline for identifying and characterizing processes that are likely to shape future vulnerability.

Firstly, neither climate-related conditions nor human stresses alone would have resulted in compromised food-security in 2006, but their consequences were heightened by their interaction. In recent years, Inuit in Igloolik have been struggling with the effects of rising gas and commodity prices and the economic burden of adapting to a changing climate. Sea ice conditions in 2006 compounded these stresses, overwhelming the adaptive capacity of many community members and compromising food access and availability. Adaptive responses which Inuit previously utilized to manage climate stress—and documented by Ford et al. (2006a)—were not accessible to many due to financial reasons. Study participants described themselves as caught in a 'food trap' in summer and fall 2006, unable to afford to adapt to climatic extremes and unable to offset traditional foods with store-food. Moreover, the interaction of climatic and non-climatic stresses in 2006 occurred in the context of underlying vulnerabilities in the community, a consequence of long-term changes in Inuit livelihoods and community dynamics.

Secondly, the implications of climate change for food security may be moderated or exacerbated through dynamic interactions with local resource use patterns, wildlife ecology, community dynamics, and social and economic context, alongside the nature of changing climatic conditions. For example, if the trend towards reduced dependence on traditional foods among younger generations continues—while having potential negative nutritional, cultural, and health effects—it could reduce dependence on climate sensitive resources and hence decrease exposure-sensitivity and vulnerability to changing climatic conditions. While transportation of store-foods to small isolated communities is affected by vagaries of the weather, store-food availability, access, and quality is less exposed-sensitive to climate-related conditions. Indeed, the diversification of Inuit food consumption in recent decades away from complete reliance on traditional foods has reduced exposure-sensitivity to environmental fluctuations, and increased security against the most serious manifestations of food insecurity including starvation (recorded as late as the 1950s in Nunavut). Similarly, if climate change affects the population of wildlife resources of minimal importance in community diet or affects accessibility to hunting areas at non-critical times, then even significant changes in climate may have limited local effects on food security. For instance, future negative effects of climate change on walrus availability and/or access (similar to 2006) could be minimized by the continued decrease in importance of walrus meat among Igloolik's younger generations. Equally, relatively minor changes in climate may have a disproportionate effect on food security if change negatively affects hunting-access routes at key times of the year, nutritionally-important wildlife species, or if there is negative synergy with non-climatic stresses. If seal hunting was to be negatively affected for instance, the implications would be serious given the widespread appeal of seal meat, and the use of seal as a food source all year round.

Thirdly, and a corollary of the first two points, the case study indicates that there will be 'winners' and 'losers' as the climate changes along with people who will be largely unaffected. Winners will be able to take advantage of new opportunities without having to compromise food-access, availability, and quality. In 2006 those who access to boats and the money to purchase gasoline were able to take advantage of the long open-water period. Losers will have difficulty maintaining individual and household food-security and will be vulnerable to short-term and chronic food-insecurity as the climate changes. The case study indicates that access to financial resources will be a major factor in determining winners and losers, alongside social networks and traditional knowledge—an observation noted in different geographic contexts (Huntington et al. 2007; Leary et al. 2008). There will also be community members and households whose food security will be little affected by changing climatic conditions, particularly those who largely rely on store-food for their diet.

Fourthly, scaling-up the findings of this study to understand the vulnerability of Inuit food systems in the Canadian Arctic to climate change, a number of key points can be made. The specific nature of vulnerability will differ by community across the Canadian north. Food systems, in terms of the balance between traditional and store foods and the nature of food production, processing, distribution, preparation, and consumption, vary between region and community, and will result in differential exposure-sensitivity and adaptive capacity. Notwithstanding, research across Inuit regions of northern Canada—and North America—has indicated similar processes and drivers of climate change vulnerability to those identified here (Pearce 2005; Pratley 2005; Ford et al. 2006b; Furgal and Seguin 2006; Gearheard et al. 2006; Nickels et al. 2006; Riewe and Oakes 2006; Furgal and Prowse 2008; Huntington et al. 2007). While the aforementioned research is not concerned with food systems per se, it indicates that the insights from this study could be broadly applicable to small Inuit communities in the North.

Fifthly, this study provides a snapshot of the drivers of food insecurity at a *specific* moment in time. The dynamic nature of food insecurity revealed during 2006 indicates the need for longer term monitoring of how the food system responds to climatic and non-climatic stresses. Longitudinal studies are essential in human dimensions of climate-change research allowing characterization of the complex interplay between human and natural drivers of food insecurity, and allowing long term cumulative impacts to be specified. Such studies should be a focus of research endeavor to uncover the links between climate change and food-security outcomes.

Conclusion

This paper developed a model to assess food-system vulnerability to climate change. The model is generally applicable in climate change–food security studies in food systems with agricultural *and* subsistence components. In the case study from Igloolik, the model structured empirical analysis of the processes, conditions, relationships and feedbacks shaping food-system vulnerability during extreme climate-related conditions in 2006. The study demonstrates that the link between climatic conditions and food-security outcomes is rarely simple but is mediated by complex interaction between multiple stresses affecting coupled human–environment systems, influenced by factors at different spatial–temporal scales and shaped by internal system dynamics, and establishes a baseline for identifying and characterizing processes that are likely to shape future food-system vulnerability.

It is noteworthy that the results presented in this paper are a preliminary analysis of food-system vulnerability to climate change in Inuit food systems. The study raises a number of important research questions. Firstly, the study is a snapshot of community experience and response to climatic extremes in 2006; the long-term implications of cumulative climate-change impacts for food security (and health) remain unknown. For example, improved climatic conditions for walrus hunting in 2007 moderated some of the potential longer-term effects of climatic extremes in 2006. If extreme conditions had also occurred in 2007, would the impact on food security been magnified? Did the stress of adapting to extremes in 2006 reduce resources available to resist and recover from future extremes? How have adaptations utilized in 2006 affected adaptive options available for responding to future extremes? Continued monitoring and assessment of food-system vulnerability is being undertaken to provide insight on these questions. Secondly, more case studies are necessary to develop a broader understanding of food-system vulnerability to climate change. Thirdly, comparative analysis between case studies is required to develop more general ideas about relationships between food security and climate change. Finally, research into policy options to address vulnerability determinants should be a priority given the documented negative health-implications of climate change on food insecurity.

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