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Article *in* EcoHealth · September 2010

DOI: 10.1007/s10393-010-0344-8 · Source: PubMed

2 authors:

Sonia Wesche

University of Ottawa

Laurie Hing Man Chan

University of Ottawa

EcoHealth 7, 361–373, 2010
DOI: 10.1007/s10393-010-0344-8

ECOHEALTH

Original Contribution

Adapting to the Impacts of Climate Change on Food Security among Inuit in the Western Canadian Arctic

Sonia D. Wesche[1,2] and Hing Man Chan[1]

[1]*Community Health Sciences, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9, Canada*
[2]*Métis Centre, National Aboriginal Health Organization, Ottawa, ON K1P 5Z9, Canada*

Abstract: This study examined critical impacts of climate change on Inuit diet and nutritional health in four Inuit communities in the Inuvialuit Settlement Region, Western Arctic, Canada. The first objective was to combine data from community observation studies and dietary interview studies to determine potential climate change impacts on nutritional quality. The second objective was to address the scale of data collection and/or availability to compare local versus regional trends, and identify implications for adaptation planning. Information was compiled from 5 reports (4 community reports and 1 synthesis report) of climate change observations, impacts and adaptations in 12 Inuit communities (2005–2006), and from a dietary report of food use from 18 Inuit communities (1997–2000). Changing access to, availability of, quality of, and ability to use traditional food resources has implications for quality of diet. Nutritional implications of lower traditional food use include likely reductions in iron, zinc, protein, vitamin D, and omega-3 fatty acids, among others. The vulnerability of each community to changing food security is differentially influenced by a range of factors, including current harvesting trends, levels of reliance on individual species, opportunities for access to other traditional food species, and exposure to climate change hazards. Understanding linkages between climate change and traditional food security provides a basis for strengthening adaptive capacity and determining effective adaptation options to respond to future change.

Keywords: climate change impacts, adaptation, food security, Inuit, community health, scale, nutritional health, Inuit nutrition

Introduction

Whereas climate change has widespread effects on communities globally, indigenous peoples who rely on traditional, locally harvested foods are especially vulnerable. Canadian Inuit are experiencing challenges to their food security, with consequences for nutritional composition in their diets and other aspects of well-being. The identification of feasible adaptation options, such as other available traditional wildlife species, and improved understandings of local and regional trends are urgently required for maintaining food security under changing and uncertain conditions.

Food systems encompass a set of dynamic human-environment interactions that result in the production, processing, distribution, preparation, and consumption of food (Gregory et al., 2005; Willows, 2005). This holistic

Published online: August 3, 2010

Correspondence to: Hing Man Chan, e-mail: lchan@unbc.ca

perspective recognizes sociocultural meanings as an important aspect and moves beyond the common focus on food production. This approach provides a basis for understanding the multifaceted relationship between food and well-being.

The Food and Agriculture Organization of the United Nations defines food security as existing "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." Food security is a determinant of human health (McIntyre, 2003, 2004; Public Health Agency of Canada, 2004; Tarasuk, 2004) existing at multiple levels of social organization: individual, household, national, regional, and global (FAO, 1996). The World Health Organization recognizes three pillars of food security: food availability (sufficient quantities consistently available), food access (resources and ability to obtain healthy foods), and food use (knowledge and safe environment for appropriate use) (World Health Organization, 2007).

The traditional food security of indigenous peoples has additional dimensions. Paci et al. (2004) defined northern traditional/country food security as "the continued and predictable availability and access to food, derived from northern environments through indigenous cultural practices." This definition stresses the importance of the food system from a social perspective, acknowledging the importance of all aspects of harvesting, preparing, and consuming traditional foods. Sharing is an important cultural practice, and although it helps to spread the risk of food deficiency (Berkes and Jolly, 2001), sharing also acts as a mechanism for social bonding. The Inuit relationship to traditional food must be recognized not only for its importance for physical health, but also for its connection to emotional, spiritual, social, and cultural well-being.

Building on the models developed by Gregory et al. (2005) and Ford (2009), this paper proposes that four main aspects of food security be recognized as a means of understanding the importance of social and environmental factors relevant to traditional aboriginal food systems. These include food availability, access, quality, and use. The primary impacts of environmental change are on availability, access, and quality, whereas changing livelihoods and intergenerational knowledge transmission have impacts on access and the ability to use (harvest, prepare, and consume) traditional foods. Food security is continually in flux as Inuit livelihoods and environmental conditions continue to change and evolve. In the Arctic, Inuit are part of a global-scale nutrition transition (Kuhnlein et al., 2004). Whereas market foods now make up more than half of Inuit dietary intake (Kuhnlein et al., 2000), the consumption of traditional foods remains important to local livelihoods, key to dietary quality (Kuhnlein and Receveur, 2007), and an essential component of Arctic food security (Lambden et al., 2007).

Traditional food consumption helps to provide both the intake of many essential nutrients, vitamins, and minerals, and to reduce the intake of the saturated fats, sucrose, and excess carbohydrates that often are found in store-bought alternatives. The traditional food portion of the diet provides Inuit with high levels of protein, omega-3 fatty acids, riboflavin, pyridoxine, iron, zinc, copper, magnesium, potassium, and phosphorous (Berti et al., 1999; Kuhnlein et al., 2000). Even a single portion of food derived from local animals is found to increase levels of important nutrients (Kuhnlein and Receveur, 2007). In contrast, shifts away from traditional foods have been linked with increases in obesity (Kuhnlein et al., 2004).

A recognized link exists between externally induced impacts of change, indigenous food security, and health (Cannon, 1995). Climate change in particular is an important stressor for food systems (ACIA, 2005; Gregory et al., 2005; IPCC, 2007). Impacts on northern traditional food species are of particular concern to Inuit who derive subsistence from them, with implications for nutrition and diet (among others; Guyot et al., 2006; Lambden et al., 2007; Nancarrow, 2007; Ford, 2009).

Some work has been undertaken to look at the qualitative aspects of indigenous food security in relation to climate change, but there is limited work that explicitly links environmental change with nutritional implications for Inuit. This paper examines critical impacts of climate change and implications for Inuit diet and nutritional health in four communities in the Western Arctic to determine both regional and community-based trends. The first objective is to compare observations of climate change impacts on traditional food species, with dietary data to determine potential climate change impacts on nutritional quality. The second objective is to address the scaling issue between regional trends and local concerns, and to identify implications for adaptation planning. While recognizing that improving the quality/quantity of market food is a key solution for all communities, we provide a regional case study analysis using primary data focusing on potential alternative traditional food species. The goal is to use the data to develop local and regional adaptation plan and to demonstrate the interdisciplinary approach required to study impacts of global climate change on ecohealth in the Arctic.

Methods

Our analysis is based on the results of two pre-existing studies that depict trends across Canadian Inuit regions. The first source a set of four community reports and one synthesis report from a study of Inuit perspectives on climate change in 12 Inuit communities across the 4 Arctic regions (Community of Aklavik et al., 2005; Community of Holman Island et al., 2005; Community of Paulatuk et al., 2005; Community of Tuktoyaktuk et al., 2005; Nickels et al., 2006). Participatory workshops were held in each community to document Inuit-observed changes in the Arctic environment, and results were categorized into three main sections: observations, impacts, and adaptations. Based on overlaps in community-level information between the dietary and environmental change source data sets, four communities were selected for this study: Aklavik, Tuktoyaktuk, Paulatuk, and Ulukhaktok (Holman). These communities are all located in the Inuvialuit Settlement Region in the Northwest Territories, Canada (Fig. 1). The second source is a detailed report of dietary data from 18 communities across the 4 Inuit regions in the Canadian Arctic: Inuvialuit, Nunavut, Nunavik, Nunatsiavut (Kuhnlein et al., 2000). Research was undertaken from 1997 to 2000 using multiple methods (harvest calendars, 24-h recalls, food frequency interviews, 7-day food records, sociocultural interviews, food perception interviews, and analyses of nutrient and contaminant content in foods), with a specific focus on documenting the benefits of traditional food use.

Community-scale information on community characteristics (e.g., harvesting activities, food cost, etc.), traditional food consumption patterns, and nutritional outcomes was extracted from Kuhnlein et al. (2000) for the four case-study communities and documented in tabular format. Concurrently, community-scale observations of climate-related changes and impacts on traditional food species (related to the ability of residents to harvest and consume them) were extracted from both the community and synthesis reports and documented in tabular form (Community of Aklavik et al., 2005; Community of Holman Island et al., 2005; Community of Paulatuk et al., 2005; Community of Tuktoyaktuk et al., 2005; Nickels et al., 2006). Comparative analyses were undertaken for the traditional food species identified as being both impacted by climate change and an important component of the Inuvialuit diet. The community-scale model developed by

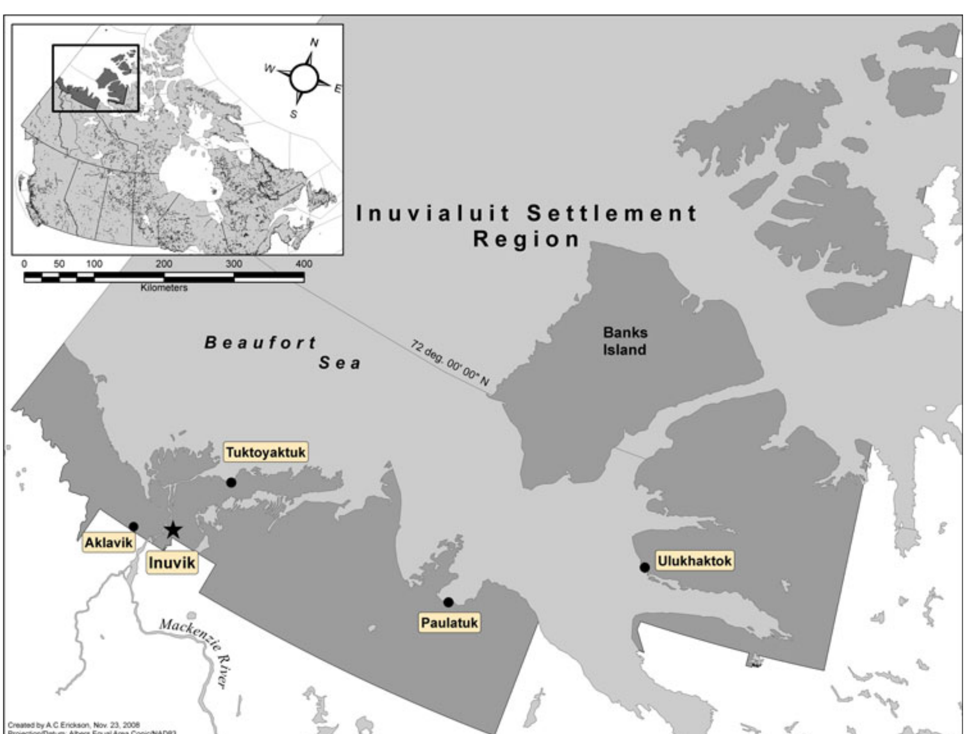

Figure 1. Map of the Inuvialuit Settlement Region indicating the location of the four case study communities in relation to the nearest urban centre, Inuvik.

Guyot et al. (2006) and Nancarrow (2007), which links dietary data and environmental change data in two Nunavut communities, provides a useful basis for linking such information over a larger geographical range (Table 1).

All four Inuvialuit communities selected for this study are small and remote, without year-round road access to Inuvik, the nearest urban regional center. Tuktoyaktuk is the largest with 956 people and Paulatuk the smallest with 324, and all are populated mostly by Inuvialuit (Table 2). Although each community has at least one grocery store, the cost of living—and particularly of food—is significantly higher than in urban regional centres and in cities in southern Canada. Inuvialuit culture is tied to the land and remains strong in these communities. A significant proportion of the population participates in traditional food harvesting activities, and between 35.5% and 51.9% of households report that most or all meat consumed comes from the land (Northwest Territories Bureau of Statistics, 2007a, 2007b, 2007c, 2007d). Alternative traditional food species available in the region and with similar nutritional composition were considered and suggested as possible substitutions.

Table 1. Example of model linking dietary and environmental change data (adapted from Nancarrow 2007)

Observation	Consequence	Country food	Nutrients affected
Thinner ice	Use boat earlier	↑ fish	Vitamin D, protein, ω-3 fatty acids
		↑ caribou	Iron, zinc, protein
		↑ seal	Iron, protein, ω-3 fatty acids

Results

Psychologically, the land is seen as less accessible overall, and hunting activities are associated with more fear and uncertainty than before, particularly by the younger generation (Community of Paulatuk et al., 2005).

Inuvialuit elders and harvesters hold substantial detailed knowledge about the land and the relationships between and among its inhabitant species. Traditional knowledge holders have documented a number of environmental changes occurring in the traditional territory around their communities, and many of the same changes are documented in different areas across the region. Climate-related changes observed in at least three of the four communities include increased variability and unpredictability of weather patterns, stronger or more frequent winds, changes in prevailing wind direction, fewer extreme cold winter temperatures, increased rainfall, decreased snowfall or snow pack, thinner ice, earlier ice break-up, later ice freeze-up, increased coastal erosion, lower freshwater levels, decreased wildlife health, and the appearance of new wildlife and plant species. At the same time, certain trends are more community-specific, only being documented in one or two communities (Table 3a, b; Nickels et al., 2006). These changes have impacts on aspects of species abundance, movement and migration patterns, behavior, and health. Additionally, they impact harvesters' movement on the land and access to hunting and fishing grounds. Local observations reported during community workshops linked specific environmental changes to harvesting outcomes for a range of traditional food species (Table 3a, b).

To assess the impacts of climate change on traditional foods in Inuvialuit diets, it is essential to understand which species are most important to residents in each of the four

Table 2. Profiles of communities addressed in this study (Northwest Territories Bureau of Statistics 2007a, 2007b, 2007c, 2007d)

Community	Population (2007)	Aboriginal population, % (2007)	Individuals who hunted and fished, % (2003)	High household country food consumption, % (2003)	Average family income (2006)	Unemployment rate, % (2006)	Cost of living difference (Edmonton = 100; 2005)	Food price index (Yellowknife = 100; 2004)
Aklavik	629	95.1	49.3	35.5	$55,813	22.9	162	183
Tuktoyaktuk	956	97.1	56.9	49.5	$56,724	33.3	162	206
Paulatuk	324	82.4	49.5	51.9	$46,757	28.0	167	222
Ulukhaktok	406	98.7	76.1	45.8	$56,770	22.2	167	188

Table 3. Examples of regional- and community-scale trends of observed changes in climate-related phenomena and related food security impacts (Community of Aklavik et al., 2005; Community of Holman Island et al., 2005; Community of Paulatuk et al., 2005; Community of Tuktoyaktuk et al., 2005; Nickels et al., 2006)

		Aklavik	Tuktoyaktuk	Paulatuk	Ulukhaktok	Examples of food security-related impacts
(a) Regional trends						
Weather	Variable and unpredictable weather	√	√	√	√	Reduced travel safety Reduced access to harvesting areas Shorter hunting trips
	Stronger/more frequent winds	√ (S)	√ (S)	√	√	Reduced travel safety limits fishing and hunting
	Prevailing winds shifted	√		√	√	Potential effects on travel safety and planning
Temperature	Fewer winter extreme cold temperatures	√		√	√	Increased ease of travel
Precipitation	Increased rainfall		√	√	√	Reduced motivation and ease of travel
	Decreased snowfall/snow-pack	√	√	√	√	Reduced travel, especially during shoulder seasons Increased strain on polar bears and seals
Ice	Thinner ice	√	√	√	√	Reduced access to harvesting areas Shorter and fewer hunting trips Increased strain on seal health
	Earlier ice break-up	√	√	√	√	Reduced travel safety Reduced access to harvesting areas Shorter waterfowl hunting season Shorter fishing season Increased strain on seal health
	Later ice freeze-up	√	√	√	√	Reduced travel safety Reduced access to harvesting areas Delayed hunting season for caribou Delayed fishing season Prolonged hunting season for whale and seal
Land	Increased erosion	√	√	√		Reduced access to harvesting areas Reduced fish spawning due to sediment
Water	Lower freshwater levels	√	√		√	Reduced travel safety Reduced access to harvesting areas
Vegetation and wildlife	New species	√	√	√	√	Displacement of existing species Potential increase in harvesting opportunities
	Decrease in animal health	√	√	√	√	Reduced consumption due to contaminant concerns

Table 3. continued

		Aklavik	Tuktoyaktuk	Paulatuk	Ulukhaktok	Examples of food security-related impacts
(b) Community-specific trends						
Weather	Increased freezing rain		√	√		Reduced travel safety Drives caribou away
Land	Melting/thinner/less permafrost	√	√			Reduced travel safety Reduced berry habitat Reduced caribou wellbeing

Checkmarks indicate the communities where climate-related trends were reported; (S) indicates summer only.

case study communities (Table 4). To a large degree, the consumption level of specific species relies on, and changes with, seasonal availability. A significantly higher diversity of species is available and harvested during summer months compared with winter months.

Caribou provides a large portion of the total energy intake from traditional foods for these and other Inuit communities across the Canadian Arctic. Aklavik, Tuktoyaktuk, and Paulatuk rely very heavily on this species in summer, and in winter it is the only traditional food consumed at high frequency. Ulukhaktok show important but slightly lower consumption frequency over both seasons, with additional reliance on muskox and char in winter. All four communities regularly consume different types of fish and sea mammals, whereas birds and land plants show more selective importance.

Inuvialuit participants observed that environmental change affects various aspects of harvestability in both positive and negative ways. The general trend is that harvest levels for some of the most important traditional foods, including caribou, geese, fish, and whales, are declining due to changes in migration patterns and population numbers (availability), changes in the ability to travel to harvesting areas (access), or declines in species health (quality; Table 5). A reduction in consumption levels of these species has important nutritional implications, particularly related to nutrients that are difficult to replace with available and affordable market foods. Selected primary nutrients associated with individual traditional food species are indicated in Table 5. Trends for each species are discussed below.

Caribou (*Rangifer tarandus*)

A common theme across all Inuit regions is the concern about harvesters' access to and the availability and condition of caribou. Decreased travel and harvesting opportunities and inconsistent access due to changing migration patterns and distribution reduce the caribou harvest. It was observed that caribou often were thin due to changes in snow and ice cover that affect access to lichen, their primary food source. Furthermore, increased abnormalities in the meat, increased numbers of flies near the herds, and concerns about parasite infections have led the Inuit to be increasingly selective about meat quality for consumption (Nickels et al., 2006).

At the same time, caribou is the single most frequently consumed species across all regions in both summer and

Table 4. Significant frequency of traditional food consumption by species and season in the Inuvialuit Settlement Region (adapted from Kuhnlein et al., 2000)

		Aklavik		Tuktoyaktuk		Paulatuk		Ulukhaktok	
Category	Species	S	W	S	W	S	W	S	W
Land mammals	Caribou	VH	H	VH	VH	VH	H	H	M
	Muskox							H	H
Fish	Trout							M	
	Whitefish	M		M					
	Herring	H							
	Cisco			M					
	Char					H		H	M
Sea mammals	Beluga	M		H		M			
	Ringed seal							H	
	Bearded seal					M			
Birds	Diving ducks							H	
	Geese/swans			M		H			
Land Plants	Cloudberry	M		M					

Seasons: *S* summer, *W* winter.
Consumption: *VH* very high (more than twice per week during the 3 summer months or 3 winter months surveyed), *H* high (more than once per week), *M* moderate (2–4 times per month). Low (1–2 times per month) and very low (less than once per month) scores were excluded.

Table 5. Changing species harvestability trends and primary nutrient content of important traditional food species and species increasing in potential availability and accessibility in the Inuvialuit Settlement Region (adapted from Kuhnlein et al., 2000; Community of Aklavik et al., 2005; Community of Holman Island et al., 2005; Community of Paulatuk et al., 2005; Community of Tuktoyaktuk et al., 2005; Nickels et al., 2006; Health Canada, 2007; Nancarrow, 2007)

Species	Aklavik	Tuktoyaktuk	Paulatuk	Ulukhaktok	Primary nutrients
Caribou	↓ **caribou**	↓ **caribou**	↓ **caribou**	↓ **caribou**	Iron, zinc, protein
Muskox	↑ muskox	↑ muskox	↑ muskox	↑ **muskox**	Iron, protein, zinc
Fish	↓ **(whitefish, herring)**	↓ **(whitefish, cisco)**	↓ **char**	↑ cod	Vitamin D, protein, ω-3 fatty acids
		↑ salmon, jackfish, char, cod	↑ salmon		
Waterfowl	↓ ducks	↓ ducks		↓ **king eider**	Protein, iron, copper
		↑ water fowl		↑ common eider	
Seals		↑ seals	↓ **bearded**	↓ **ringed**	Iron, protein, selenium, zinc
Whales	↓ **(beluga)**	↓ **(beluga)**	↑ **(beluga)**		Selenium, ω-3 fatty acids
		↑ bowhead			
Berries		↓ **(cloudberries)**		↓ berries	Vitamin C, phytochemicals
Moose	↑ moose	↑ moose			Iron, zinc, protein, selenium
Beaver	↑ beaver	↑ beaver			Iron, zinc, protein, selenium
Geese		↓ **geese**			Protein, iron, zinc, copper

Species groupings are presented in order of observed trends, from regional trends (across all communities) to community-specific trends.
Bolded species names are those that are both consumed at medium to very high frequency by community and for which changes in harvestability have been observed.
Bracketed species names are inferred from Table 4.

winter. Proportional averages of community populations that consume caribou exceeded 92% for all regions, with two thirds of the documented communities indicating a consumption frequency of more than once per week (Kuhnlein et al., 2000). The decline in caribou harvesting is particularly troubling during the winter months when the consumption of most other species tends to be very low, indicating that substitutability may be limited.

Muskox (*Ovibos moschatus*)

Muskox availability is shown to have increased in the vicinity of all four Inuvialuit Settlement Region communities. In response, two communities have increased their muskox harvest to compensate for declines in caribou meat (Community of Holman Island et al., 2005; Community of Paulatuk et al., 2005); however, muskox is generally less preferred (Nickels et al., 2006) and provides a slightly different (although comparable) combination of nutrients than caribou (Health Canada, 2007). Current muskox consumption levels are as follows: Aklavik—zero, Tuktoyaktuk—very low in winter only, and Paulatuk—low in winter only. Ulukhaktok is the only community that shows high frequency of consumption, and this occurs in both seasons. Residents in this community have embraced the usage of muskox beyond subsistence; increased availability has resulted in various forms of wage employment, including sports hunting, fur sales, and meat sales (Community of Holman Island et al., 2005). In contrast, some Inuit in Aklavik report negative feelings toward muskox because they scare away the caribou and are not interested in eating the meat (Community of Aklavik et al., 2005).

The amalgamated data for Inuvialuit communities show an interesting intergenerational trend in the consumption of muskox meat (already in the year 2000) that may indicate increasing acceptance by younger generations. Whereas elders (older than age 61 years) reported zero average intake, younger adults (women aged 15–40 years and men aged 20–60 years) reported intake of 26–33 g per person per day (Kuhnlein et al., 2000).

Beluga Whales (*Delphinapterus leucas*)

Aklavik and Tuktoyaktuk have a long history of beluga harvesting in the Mackenzie River estuary; Inuvialuit travel annually to traditional whaling camps along the Beaufort Sea coast (DFO, 2000). In contrast, beluga hunting in Paulatuk is less common. The community only formalized its beluga hunting in 1989, and harvest numbers have generally been quite low (DFO, 2000). However, Paulatuk hunters are reporting increases in recent harvests—the possible result of an eastward shift in the migration route (Community of Paulatuk et al., 2005).

Geese (*Branta canadensis*)

Geese provide an important food source for both Tuktoyaktuk and Paulatuk (Table 4). Residents of both communities indicate that the migration route for geese has shifted eastward, resulting in fewer birds in Tuktoyaktuk and a comparative increase in birds in Paulatuk. Although both communities describe shorter hunting seasons due to uncertain spring weather conditions and earlier ice break-up, only Tuktoyaktuk noted a directional change (decline) in harvest levels for geese (Community of Paulatuk et al., 2005; Community of Tuktoyaktuk et al., 2005).

Moose (*Alces alces*) and beaver (*Castor canadensis*)

Moose and beaver are noted to be increasing in availability in the vicinity of Aklavik and Tuktoyaktuk. Although neither of these species is commonly consumed in the Inuvialuit Settlement Region—except to some degree in Aklavik (Kuhnlein et al., 2000)—both, especially moose, are essential traditional food resources in other Aboriginal communities across the north (Receveur et al., 1997; Receveur et al., 1998) and elsewhere. These species offer potentially important options for Inuvialuit communities.

Discussion

The results of this study have multiple implications for food security and healthy diets in the Inuvialuit Settlement Region. They offer an understanding of the multiple variables at play at both local and regional scales. The nutritional outcomes of these changes and one possible adaptation option are examined, and the notion of scale is further explored.

Nutritional Implications: Impacts and Adaptation

Nutritional outcomes are an important result of reductions in harvesting and consumption of specific species. Existing downward trends among highly consumed species across the four Inuvialuit communities include the following *nutrients of concern*: protein, iron, zinc, vitamin D, omega-3 fatty acids, and selenium. Levels of copper, vitamin C, and phytochemicals also are a concern in some communities.

Of the *nutrients of concern* outlined above, average intake levels of two of these were already low for particular

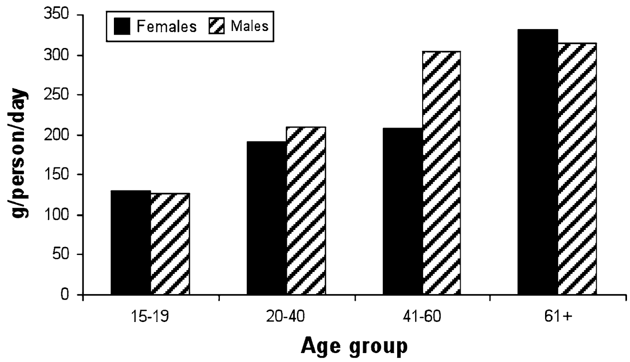

Figure 2. Estimated total intake of traditional food (g/person/day) averaged over fall and late winter for the Inuvialuit region, by sex and age group (adapted from Kuhnlein et al., 2000, pp 137–140).

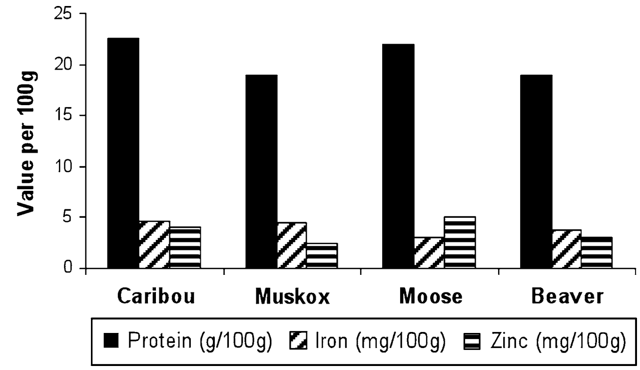

Figure 3. Protein, iron, and zinc levels in caribou and potential substitution species (data from Health Canada, 2007).

segments of the population during the late 1990 s (Kuhnlein et al., 2000) compared with current Recommended Dietary Allowances (RDA) or Adequate Intakes (AI) when RDAs are not available (Otten et al., 2006). Average intake levels for omega-3 fatty acids were low for Inuvialuit women between age 15 and 40, and borderline for most other groups. Average intake levels for selenium were low for all men and women older than age 14 years except elder men (61+ years; Kuhnlein et al., 2000). Although adaptation strategies should address these nutrients specifically, it is important for nutritional monitoring to continue as updated food use data becomes available (e.g., through the Inuit Health Study). Such approaches are especially important in response to the overall declining trend in the consumption of locally harvested food among Inuit and across the Arctic (Bjerregaard and Jørgensen, 2008), especially among youth and women of child-bearing age (Boult, 2004; Fig. 2).

Adaptation option: Species substitution

Maintaining significant levels of traditional food in the diet is important to Inuit (Kuhnlein et al., 2000), and access to these foods is essential for Arctic food security (Lambden et al., 2007). Substituting among food sources has historically been an important type of adaptation to changing food security, and it continues to be practiced in the Inuvialuit region (Nickels et al., 2006). In terms of traditional food, several wildlife species are reported to be increasing in availability by members of the Inuvialuit communities profiled in this study (Table 5). These may have potential as substitutes to offset declining harvestability of frequently consumed species.

Substitutions may be one of several options for maintaining food security and nutritional health. For example, concern about reduction in caribou harvest may be somewhat alleviated by the possible increase in comparable substitution species. It is useful to look at nutrient profiles to gauge whether consumption of these species will maintain nutrient levels. Upon comparison of the nutritional content of possible substitution species for declining caribou harvests, muskox, moose, and beaver all offer positive results (Fig. 3). All three substitutes contain similar levels of protein to caribou. Muskox has similar levels of iron, whereas moose and beaver have slightly less. Moose contains more zinc than caribou, whereas beaver offers approximately three-fourths the amount and muskox offers slightly more than half (Health Canada, 2007).

During the 18th and 19th centuries, muskox were widely harvested and consumed by Inuit until the Canadian government put them under complete protection in 1917 to avoid extermination. Populations have since recovered, with harvesting resuming under a quota system during the late 1960s (Government of the Northwest Territories, 2009). In the current era, while muskox has been deemed an acceptable food substitute in Ulukhaktok and is being harvested to a limited degree in both Paulatuk and Tuktoyaktuk, this transition has not yet taken place in Aklavik (Joint Secretariat, 2003; Nickels et al., 2006). Muskox harvesting for subsistence and sport may happen over time as populations increase and young Inuit develop a taste for the meat, as the frequency of consumption of particular traditional food species tends to be largely dependent on its availability within the region (Wein and Freeman, 1995).

Although some *nutrients of concern* may be available through substitution species, alternate sources for those found in sea mammal blubber and skin (*mattak*) are less readily available. These sources contain significant levels of important nutrients, such as retinol, tocopherol, ascorbic

Table 6. Examples of important regional- and local-scale variables for adaptation

Regional variables	Local variables
Macro-level climate conditions (e.g., temperature, precipitation, ice freeze-up, ice break-up)	Micro-level climate conditions (e.g., freezing rain, permafrost melt, shoreline erosion)
Large land wildlife species (e.g., caribou, muskox)	Migratory wildlife species (e.g., geese, fish, marine mammals)
Regional social networks (e.g., inter-community trading)	Vegetation (e.g., berries)
Oil and gas impacts (e.g., economic input, environmental disturbance, population size)	Level of traditional food use
Regional resource management policies (e.g., co-management)	Susceptibility to change of highly consumed traditional foods
	Local social norms and networks (e.g., food sharing, hunting practices)
	Food preferences

acid, n-3 fatty acids, and selenium, and a reduction in intake may result in nutrient deficiency in some individuals (Kuhnlein et al., 2000). Nutritionists and public health officials will need to develop feasible nutrition supplement programs.

Communities will have differential capacity to adapt depending on, for example, levels of dependence on traditional food species, other food options available (including purchased food), and the already demonstrated ability to adapt, which indicates an openness and resourcefulness to alter behavioral patterns as the need arises. Aside from food shifting or substitution, other existing adaptations include traveling further for caribou and intercommunity trading. In the past, community members often relied on other locally available, small game species (e.g., ground squirrels or "*sik sik*") to make up for a shortfall (Community of Paulatuk et al., 2005). The existing knowledge, skills and networks that facilitate such adaptations are important community "assets" that form a basis for capacity-building. As residents become more aware of the nutritional implications of the changing harvestability of traditional food, and opportunities for substitutions, their ability to choose healthy adaptation options will improve. It is important to promote Inuit led initiatives and mobilization of Inuit lead strategies to help improve community health.

Issues of scale

Climate change modeling, used to predict future trends, tends to be regional in nature. As such, it is important to take a regional approach to adaptation. The above data shows that some of the observed changes and impacts are occurring across the region (e.g., less predictable weather, changing distribution of large wildlife species, etc.) and can be addressed at that scale. However, other challenges are specific to individual communities in the Inuvialuit Settlement Region and must be recognized and dealt with as localized trends.

Table 6 provides examples of variables that are important to adaptation, some of which are regional in nature, and others that are more community-specific. The development of regional food security models may require a combination of both regional- and local-scale data. This necessitates monitoring at different levels, incorporating both scientific and traditional knowledge.

Within a region, some communities may be more susceptible than others to changing food security. For example, the heavy dependence on a singular resource, such as caribou, may increase community vulnerability to food insecurity, especially when the species is prone to disturbance by climate change (Callaghan et al., 2004; Hinzman et al., 2005; Nancarrow, 2007). To gain an understanding of the nutritional importance of caribou in the diet, we can estimate the impact on specific nutrients that correlate with specific levels of species decline. Kuhnlein et al. (2000) report an average intake of approximately 100 g per person per day of caribou in the ISR, containing 32 g of protein (Health Canada, 2007). This equates to 57–62% of the RDA for men and 70% of the RDA for women (Otten et al., 2006). If, for example, we estimate a 50% decline in caribou harvest and consumption across the Inuvialuit Settlement Region, this would equate to a loss of approximately a third of overall protein intake in the diet, if foods of equal value were not eaten.

Despite the regionally observed decline in caribou, the staple species in the Inuvialuit Settlement Region, each of the four communities in this study is impacted to different degrees by changing harvestability of traditional foods. A combination of factors may affect community adaptability. Communities with a higher current level of dependence on traditional foods may find it more challenging to adapt as species harvestability declines. Tuktoyaktuk shows the

Table 7. Percent energy from traditional food and harvestability trends for frequently consumed species

	% households consuming traditional foods (most or all meat consumed)[a]	Frequently consumed traditional foods[b]	
		No. decreasing in harvestability	No. increasing in harvestability
Aklavik	35.5	3	0
Tuktoyaktuk	49.5	5	0
Paulatuk	51.9	3	1
Ulukhaktok	45.8	3	1

[a](Northwest Territories Bureau of Statistics, 2007a, 2007b, 2007c, 2007d)
[b]Table 5

highest overall consumption (in fall and late winter), whereas Ulukhaktok maintains high intakes throughout these seasons. Aklavik shows the lowest consumption (Table 7). On the other hand, where communities indicate a wider range of species that residents are accustomed to harvesting and eating, options for maintaining a healthy diet are likely improved (e.g., Tuktoyaktuk). Furthermore, where an already frequently consumed species is increasing in harvestability (e.g., Paulatuk and Ulukhaktok), the impacts of reductions in other species may be mitigated.

The community of Aklavik may actually be impacted the most from a nutritional standpoint because residents are already intaking the lowest levels of nutrients from traditional foods (Kuhnlein et al., 2000). Moreover, Aklavik also may be the community most resistant to species substitution. By contrast, Paulatuk and Ulukhaktok have already increased the harvest of previously less used or less available species, including beluga and muskox, respectively. And in Tuktoyaktuk the harvestability of bowhead whales appears to be increasing, offering a substitute for beluga. In these three communities (but not in Aklavik), there also were mentions of increases in certain fish species, offering further substitutability. More in-depth fieldwork is required to discern a clear trend in food security adaptability.

Conclusions

This work recognizes that adaptation planning based solely on regional-scale climate change models ignores the relevance of local-scale concerns and capacities, although this is the level at which adaptation occurs. We address this question by undertaking an intercommunity comparison within a particular case study region (the ISR) to better understand how the food security experiences compare among communities and to identify the relevant scales for monitoring and assessment of individual variables. Substantial complementary data has been documented for the ISR communities of Aklavik, Paulatuk, Tuktoyaktuk, and Ulukhaktok. This has allowed us to verify where significant overlap in observations between communities exists (or not) and determine whether we can justify extrapolating trends to a regional scale based on information from fewer communities in other regions. However, it should be noted that the nutritional data used is more than a decade old, and thus values may be different in current day.

This analysis of levels of harvestability and consumption of traditional food provides a basis for assessing different dimensions of food-related vulnerability and adaptability in the Inuvialuit Settlement Region. It also provides information on levels of traditional food dependence, alternate traditional food options, and existing adaptations (e.g., species substitution).

In addition to environmental factors, such as climate change, Inuit families face many challenges to food security, including low income levels, changing diets, high food costs, and lack of awareness of healthy eating habits (Boult, 2004; Guyot et al., 2006; Nancarrow, 2007; Ford, 2009). Community members face barriers to traditional food consumption, such as high costs of hunting, changes in lifestyle, and changes in cultural practices among Inuit (Chan et al., 2006; Lambden et al., 2006). Heavy dependence on caribou may further decrease options for maintaining traditional food intake levels, especially where species showing recent increases in harvestability are limited. These and other factors, such as food preference and food choice (Willows, 2005), must be considered in the adaptation planning process. The complexity of interrelationships among the multiple and multifaceted features affecting food security emerge when we address the issue from a holistic food systems perspective. The fourfold approach to the concept of food security described earlier in this paper (availability, access, quality, use) has allowed for a particularly useful analysis of the food security dilemma among Inuvialuit populations.

Although substitute species may provide an alternative form of important nutrients, they do not address people's food preferences. Caribou is clearly both the preferred food in Canadian Inuit communities across all regions. Furthermore, traditional harvesting skills, knowledge, and equipment are geared toward specific species, challenging the ability to harvest newly available species. Further qualitative work is required to assess the feasibility of incorporating higher levels of substitute traditional foods into the diet.

This paper offers some insight into the types of variables that are more localized and those that can be scaled-up to the regional level. Lessons from this study can be shared with other Arctic regions and other indigenous peoples who are facing similar challenges relating to environmental change.

Acknowledgments

We thank Crystal Lennie of the Inuvialuit Regional Corporation and the three anonymous reviewers for their helpful comments on an earlier version of this manuscript. We thank Ms. Tamara Charlie for her help in aggregating the data. Funding was provided by the Natural Sciences and Engineering Council of Canada through ArcticNet and the International Polar Year Program.

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