THE INUIT FOOD SYSTEM: ECOLOGICAL, ECONOMIC AND ENVIRONMENTAL DIMENSIONS OF THE NUTRITION TRANSITION

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ABSTRACT

From the Arctic to the South Pacific, Indigenous Peoples have experienced a rapid nutrition transition involving the decline of traditional/subsistence-based ways of life and the adoption of a "Western" diet that is high in saturated fats, sugar, and processed foods. This dietary shift has been paralleled by an increased prevalence of obesity, diabetes, and, other diet-related chronic diseases.

In the Arctic, rapidly changing biophysical conditions, globalization, and integration into market economies are collectively challenging access to both country foods and nutritious market foods. Food security and nutrient adequacy thus remain elusive for Inuit communities of northern Canada. Premised upon the view that human well-being is predicated upon complex and dynamic interactions between ecosystems, economies, and societies, this dissertation integrates multiple lines of inquiry and scales of engagement (community, regional, and national) to further understanding of the nutrition transition among Inuit in Canada. The thesis is comprised of two sections.

Section 1 bridges the often disparate fields of human nutrition and wildlife conservation by addressing key questions about the status and management of Arctic species, and the implications for Inuit food security and health. For example, caribou (*Rangifer tarandus*) populations across the circumpolar north are currently experiencing dramatic declines in abundance and restrictions on Inuit subsistence harvest are currently implemented for several caribou populations. Caribou, however, is the primary source of protein and several micronutrients involved in the prevention of anemia (e.g. iron zinc, copper, riboflavin, and vitamin B12) in the contemporary diet of Inuit adults. Caribou consumption is also positively associated with hemoglobin levels in Inuit adults.

Section 2 considers elements of the market food system in Inuit communities. We found that the most popular market foods consumed by Inuit (e.g. sweetened beverages, added sugar, and bread) contribute significantly to total diet energy while contributing minimally to most micronutrients. Using optimization models, we have demonstrated that a nutritious diet (one meeting Health Canada dietary reference intake values) is theoretically feasible based on a mix of country food and market food, and at relatively little additional cost from current diets. However, significant deviations in patterns of food expenditure away from sweetened beverages, towards dairy, and whole fruits and vegetables would be required.

Taken collectively, this thesis provides important information, as well as new tools, and approaches, for communities, wildlife conservation and public health professionals to jointly promote ecosystem and human health in a rapidly changing environment.

RÉSUMÉ

De l'Arctique au Pacifique Sud, les peuples autochtones connaissent une transition nutritionnelle impliquant le déclin des modes de vie axés sur la subsistance (par exemple, la chasse, la pêche et la cueillette) et l'adoption d'un régime alimentaire « occidental », qui favorise la consommation d'aliments du commerce (notamment, les aliments transformés et les aliments riches en glucides, sucre, et graisses saturées). Ce changement nutritionnel a donné lieu a une prévalence accrue de l'obésité et autres maladies chroniques liées à l'alimentation.

La transition vers une économie fondée sur la rémunération, la perte des savoirs traditionnels, ainsi que les changements biophysiques, écologiques, et sociaux dans l'Arctique, défient collectivement l'accès aux aliments sains pour les collectivités Inuites. Ainsi, l'insécurité alimentaire et la malnutrition constituent de défies particulièrement sérieux pour les Inuits. Cette thèse fondée sur la reconnaissance des interactions complexes et dynamiques entre les écosystèmes, les économies, et les sociétés (approche écosystémique à la santé) intègre de multiples pistes d'enquête dans le but de mieux comprendre la transition nutritionnelle chez les Inuits de l'Arctique canadien. La thèse comprend deux sections.

La première section se concentre sur le système alimentaire relatif aux aliments traditionnels. Cette section aborde plusieurs questions clés sur l'état et la gestion des espèces nordiques et les répercussions sur la santé et la sécurité alimentaire inuits. Le caribou (*Ranfiger tarandus*), par exemple, est la principale source de protéine, et plusieurs micronutriments impliqués dans l'érythropoïèse (par exemple, le fer, le zinc, le cuivre, la riboflavine et la vitamine B12) dans la diète contemporaine des Inuits. De plus, la consommation de caribou est positivement associée aux taux d'hémoglobine chez les adultes inuits. Cependant, plusieurs hardes de caribou circumpolaires sont en situation périlleuses avec des déclins significatifs au cours des dernières décennies.

La seconde section aborde le système alimentaire relatif aux aliments du commerce. Nous avons constaté que les aliments les plus souvent consommés par les Inuits (par exemple, les boissons sucrées, le sucre ajouté et le pain) contribuent de façon importante à l'apport énergétique, tout en contribuant de façon minimale à la plupart des micronutriments. À l'aide de la modélisation (optimisation), nous avons démontré qu'une saine alimentation est théoriquement réalisable selon un mélange d'aliments locaux et aliments provenant du marché. Cependant, des changements importants dans les dépenses alimentaires favorisant les produits laitiers, et les fruits et légumes entiers, sont nécessaires.

Cette thèse fournit des informations importantes, ainsi que de nouveaux outils et approches pour permettre aux communautés, aux gestionnaires de la faune, et aux professionnels de la santé publique, de promouvoir conjointement la santé humaine et la durabilité des écosystèmes dans un environnement arctique en évolution rapide.

ETHICS STATEMENT

Research presented in this dissertation conforms to all ethical standards of work with humans.

A certificate of Ethical Acceptability for the International Polar Year Inuit Health Survey (IHS) was granted by the McGill Faculty of Medicine Institutional Review Board. Informed consent was obtained from all participants of the Inuit Health Survey.

Ethical approval for secondary analysis of data from the Inuit Health Survey was granted by the University of Ottawa Health Sciences and Science Research Ethics Board (file number H05-15-16). Ethical approval for community based work in the Inuvialuit Settlement Region was granted by the University of Ottawa Health Sciences and Science Research Ethics Board (file number H01-14-10C).

Scientific Research licenses (license no. 15943) for the participatory and community-based work in the Inuvialuit Settlement Region were granted by the Aurora Research Institute (Inuvik, Northwest Territories).

Copies of the scientific research licenses and ethics approval letters are provided in the Appendix 1-2.

STATEMENT OF AUTHORSHIP & COLLABORATION

CHAPTER 3: TK performed the analyses, interpreted the data and drafted the manuscript. HMC oversaw the research, provided intellectual support, and feedback on the drafted manuscript. Research priorities were identified during a regional food security workshop in the Inuvialuit Settlement Region (Northwest Territories, Canada).

CHAPTER 4: TK conceived of the research question, compiled, analyzed, and interpreted the data and drafted the manuscript. MF, assisted with the study design and provided feedback on the drafted manuscript. SS provided support with the creation of the map. SDW and HMC oversaw the research, provided intellectual support, and feedback on the drafted manuscript.

CHAPTER 5: TK conceived of the research question, performed the statistical analyses, interpreted the data and drafted the manuscript. XH assisted with the statistical analyses and interpretation of the data and provided feedback on the drafted manuscript. JAJ collected data and analyzed iron status biomarkers, and assisted in the interpretation of the study results. HVK contributed to survey design and data collection, and interpretation of the results. SDW and HMC oversaw the research, provided intellectual support, and feedback on the drafted manuscript.

CHAPTER 6: TK conceived of the of the research question, conducted the analyses, interpreted the data and drafted the manuscript. XH provided guidance on the interpretation of the results, and input on the drafted manuscript. HVK contributed to survey design and data collection, and interpretation of the results. SDW and HMC oversaw the research, provided intellectual support, and feedback on the drafted manuscript.

CHAPTER 7: TK designed the study, trained the research assistants, prepared and analyzed the data and drafted the manuscript. MF provided guidance on the field work and data collection, and provided input on the drafted manuscript. JM contributed to the study design, supervised the data collection, and provided input on the drafted manuscript. SDW and HMC oversaw the research, provided intellectual support, and feedback on the drafted manuscript.

CHAPTER 8: TK conceived of the research question, prepared the data, developed and coded the models, interpreted the results and drafted the manuscript. SDW and HMC oversaw the research, provided intellectual support, and feedback on the drafted manuscript.

CHAPTER 9: TK was responsible for the development, coordination, and implementation of the project, and for drafting the manuscript. JM, PG, and SK collaborated on the development and implementation of the project in the community, and provided feedback on the drafted manuscript. SDW and HMC oversaw the research, provided intellectual support, and feedback on the drafted manuscript.

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ACRONYMS

AMAP	Arctic Monitoring and Assessment Program
ASF	Animal source food
CBD	Convention on Biodiversity
CNF	Canadian Nutrient File
FNDDS	Food and nutrient database for dietary surveys
FFQ	Food frequency questionnaire
Hb	Hemoglobin
IHS	Inuit Health Survey
IPY	International Polar Year
ISR	Inuvialuit Settlement Region
LP	Linear programming
MA	Millennium Ecosystem Assessment
MPA	Marine protected area
MUFA	Monounsaturated fatty acids
POP	Persistent organic pollutant
PUFA	Polyunsaturated fatty acids
RAE	Retinol activity equivalents
SES	Socio-ecological systems
WEP	Wild edible plant

Organizations

CINE	Centre for Indigenous Nutrition and Environment (McGill University)
FAO	Food and Agricultural Organization
IRC	Inuvialuit Regional Corporation
UN	United Nations
USDA	United State Department of Agriculture
WHO	World Health Organization (of the United Nations)

1 PREFACE AND INTRODUCTION

TiffAnnie Kenny

Chapter 1 opens the dissertation by elaborating the background, context, and rationale that inform the thesis research. The chapter outlines the aims and objectives of the research, the structure of the dissertation chapters, and provides an overview of the methodology and guiding principles of the research.

1.1 Background and Rationale

1.1.1 General Background

Health of Indigenous Peoples and the Nutrition Transition

Indigenous Peoples represent approximately 5% (370 million) of the world's total population, yet they account for up to one-third of the world's extremely poor, and some of the world's most disadvantaged and marginalized peoples (APF & OHCHR 2013). Furthermore, Indigenous Peoples experience significant disparities in health status relative to national, and non-Indigenous, averages (Valeggia & Snodgrass 2015), including in developed countries such as Canada (Adelson 2005). Indigenous Peoples reside in over ninety countries where diverse ecosystems have traditionally provided the foundation for diet, cultural identity, and social cohesion. Indigenous Peoples' traditional food systems include culturally significant and locally available foods (i.e. "traditional foods), as well as the technologies, beliefs, practices, traditional knowledge, and cultural institutions embedded within modes of food production, processing, and sharing (Kuhnlein et al. 2009).

From the Arctic to the South Pacific, Indigenous Peoples have experienced a rapid transition in diet and lifestyle (Popkin 1998; Popkin & Gordon-Larsen 2004). This change has involved the decline of traditional/subsistence-based ways of life, and the adoption of a "western" diet (i.e. high in saturated fats, sugar, and processed foods) (Albala et al. 2006; Port Lourenco et al. 2008; Kuhnlein et al. 2004; Hughes & Lawrence 2005). Declines in traditional food consumption have arisen consequent to many factors – from challenges to accessing traditional food species and harvest territories, to changing lifestyles and dietary preferences, to the loss of local and traditional knowledge (Kuhnlein & Receveur 1996; Kuhnlein et al. 2009).

The increased consumption of foods sourced from industrial and commercial processes has compromised the nutritional quality of the diet, and across the globe, the nutrition transition has been paralleled by an increased prevalence of obesity, diabetes mellitus type II, and other diet-related chronic diseases (Albala et al. 2006; Port Lourenco et al. 2008; Kuhnlein et al. 2004; Hughes & Lawrence 2005; Popkin 2001; Popkin & Gordon-

Larsen 2004; Dounias & Froment 2006; Dounias & Froment 2011; Kuhnlein et al. 2009; Kuhnlein & Receveur 1996). Indigenous Peoples, including those in developed countries, often reside in remote and/or rural regions, where the logistics of food retailing (e.g. high prices, and limited availability of nutritious perishable foods), coupled with low per capita income, collectively promote higher reliance on a limited diversity of non-perishable, and highly-processed foods (Kuhnlein & Receveur 1996; Ferguson et al. 2016; Hughes & Lawrence 2005). Indeed, Indigenous Peoples of Australia, the United States, and Canada pay some of the highest food prices in each respective country (First Nations Development Institute 2016; Ferguson et al. 2015; Duhaime & Caron 2012).

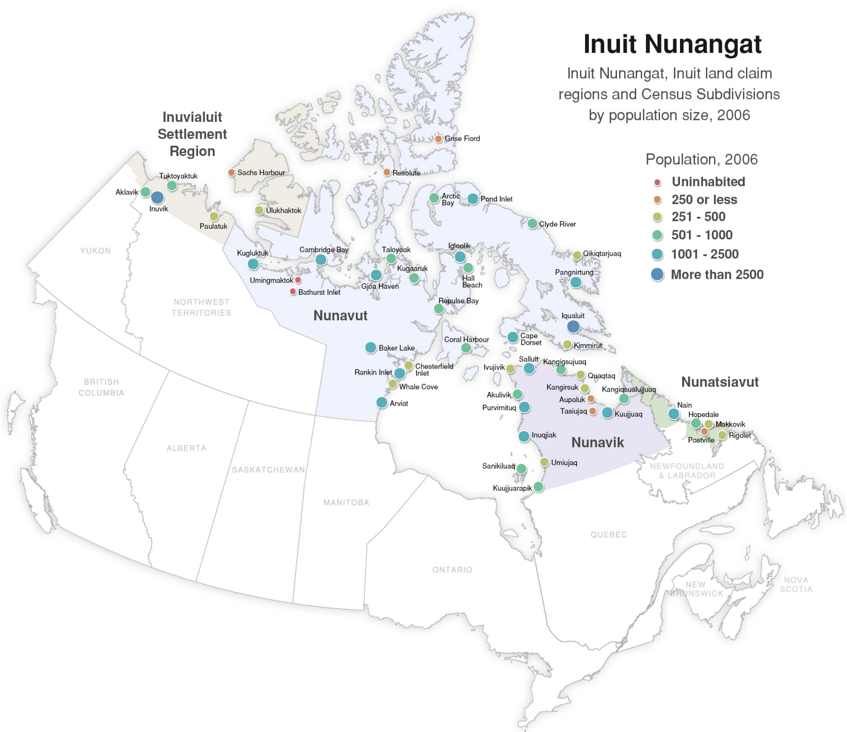
The maintained use of traditional foods and traditional food systems has been proposed as a means of mitigating these transitions (Powell et al. 2013). Indeed, the sustainable use of local biodiversity can be an effective and culturally-relevant approach to addressing current dietary challenges faced by Indigenous Peoples (Johns & Eyzaguirre 2007). However, the harvest of wild food for human consumption represents one of the most important global threats to wildlife populations (Bowen-Jones et al. 2003; Wilkie et al. 1998; Fa & Brown 2009; Brashares et al. 2004; Heinsohn et al. 2004). On an international scale, studies promoting the use of local biodiversity for human nutrition have been mainly carried out in areas of high local biodiversity and in low- and middle-income countries (Penafiel et al. 2011). Likewise, the literature on reconciling wildlife conservation and food security has largely favored the "bushmeat" context in the humid tropics of the Americas, Asia, and Africa (Golden et al. 2011; Fa et al. 2002; Davies & Brown 2008).

1.1.2 Context: The Inuit Food System

Using a case study of the Inuit food system in northern Canada, this thesis explores the ecological, economic, and societal factors underlying the nutrition transition among Indigenous Peoples. The magnified response of the Arctic to global environmental change, coupled with the importance of local ecosystems for various facets of life (culture, food security, health, economy) in the North, renders this case study a sensitive indicator of change in other global regions.

The land that is now considered Canada constitutes the homeland and traditional territory of over 1.1 million Indigenous Peoples. Indigenous Peoples in Canada are constitutionally recognized (section 35, Constitution Act of 1982) by three distinct cultural groups: First Nations, Inuit, and Métis. Adelson (2005) provides a comprehensive synthesis of the demographic profile of the Indigenous Population in Canada (Adelson 2005). Throughout the thesis, statements such as "Inuit in Canada" are made to provide geographic reference, however, the author acknowledges that Indigenous Peoples reside in their traditional homeland, foremost, rather than their residence in a post-colonial nation. The majority of the 59,445 Inuit people in Canada reside in the Inuit Nunangat (Figure 1.1), the traditional Inuit homeland (Statistics Canada 2016; Inuit Tapiriit Kanatami & Inuit Circumpolar Council 2010) comprised of four Inuit Land Claim regions from west to east: Inuvialuit Settlement Region (Northwest Territories), Nunavut (comprising the Kitikmeot, Kivalliq, and Baffin regions), Nunavik (northern Quebec), and Nunatsiavut (Labrador).

Figure 1.1 Map of the Inuit Nunangat, the Inuit Homeland in Canada



Source: (Canadian Environmental Health Atlas n.d.)

Lifestyle Change in the Arctic

The Arctic hosts some of the most extreme habitats and some of the lowest biodiversity and species richness on the planet (ACI Assessment 2004; Walker et al. 2001). Nevertheless, Inuit have been sustained by harvesting, trapping, fishing, and gathering local species (i.e. "country foods") for thousands of years (Nuttall et al. 2005).

Targeted policies and programs initiated by the federal government during the mid twentieth century to assert sovereignty over the Arctic, coupled with increasing commercial/economic interest in the development of Arctic resources, systematically undermined the sovereignty and wellness of Inuit communities (Bonesteel & Anderson 2008). Colonial programs, like the residential school system (Truth and Reconciliation Commission of Canada 2015), have enduring impacts on individuals and whole communities across the North. Consequently, Inuit have endured rapid lifestyle changes during the last several decades, including the relocation into permanent settlements, the development of a wage economy, and the introduction of market foods to remote northern communities (Akande et al. 2015). While most Inuit adults (74% to 80%, according to region) prefer to eat a mix of market food and country food (Egeland 2010a; Egeland 2010b; Egeland 2010c), greater reliance on market foods has led to excessive intakes of energy and carbohydrates, coupled with inadequate intakes of several micronutrients (namely dietary fibre, calcium, folate, and vitamins A, D, and E) (Kuhnlein et al. 2004; Egeland et al. 2011; Sharma 2010; Sharma et al. 2010; Erber et al. 2010). Furthermore, this dietary transition has been linked to increased incidence of obesity and unhealthy body weight (Kuhnlein et al. 2004; Sheikh & Egeland 2011).

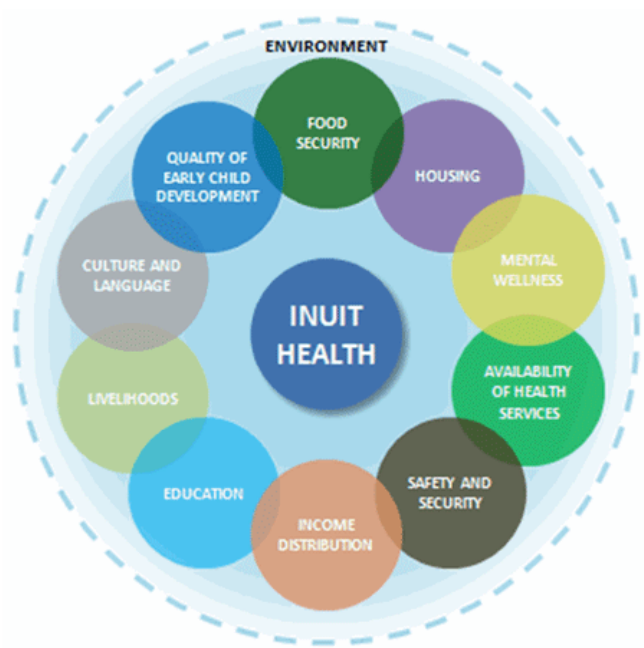
Inuit Health and Wellness

"Western diseases" (e.g. cancer, ischemic heart disease, stroke, diabetes, obesity) (Trowell 1981) are increasingly prevalent in the Inuit population. Lung cancer and colorectal cancer are extremely high among Inuit and have risen over the last few decades (Carrière et al. 2012; Young et al. 2016). Age-standardized mortality rates due to major chronic diseases in Inuit Regions of the Canadian Arctic are considerably higher than Canada as a whole (235.5

compared to 167.1 per 100,000, in 2004-2008) (Statistics Canada 2012). Significant health disparities between Indigenous populations and national non-Indigenous averages have been documented for much of the circumpolar regions (Bjerregaard et al. 2004), but have arguably (Chatwood et al. 2012) not attracted the same level of attention as health inequities in other parts of the world.

Conceptualization of Inuit health which emphasize statistics on health deficits, however, fail to capture the underlying socioeconomic conditions that influence Inuit health outcomes (Inuit Tapiriit Kanatami & Inuit Circumpolar Council 2014). Holistic approaches that recognize the social determinants of Inuit health (Figure 1.2), including the legacy of colonialism, and the importance of self-determination to Inuit communities, are integral to understanding and addressing health in the Inuit context.

Figure 1.2 Social Determinants of Inuit Health



Source: (Inuit Tapiriit Kanatami & Inuit Circumpolar Council 2014)

Inuit Food Security and Arctic Change

Food security (i.e. the state of having sufficient and reliable access to safe, nutritionally adequate, and socially acceptable food) is an important social determinant of health for Inuit

(Inuit Tapiriit Kanatami & Inuit Circumpolar Council 2014). Inuit of the Canadian Arctic experience the highest documented prevalence of food insecurity (i.e. the state of lacking reliable and adequate access to safe, nutritious, and culturally-preferred food) among all Indigenous Peoples in a developed country (Egeland 2011). Over sixty percent (62.6%) of Inuit households in Canada experienced food insecurity in 2007-8 (Rosol et al. 2011; Egeland 2011; Huet et al. 2012). By contrast, less than eight percent (7.7%) of Canadian households experienced food insecurity during this same period (Health Canada 2012). Food insecurity among Inuit has been associated with disturbed eating patterns, reduced diet quality, and increased susceptibility to chronic and infectious disease (Egeland et al. 2011; Jamieson et al. 2012).

In addition to conventional metrics of food security (which emphasize monetary access to nutritious food), the food security of Inuit is predicated upon the harvest and consumption of country food (Inuit Tapiriit Kanatami & Inuit Circumpolar Council 2012; Paci et al. 2004). Despite the nutrition transition, country food remains fundamental to Inuit cultural identity (Borré 1991; Searles 2002; Pufall et al. 2011), food security, and dietary quality (Schaefer et al. 2011; Jamieson et al. 2012; Power 2008; Kuhnlein & Receveur 2007)

Given the critical role of country foods in the contemporary Inuit diet, understanding of Inuit nutrition and food security, must integrate the broader dynamics of local (food-provisioning) ecosystems, including wildlife population dynamics and changes in the supporting ecosystems. The Arctic is among the most ecologically-sensitive regions on Earth to climate variability (Seddon et al. 2016). Global warming has occurred more rapidly in the Arctic than elsewhere on the planet (IPCC 2014) and Inuit have witnessed climate-mediated changes on both the abiotic (e.g. sea-ice conditions that impact harvesting activities) and biotic (e.g. health of wildlife populations) dimensions of their local food systems (Nancarrow et al. 2008; Wesche & Chan 2010). Furthermore, it is now well established that the Arctic, although largely isolated from industrial activity, acts as a sink to contaminants from long range transport (Van Oostdam et al. 2005). Despite generally low concentration at low trophic levels, these contaminants can be assimilated into wildlife – where they become subject to bioaccumulation and biomagnification across trophic levels (Kuhnlein & Chan 2000; Kuhnlein 1995). The consumption of country food is recognized as the principal exposure pathway for many persistent environmental contaminants in the Arctic (Van Oostdam et al. 2005).

Although Inuit have been sustained by harvesting Arctic wildlife for thousands of years (Bonesteel & Anderson 2008; Nuttall et al. 2005), the loss of Arctic biodiversity in the Arctic, represents a critical challenge to food security and the sustainability of country food harvests (Brinkman et al. 2016; Theriault et al. 2005). While the vulnerability of northern Indigenous food systems to climate change has been highlighted for the past several years (Pollock et al. 2009; Kuhnlein et al. 2002; Zellner 2008; Wesche & Chan 2010), limited research has sought to explicitly link environmental change with nutrition implications for Inuit (Nancarrow et al. 2008; Nancarrow & Chan 2010; Wesche & Chan 2010). Furthermore, the economic factors underlying the nutrition transition in the Arctic have been scarcely explored (Pakseresht et al. 2014).

1.1.3 Problem Statement

A number of authors have cited an urgent need develop appropriate policies to support Indigenous food security in northern Canada (Rosol et al. 2011; Canadian Council of Academies 2014; Egeland 2011). To overcome the world's nutrition problems, experts contend that nutrition must direct improvement towards the causes of malnutrition, as opposed to nutrition-specific interventions that target malnutrition directly (Pinstrup-Andersen 2009; Powell et al. 2013). Complex problems in human nutrition are characterized by a multiplicity of factors, interrelatedness, and associated feedbacks (Schneider & Hoffmann 2011). A systems-based approach is one that explicitly takes the complexity of the system into account – the approach recognizes that complex systems are defined by many inputs and that behaviors of the system emerge from the system as a whole, rather than from any singular element of it. A holistic, systems-based approach may therefore be of particular value in understanding food and nutrition security in the Arctic, where the complex dynamics between the traditional and market food systems require innovative approaches to research, policy dialogue, and practice.

1.2 The Thesis

1.2.1 Theoretical Framework and Research Design

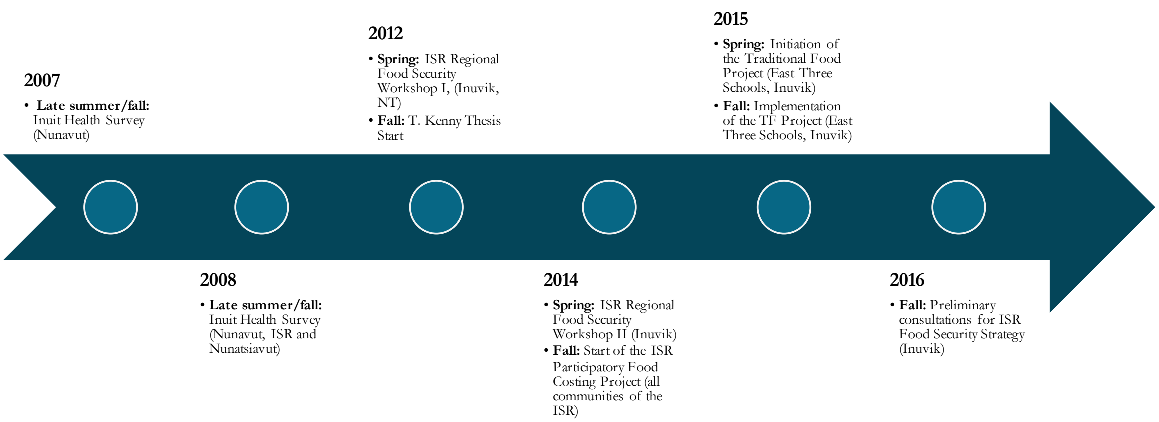
Theoretical Framework

This dissertation is premised on the view that human health is inextricably linked to local environments – from local ecosystems, socioeconomic contexts, and broader cultural and political environments. Ecosystem approaches to health (termed "ecohealth") situate human health within biophysical, social, and economic contexts. Ecohealth approaches often employ participatory and systems-based methodologies to integrate socio-ecological complexity and publicly-engaged policy-relevant science to understand the complex links between human health and the environment (De Plaen & Kilelu 2004; G. Forget & Lebel 2001). While acknowledging the importance of pointed disciplinary expertise, this thesis does not draw divisive disciplinary boundaries between the study of ecosystems, human health, and the broader supporting forces of education and culture. Rather, the dissertation seeks integration between the knowledge, philosophies, and frameworks of each discipline toward a more integrated understanding of the inextricable links between human and environmental health, as expressed through diets. Real-world issues, as experienced by communities, are embedded in various disciplines and manifest with disregard to disciplinary boundaries. For example, food security status is related to various socioeconomic factors, housing conditions, and the integrity of northern ecosystems and wildlife populations (among many other factors). Accordingly, understanding and addressing food security in this context requires integration between the knowledge and methodologies of each respective discipline, including meaningful inclusion of the knowledge, perspectives, and experiences of local community members. Taken together, this multidisciplinary dissertation attempts to address a number of key questions about the ecological, economic, and societal dimensions of the contemporary Inuit food system in Canada.

Research design

This thesis involves two broad paradigms of research: (i) dietary/epidemiological research involving analysis of data from the 2007-8 International Polar Year (IPY) Inuit Health Survey (IHS); and (iii) participatory research involving Inuit communities and consultation with northern wildlife experts and health professionals. Consistent with the nature and scope of these paradigms, the thesis represents multiple scales of engagement and inquiry: the former spanning the Canadian Inuit Nunangat (namely the Inuvialuit Settlement Region, Nunavut, and Nunatsiavut, which participated in the IHS), and the latter localized in the Inuvialuit Settlement Region (Northwest Territories). A timeline of significant activities in the realization of the thesis is presented in Figure 1.3.

Figure 1.3 Timeline of significant activities and developments in the project



Dietary / Epidemiological Research (Inuit Health Survey)

The 2007-8 International Polar Year (IPY) Inuit Health Survey (IHS) was developed in response to the disparity in available information regarding the health of Inuit throughout the Canadian North, so to better understand the factors contributing to Inuit health and the health transition. The IHS was developed through a participatory process involving consultation with steering committees representing the three Inuit jurisdictions and was intended to assist stakeholders to prioritize health issues to improve health in Inuit communities. The IHS collected comprehensive baseline data about the health and living conditions of Inuit adults across three Inuit land claim regions (Nunatsiavut, Nunavut, and the Inuvialuit Settlement Region) spanning the Canadian north (latitude of 54°10'N to 76°25'N; Figure 1.4). A certificate of Ethical Acceptability for the IHS was granted by the McGill Faculty of Medicine Institutional Review Board. Scientific Research Licenses were obtained from relevant northern research granting institutions (e.g. Aurora Research

Institute). Ethics approval for secondary analysis of data was granted by the University of Ottawa Health Sciences and Science Research Ethics Board (file number H05-15-16). All manuscripts resultant from the Inuit Health Survey were reviewed and approved (or are currently in review) by the New Inuit Health Survey Steering Committee.

Figure 1.4 Map of participating communities of the 2007-8 International Polar Year Inuit Health Survey

Source: Steven Fick/Canadian Geographic in Forget (2010)

Participatory and community- based work

This dissertation reflects a collaborative and participatory approach to food system research (Cornwall & Jewkes 1995). As the research was intended to prioritize the inclusion of local collaborators in the research process, questions addressed by the thesis were selected to be of both scholarly significance, and practical importance, to Inuit communities. This thesis represents the culmination of five community visits to the Inuvialuit Settlement Region, spanning three years (2014 – 2016). Countless discussions with people of the region – including harvesters, youth, and elders, and health professionals and wildlife experts – have both directly and indirectly guided and enriched the direction of research. Time spent building equitable relationships, and trust is a paramount facet of research involving

Indigenous Peoples. Time in the north also therefore included volunteering (Inuvik Food Bank) and involvement in community events. Ethics approval was granted by University of Ottawa Health Sciences and Science Research Ethics Board, and scientific research licenses were obtained from the Aurora Research Institute for the work conducted in the Inuvialuit Settlement Region and are included in the Appendix 1-2. Appendix 3 also includes supplemental materials (e.g. letters of information) materials related to the community-based work undertaken in the Inuvialuit Settlement Region.

1.2.2 Thesis Objectives

Broadly defined, the objective of this thesis is to integrate ecological, economic and societal dimensions of the Inuit food system, to further understanding of the complex dynamics that mediate the nutrition transition. This thesis represents, therefore, an initial attempt to situate species conservation into the realm of human nutrition and food security, and, likewise, to situate issues of human health and nutrition within the broader context of the food-provisioning ecosystem.

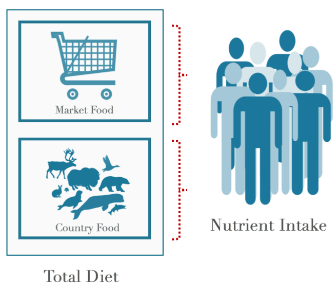
Figure 1.5 Linking human nutrition to local ecological and economic environments

The central research objectives of the thesis are as follows:

- Characterize the contemporary diet of Inuit adults across the Canadian north

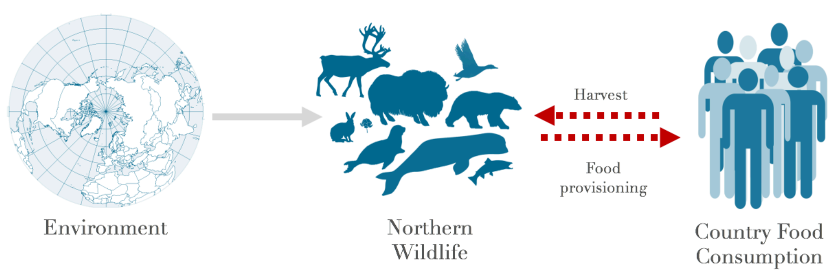
- Define contemporary patterns of food consumption
    - Summarize food and nutrient intakes
    - Identify principal dietary sources of energy and nutrients in the diet

Figure 1.6 Contribution of market food and country food to diet and total nutrient intake



- Situate issues of Inuit food security within a forum that is mutually relevant to communities, wildlife/species conservation interests, and the public health sector
    - Establish estimates of country food use for selected species of wildlife (prioritized for importance to current diet)
    - Translate dietary data regarding country food consumption to the equivalent wildlife harvest requirement

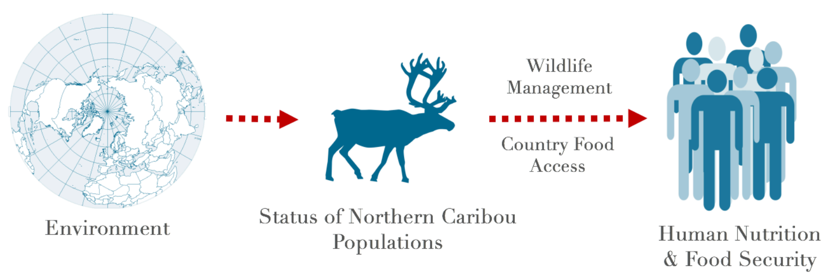
Figure 1.7 Linking country food harvest and consumption



- Assess how a linked understanding of human diet/health and wildlife status can support decision-making concerning food security
    - Relate status of country food species to the potential implications for Inuit food and nutrition security by using a case study of caribou (*Rangifer tarandus*)

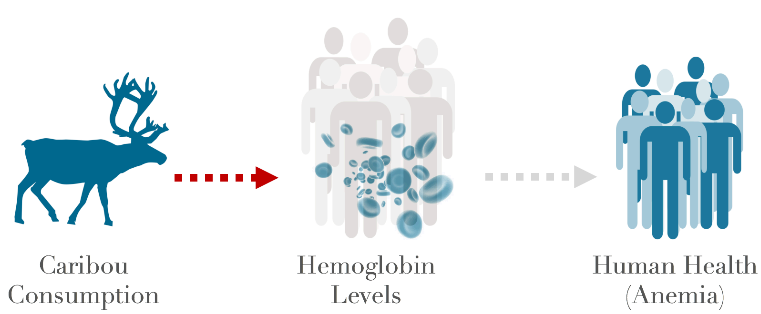
- Demonstrate the importance of caribou to the nutrition security of Inuit by relating caribou consumption to nutrient intakes
- Compile and assess trends in northern caribou population status, including the relevant wildlife management policies, across the Canadian Inuit Nunangat (Inuit regions of northern Canada)

Figure 1.8 Linking human nutrition and food security to species status and wildlife management



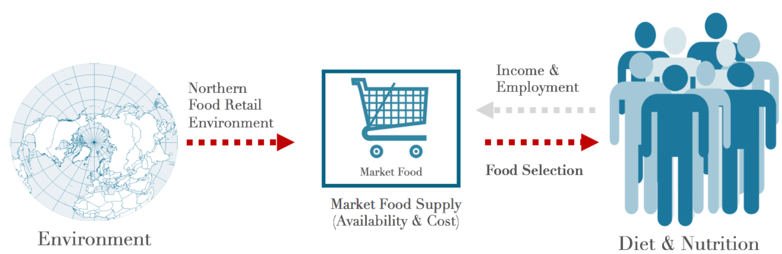
– Relate country food consumption to human health, and investigate the impacts of restricted country food consumption on human health
  - Examine the relationship between caribou consumption and blood biomarkers in humans
  - Using empirically derived models, investigate the potential impact of restricted caribou consumption on the prevalence of anemia in the study population

Figure 1.9 Relating caribou consumption and human health



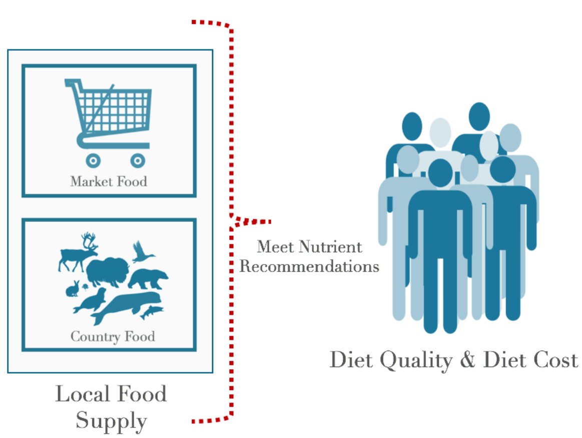
- Investigate the economic dimensions of diet and nutrition in remote northern regions
    - Examine the relation between food cost, energy density, and nutrient density
    - Examine the cost and affordability of nutritious diets

Figure 1.10 Relating the northern food retail environment to diet quality and human nutrition



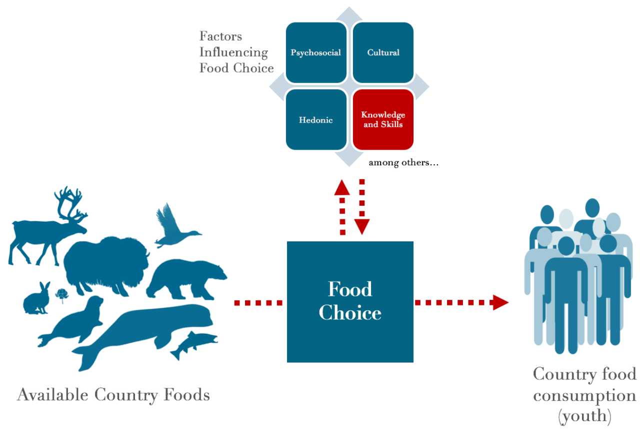
- Investigate the utility of mathematical models to furthering understanding of the relationship between the traditional and market dimensions of the Inuit food system
    - Identify dietary patterns that meet nutrient requirements
    - Identify limiting nutrients in the food supply
    - Investigate the effect of applying nutrient recommendations on the structure and cost of the diet

Figure 1.11 Assessing the feasibility of meeting national nutrient recommendations based on a mixed diet of country food and market food



- Work collaboratively with communities to address priorities for research and action to enhance food security
    - Develop a school-based country food program to enhance youth skills and knowledge surrounding country food

Figure 1.12 The importance of knowledge and skills in influencing food choice



1.2.3 Dissertation Structure

This dissertation is comprised of ten chapters (Table 1.1). Chapters 3 – 9, have been prepared as manuscripts for publication, or eventual publication, in relevant peer-reviewed academic journals. Please refer to Appendix 4 for permission to reproduce published material. Contributions by academic and northern collaborators to the realization of the research are recognized through co-authorship on relevant manuscripts. A statement of authorship for each manuscript is presented as a footnote on the title page of each chapter, and is also summarized in Table 1.1 below.

Each chapter uses a case study of the contemporary Inuit food system to address a specific research question, or set of research questions, with the goal of furthering understanding of human reliance on biodiversity for diet and nutrition (**Section 1**), and the challenge of the nutrition transition (focus on market foods) in Inuit communities (**Section 2**). Throughout, an emphasis is made to integrate aspects of human justice, environmental equity, and the rights of Indigenous Peoples.

Chapter 1 opens the dissertation by outlining the specific aims and objectives of the research, the structure of the dissertation chapters, and the contribution of the thesis to the advancement of knowledge. **Chapter 2** establishes the theoretical foundation for this work and contextualizes the thesis research within the existing literature of the Inuit food system.

SECTION 1 addresses the traditional dimension of the Inuit food system. Inspired by the literature linking human diets and biodiversity conducted in tropical regions, manuscripts of Section 1 explore Inuit nutrition and food security through the lens of Arctic ecology. Using dietary data from the Inuit Health Survey, review of the literature, document analysis, and consultation with Arctic wildlife experts, this section explores how ecological knowledge can be used to improve understandings of food security, human nutrition, and health in the Arctic.

1 **Chapter 3** presents the manuscript, "Estimating wildlife harvest based on consumption reported by Inuit in the Canadian Arctic" which is published in the journal *Arctic* (Kenny and Chan, March 2017).
2 **Chapter 4** presents the manuscript, "Caribou (Rangifer tarandus) and Inuit food security" which has been prepared for the journal EcoHealth.
3 **Chapter 5** presents the manuscript, "Potential Impact of Restricted Caribou (Rangifer tarandus) Consumption on Anemia Prevalence among Inuit Adults in Northern Canada" which has been prepared for the journal BioMed Central (BMC) Public Health.

SECTION 2 examines the contemporary Inuit diet and the factors underlying the nutrition transition, including food consumption patterns, food costs, and, knowledge and skills surrounding country foods. Manuscripts in this section involve: i. analysis of dietary data from the Inuit Health Survey; ii. analysis data derived from a participatory food costing study in the Inuvialuit Settlement Region (2014 - 2016); iii. the development of mathematical models as decision-support tools in the elaboration of nutrition recommendations and food security policy; and finally, iv. participatory community-based food system work, involving youth.

4 **Chapter 6** presents the manuscript "Dietary sources of energy and nutrients in the contemporary diet of Inuit adults: results from the Inuit Health Survey" which has been prepared for the journal Public Health Nutrition.
5 **Chapter 7** presents the manuscript "Calories Are Cheap, Nutrients Are Expensive – The Challenge of Healthy Living in Arctic Communities" which has been prepared for the journal Food Policy.
6 **Chapter 8** presents the manuscript "Is it possible to meet national nutrient recommendations with a mixed diet of traditional and market foods in Arctic Canada?" which has been prepared for the journal PlosOne.
7 **Chapter 9** presents the manuscript, "Linking health and the environment through education – A Traditional Food Program in Inuvik, Western Canadian Arctic" which reflects the participatory approach to research taken through the thesis.

Chapter 10 concludes the dissertation. It describes the overall success in achieving the objectives outlined in Chapter 1 and discusses the significance and practical implications of this thesis.

Four appendices are included in this dissertation:

1 **Appendix 1** includes ethics approval documentation
2 **Appendix 2** includes scientific research licenses for work in northern Canada
3 **Appendix 3** includes materials related to the community-based work undertaken in the Inuvialuit Settlement Region.
4 **Appendix 4** includes copyright information for articles published in peer-reviewed journals.

Table 1.1 Thesis summary – themes, chapter/manuscript titles, and methodology

Thesis Chapter	Manuscript Number	Title	Regional scope	Methods	Status	Co-Authors
Section 1: Biodiversity, Food Security and Human Nutrition						
Chapter 3	Manuscript 1	Estimating Wildlife Harvest Based on Reported Consumption by Inuit in the Canadian Arctic	Inuit Nunangat (regions of the IHS)	Analysis of dietary data and review of northern wildlife literature	Published in Arctic (March, 2017)	TK & HMC
Chapter 4	Manuscript 2	Caribou *(Rangifer Tarandus*) and Food Security	Inuit Nunangat	Analysis of dietary data, document analysis, and consultation with northern wildlife experts	Prepared for EcoHealth	TK, MF, SS, SDW, HMC
Chapter 5	Manuscript 3	Potential Impact of Restricted Caribou (Rangifer tarandus) Consumption on Anemia Prevalence among Inuit Adults in Northern Canada	Inuit Nunangat (regions of the IHS)	Empirical model (dietary data and blood biomarkers)	Prepared for BMC Public Health	TK, XH, JAJ, HVK, SDW, HMC
Section 2: The Contemporary Inuit Diet –Market Food, Economic and Societal Factors						
Chapter 6	Manuscript 4	Dietary Sources of Energy and Nutrients in the Contemporary Diet of Inuit Adults: Results form the Inuit Health Survey	Inuit Nunangat (regions of the IHS)	Analysis of dietary data	Prepared for Public Health Nutrition	TK, XH, HVK, SDW, HMC
Chapter 7	Manuscript 5	Calories Are Cheap, Nutrients Are Expensive – The Challenge of Healthy Living in Arctic Communities	Region / community (communities of the ISR)	Participatory food costing study	Prepared for Food Policy	TK, MF, JM, SDW, HMC
Chapter 8	Manuscript 6	Is it Possible to Meet National Nutrient Recommendations with a Mixed Diet of Traditional and Market Foods in Arctic Canada	Regional (ISR)	Optimization modelling	Prepared for PlosOne	TK, SDW, HMC
Chapter 9	Manuscript 7	Link Health and Environment Through Education – a Traditional Food Program in Inuvik, Western Arctic Canada	Community scale (Inuvik, ISR, NT)	Program development / community engagement	Submitted as a Field Note to J Hunger Environ Nutr	TK, JM, PG, SK, SDW, HMC

Acronyms: IHS = Inuit Health Survey; ISR = Inuvialuit Settlement Region (Northewst Territories, Canada)

Co-authors: TK = TiffAnnie Kenny; HMC = Laurie Hing Man Chan; SDW = Sonia D. Wesche; HVK = Harriet V. Kuhnlein; JM = Jullian MacLean; JAJ= Jennifer A. Jamieson MF= Myriam Fillion; PG = Patrick Gale; SK=Susan Keats; SS = Sarah Simpkin; and XU =Xue Feng Hu

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2 THEORETICAL FOUNDATION AND REVIEW OF LITERATURE

TiffAnnie Kenny

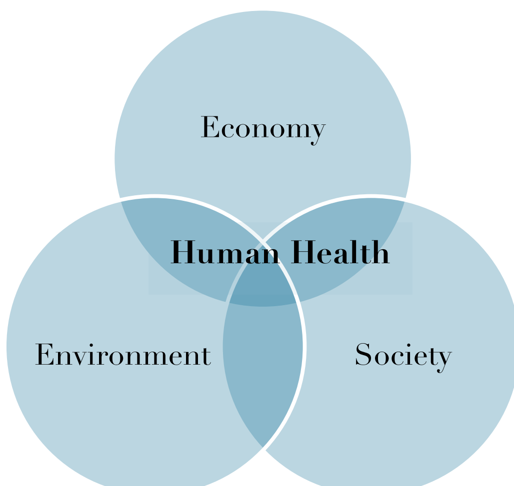
To situate the dissertation within the existing body of knowledge, and to understand how a holistic and systems-based approach would meaningfully contribute to understandings of the Inuit food system, this chapter both establishes the broader theoretical foundation for the thesis and provides a scoping overview of literature pertaining to the Inuit food system. Canada.

2.1 Theoretical Foundation

2.1.1 Ecosystem Approaches to Health

Ecosystem approaches to health (termed "ecohealth") are premised upon the view that human health and wellbeing are the result of complex and dynamic interactions between ecosystems, economies, and societies (Charron 2012). Ecohealth research is based on principles of justice, participation, and equity. Accordingly, Ecohealth research often extends to identify policies and resource management strategies that jointly support the sustainability of ecosystems and the health and wellbeing of human societies (Charron 2012; De Plaen & Kilelu 2004; Forget & Lebel 2001).

Figure 2.1 Ecosystem Approaches to Health (EcoHealth)



Linking Humans and the Environment – Food and Nutrition

Essential nutrients are compounds required by humans to sustain life and normal physiological processes. While essential are nutrients required by humans, they cannot be synthesized by the body (or cannot be synthesized in adequate amounts); rather, they must be provided by diet. Thus, diet expresses the inextricable link between human health and the environment. While food has been designated as a human right (United Nations 1952) by the United Nations (UN) Universal Declaration of Human Rights (Article 25), approximately one in nine (795 million) people are undernourished globally (FAO et al.

2015); even more (2 billion) are affected by micronutrient deficiencies (Kennedy et al. 2003). Food security, as defined by the 1996 World Food Summit, represents the state of having reliable access to sufficient, safe, affordable, and nutritious food to meet dietary needs and food preferences for an active and healthy life (FAO 1996). Conversely, food *in*security represents the condition of inadequate and/or unpredictable access to sufficient, nutritious, and culturally-preferred foods. Inequities in food access arise consequent to factors relating to food production, distribution, and access, with poverty as the most binding constraint to improving people's food security in developing countries (L. C. Smith et al. 2000).

Food Security of Indigenous Peoples

The world's most marginalized people disproportionately experience food insecurity and malnourishment (L. C. Smith et al. 2000). Food insecurity is disproportionately prevalent among Indigenous peoples, including in developed countries such as Canada (Willows et al. 2011; Rosol et al. 2011; Egeland 2011; Hanning & Tsuji 2014). In addition to conventional metrics of food security (which emphasize market-based metrics), the food security of Indigenous Peoples is predicated upon access to traditional cultural foods (Power 2008; Lambden et al. 2007). Degraded ecosystems undermine the food security and food sovereignty of Indigenous Peoples by limiting local control over the quality, safety, and acceptability of local food, and by increasing dependency on global food systems (Loring & Gerlach 2009).

2.1.2 Ecological Dimensions of Human Nutrition

Wild Food as an Ecosystem Service

Ecosystem services are the benefits that humans derive from ecosystem functions/attributes. These include provisioning (e.g. food and water), regulating (e.g. flood and disease control), cultural (e.g. spiritual and recreational benefits), and supporting (e.g. nutrient cycling) services (MEA 2005). Wild/uncultivated ecosystems provide micronutrient rich foods (including fruits, vegetables, bush meat, fish, and insects) that support the health, nutrition, and food security of millions of people worldwide (Burlingame 2000; Rowland et al. 2016; Bharucha & Pretty 2010). Using data from 7,975 households in 24 developing countries across Latin America, Africa, and Asia, Hickey et al. (2016) reported that 77% of households collected wild foods for subsistence.

Households situated in diverse ecosystems possess significant knowledge, and report use of up to hundreds of species of wild foods (Bharucha & Pretty 2010; Kuhnlein & Receveur 2007; Kuhnlein & Humphries 2017). Moreover, the harvest of wild foods, termed "traditional foods," is culturally significant to Indigenous Peoples in various global regions. In their analysis of twelve community groups of Indigenous Peoples located in different global regions, Kuhnlein et al. (2009) reported that traditional food contributed 27% to 93% of total dietary energy among adults. Coastal Indigenous communities harvest over 2.1 million metric tones of seafood annually (based on data from 1,900 coastal Indigenous communities across 87 countries) (Cisneros-Montemayor et al. 2016). In the humid forests of Central Africa, as much as 1–3 million tonnes of wild meats are harvested annually (Wilkie & Carpenter 1999; Milner-Gulland & Bennett 2003). Despite the ubiquity of wild food use, the economic contribution of wild food to household income is generally considered very modest. Across Africa, Asia, and Latin America, wild foods contributed less than 5% of total household income (Hickey et al. 2016). The principle role of wild foods is therefore generally attributed to household nutrition (Hickey et al. 2016), however, the cost of replacing wild foods with store-bought foods of similar nutrient quality has rarely been considered within such assessments.

Wild foods offer accessible and affordable means to nutritious foods (Vinceti et al. 2013). Although wild foods generally contribute modestly to total diet energy, they enhance dietary diversity and ameliorate the nutritional quality of the diet (Penafiel et al. 2011; Powell, Ickowitz, et al. 2013; C. Shackleton & S. Shackleton 2004; Termote et al. 2012; Powell et al. 2015; de Merode et al. 2004; Nasi et al. 2008; Nasi et al. 2011; M. Arnold et al. 2011; Powell et al. 2011). In rural settings, particularly in areas with significant forest cover, "bush meat" (i.e. wild game meat) provides most of the animal source food and represents up to 80% of the proteins and fats in the diet (Fa et al. 2003; Nasi et al. 2011). In remote communities, the nutritional value of wild foods generally cannot be readily substituted by store-bought foods (Fa et al. 2003; Bharucha & Pretty 2010) given the limited availability and high cost of market foods.

Wild foods can also occupy an instrumental role in supporting food security by enhancing the diversity of the local food supply, and are thus an important as source of resilience in the food system (Powell, Ickowitz, et al. 2013). During periods of food scarcity – including droughts, food shortages, and political instability – wild foods strengthen local coping strategies to support food security (Grivetti & Ogle 2000; Humphry et al. 2009). Various examples from Niger (Humphry et al. 2009), Thailand (Moreno Black & Somnasang 2000), and Tanzania (Powell, Maundu, et al. 2013) demonstrate that higher wild food usage is reported during periods of food production shortages when food insecurity is highest. These case-studies underscore the role of wild foods in supporting household resilience to food insecurity, and underscores the need to better integrate wild foods into formal food security policies and programs (Hickey et al. 2016).

Sustainability of Wild Food Harvest

Biodiversity, as defined by Article 2 (p.3) of the UN Convention on Biological Diversity (CBD), represents "the variability among living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems"(United Nations 1992). The CBD recognizes, furthermore, humanity's reliance on biodiversity for the provisioning of food, medicine, fresh air, and clean water, and to support a healthy environment. Biodiversity loss is an issue of global significance – with important consequences on the structure, dynamics, and functioning of entire ecosystems (Cardinale et al. 2012). Despite international agreements (e.g. the CBD) to support the conservation and sustainable use of biological diversity, considerable evidence suggests that biodiversity loss at the global scale has continued to decline in recent decades (Butchart et al. 2010).

Declining trends in global biodiversity have important implications for human health, particularly among the rural poor who depend on local biodiversity for subsistence and nutritional adequacy (Penafiel et al. 2011). Paradoxically, subsistence harvests may impose significant stress on local wildlife populations, and can lead to population decline and local extirpation (Bowen-Jones et al. 2003; Wilkie et al. 1998; Fa & Brown 2009; Brashares et al.

2004; Heinsohn et al. 2004). Extinction risk for mammals, birds, and amphibian species used for food and medicine have increased at an accelerating rate since 1970, with 23 to 36% of such species threatened with extinction (Butchart et al. 2010). Increasing human population size, degradation of natural environmental through urbanization and land-use change, and broader environmental change are collectively challenging the sustainability of human subsistence harvests (Jackson et al. 2012; Robinson & Bennett 2004; Bennett et al. 2007). It has been suggested that in light of high human population-density, all hunting may be unsustainable (J. Arnold 2008; Nasi et al. 2008; Nielsen 2006; Powell, Ickowitz, et al. 2013). Furthermore, considerable local knowledge on traditional food species and sustainable harvest practices is being lost at accelerating rates due to rapid social change in Indigenous societies (Kuhnlein et al. 2009).

2.1.3 The Nutrition Transition

Changing Food System

The Food and Agriculture Organization (FAO) contends that "nutrition and biodiversity converge to a common path leading to food security and sustainable development" (FAO n.d.). However, twentieth century agricultural intensification practices that mitigated the global burden of hunger (Godfray et al. 2010) have also dramatically narrowed the world's food base, fostered the simplification of human diets (i.e. reduced dietary diversity), and undermined Indigenous and traditional food systems (Frison et al. 2005; Matson et al. 1997; Johns & Eyzaguirre 2007; Toledo & Burlingame 2006). Agricultural development policies have traditionally emphasized the production of energy-rich staple crops (e.g. cereal, starchy tubers, and root vegetables) (Tontisirin et al. 2009). Fifteen crop plants provide 90% of the world's food energy intake (FAO 1995). Consequently, the global supply is rich in energy but lacks adequate essential nutrients (Johns & Eyzaguirre 2007; Toledo & Burlingame 2006).

Dietary diversity (DD) , variously defined based on the number of different foods items or food groups consumed over a reference period (Ruel 2003), has been proposed as a mediator of the relationship between biodiversity and human nutrition (Johns & Sthapit 2004). DD has been positively associated with micronutrient intake and status, in various global settings (FAO 2008; Arimond & Ruel 2004; Mirmiran et al. 2006; Fujita et al. 2012).

However, most studies examining the relation between DD and human nutrition, have focused on cultivated agro-biodiversity, and overall measures of dietary diversity (Penafiel et al. 2011). Few studies have considered the value of wild, and traditional Indigenous foods, to diversified diets (Roche et al. 2007; Powell et al. 2015).

Health Consequences of the Nutrition Transition

Food systems that provision adequate dietary energy but lack essential micronutrients represent a distinct concern for population health, including disposition to obesity and the development, and severity, of chronic disease (Via 2012; Eckhardt 2006). The global burden of obesity is increasing at accelerating rates (Popkin & Gordon-Larsen 2004; Popkin et al. 2012; Popkin 2001), with nearly 30% of the world's population (2.1 billion people) either overweight or obese (Ng et al. 2014). The increasing ubiquity of low-cost, energy-dense, nutrient-poor foods is a key driver in the rise of obesity worldwide (Swinburn et al. 2011). Poor quality diets, lacking in diversity and micronutrients, are a major cause of malnutrition. Non-communicable/chronic diseases – for which unhealthful diets, physical inactivity, and tobacco use are the three most important modifiable behavioural risk factors (WHO 2015) – account for approximately 70% (38 million deaths in 2013) of total global deaths (Naghavi et al. 2015). The "double burden of disease," which occurs when micronutrient deficiencies and infectious diseases co-exist with obesity and other chronic nutrition-related diseases (e.g. diabetes) represents an emergent health challenge in many developing countries (Popkin & Gordon-Larsen 2004; Lee et al. 2012; Barquera et al. 2007).

The Nutrition Transition Among Indigenous Peoples

The nutrition transition is characterized by a dietary shift away from traditional foods towards increased consumption of processed (and other) foods that are high in fat, refined sugar, salt, and energy (Popkin & Gordon-Larsen 2004). Understanding the nutrition transition of Indigenous Peoples necessarily involves consideration of both (i) the decline in use of traditional foods and (ii) the adoption of western dietary patterns that include highly refined and processed foods.

Reasons for the decline in traditional foods include: declining availability due to overharvesting and land clearing for agriculture; difficulties in access to land and land tenure;

perceptions of wild foods as being "food for the poor" (Weinberger & Swai 2006); loss of traditional knowledge; and the labour required to harvest, process, and prepare traditional foods (Kuhnlein et al. 2009). Changing ecological circumstances are thus foundational to understanding the cultural constructs of dietary change, however, they are incomplete unless coupled with understandings of the socioeconomic drivers of dietary change change, such as integration in market economies and globalization.

2.1.4 Economic Dimensions of Human Nutrition

Socioeconomic disparities in diet quality are documented in various settings around the globe. Low income consumers often resort to low cost diets to satisfy energy requirements within budgetary constraints (Drewnowski & Specter 2004; Agarwal et al. 2015). Likewise, households experiencing food insecurity report reducing portion sizes and changing consumption patterns to favour consumption of bulk, non-perishable, and economic foods such as rice and pasta (Gucciardi et al. 2009; Willows et al. 2011). While the standard household model in economic theory proposes that households utilize their resources (e.g. income, skills, time) toward the highest attainment of utility (satisfaction) (V. E. Smith 1959; V. E. Smith 1965), the factors influencing food purchasing behaviours in food insecure households remains poorly understood (Henson 1991; Walker & Kawachi 2012). Relative prices can affect consumer food choices, including the type, quantity, and quality of food consumed. Low-cost foods of high energy density (e.g. foods high in sugar and fat), but low essential nutrient content, are often heavily relied on by low income and food insecure consumers (Drewnowski & Specter 2004). High food costs may represent a barrier to the adoption of more healthful diets, particularly among low income consumers, and may be partly responsible for the disparities in obesity prevalence and nutritional deficiencies documented among people of lower socioeconomic status (Drewnowski et al. 2004) (Darmon & Drewnowski 2015; Darmon et al. 2002; Drewnowski & Darmon 2005a; Drewnowski et al. 2004).

It is hypothesized that poverty and obesity are linked through habitual consumption of a low-cost, high energy density diet (Drewnowski 2003). The analysis of food price in relation to energy and nutrient density represents an established approach for research into the socioeconomic determinants of diet quality (Darmon et al. 2003; Drewnowski et al. 2015; Drewnowski & Darmon 2005b). Food energy density is defined as the energy per unit weight or volume (e.g. kcal/100 g). Energy cost refers to the purchase cost per unit of energy (e.g. $ CAD/1000 kcal) or the purchase cost of a daily diet (Euros of dollars per day). Energy dense foods generally provision considerable dietary energy at low cost, and are typically dry, have stable shelf lives, and resist degradation during shipping (e.g. cereal, grains, pulses, potato chips, chocolate bars) (Agarwal et al. 2015; Drewnowski & Darmon 2005b). Furthermore, energy density and the sensory appeal of foods are inextricably linked (Drewnowski 1998). There has been debate in the literature regarding the relevance of assessing food price in terms of energy (notably Drewnowski (2010), and Darmon & Maillot (2010) have addressed the debate), the main facet of this debate centers on the fact that consumers do not purchase foods in forms that may readily be compared calorically (Jones & Monsivais 2016). Beheshti and colleagues (2016) recently demonstrated through simulation modelling that price per calorie is the dominant price metric used by low-income people in making decisions regarding consumption. The relationship between food price and nutritional value bears important implications for public health policy (Monsivais et al. 2010; Aaron et al. 2013; Jones & Monsivais 2016).

2.1.5 Food Systems

Defining the Food System

The "food system" provides a holistic framework for analyzing the multifaceted relationships between food, the environment (including both the ecological and socioeconomic environments discussed above) and human health and well-being (Story et al. 2009). The food system comprises the complex set of activities and interactions involved in provisioning food for human sustenance. Sobal et al. (Sobal et al. 1998) observed that, despite promotion of the food system for several decades, until recently relatively little scholarship of the food system has existed (Sobal et al. 1998). Rather, much of the literature has narrowly considered discrete issues in the food system through case studies (Sobal et al. 1998; Ritenbaugh et al. 1996) (e.g. agriculture, economics, nutrition), among which anthropology and agronomy/agriculture have traditionally featured as principle contributors (LaBianca 1991).

As conceptualized by Pelto et al (2010), the food system is comprised of two basic dimensions. The first dimension is materialistic, and involves available foods and the technologies, physical forces (e.g. climate and energy), chemical elements, and biological factors (e.g. biodiversity). The second dimension is socio-cultural, and includes economic factors (e.g. capital, capital markets, individual satisfaction, and utility), as well as the ideologies, policies, knowledge, skills, values, and traditions within the culture that define what food is edible, and when, how, and where specific foods are consumed. Food systems are characterized by complex interactions across spatial and temporal scales, and between biophysical, socio-economic, and cultural dimensions. Ericksen (2008a) conceptualizes food systems as socio-ecological systems (SESs) with "mutually dependent and interacting social and ecological components and highly uncertain and unpredictable."

Resilience and Vulnerability in the Food System

The vulnerability of food system to environmental, social, and economic stressors constitutes a central theme in food system scholarship. Vulnerability represents the degree to which a system, subsystem, or system component is likely to experience a destabilization from exposure to a perturbation and/or a stressor (B. L. Turner et al. 2003; Foytik 1981). Vulnerability scholarship endeavors to identify who is most vulnerable to changes, how the changes and consequences are attenuated/amplified by various conditions, and what can be done to build resilience and adaptive capacity to reduce vulnerability (B. L. Turner et al. 2003; Briend et al. 2003). This suggests that an important analytical step is to define these key functions initially to understand what vulnerability means for a given system (Ericksen 2008b). Drawing upon both social and ecological theories of food system analysis, Fraser et al. (2005) proposed a framework to assess the vulnerability of food systems to future shocks based on landscape ecology's 'Panarchy Framework' (Asfaw 2008). Briefly, the Panarchy framework is characterized by three paradigms: (i) the wealth, or the "inherent potential of the system that is available for change," (ii) the degree to which the system can control external forces, characterized by the connectedness of the system components and external drivers, and (iii) diversity, or the capacity of the system to adapt to external forces – as diverse systems are better able to tolerate a wide range of environmental conditions than simple systems. Food system diversity (from genetic to species, and ecosystem diversity) is likely to foster food system resilience and may mitigate the effects of environmental, social, cultural, and economic stressors (Powell et al. 2015; Johns & Sthapit 2004). This thesis presents a case study of the Inuit food system, set in a region of low biodiversity, to provide a contrasting example of the broader literature on the contribution of local biodiversity to food security and nutrition, which has been largely conceptualized and undertaken in the most biodiverse regions of the world.

2.2 The Inuit Food System

Sources of information

It is important to preface this section by highlighting the nature of scholarship on the Inuit diet and food system. Prior to concerted research efforts during the 1980s (See for example Kuhnlein & Soueida 1992) to systematically characterize diet and nutrients in the Inuit food system, data regarding patterns of food use and nutrient composition for country foods were scarce (Fediuk 2000). Ethnographic accounts of food use and diaries of early polar explorers provide much of the early documented information on the Inuit food system (see for example Rasmussen 1931). In recent decades participatory research methodologies, including the use of Photovoice (photographs and participant narrative to examine the experience) (Lardeau et al. 2011), are increasingly adopted as the standard of research involving Inuit. Nevertheless, a common critique of classic research approaches, is the priority of Western science over traditional knowledge and Indigenous perspectives (Tobin et al. 2010; Elliott et al. 2012). Kuhnlein et al. (2006) describe procedures for documenting the traditional food systems of Indigenous Peoples, emphasizing community participation, and training.

Conceptualization of the Indigenous food systems extend to the sociocultural meanings, processing techniques, instructions, knowledge, and cultural uses of foods (Kuhnlein et al. 2007). Thus, activities related to food do not merely constitute a means of acquiring sustenance, but rather "a mode of production, that sustains social relationships and distinctive cultural characteristics" (Kuhnlein & Receveur 2007). Subsistence activities (e.g. hunting, fishing, trapping, and gathering) remain inextricably linked to culture and identity in Inuit communities (Searles 2002). For Inuit, health, wellness, and cultural identity are embedded in ideologies of the food system – including, the relationship between humans and non-human animals, and the relationship between the body, the soul, and life (Borré 1991; Kuhnlein et al. 2004). The importance of country food to wellbeing and the role of kinship, reciprocity, and food sharing in Inuit communities is highlighted in a significant body of anthropological and sociological research (Duhaime et al. 2002; Wenzel 1991; Collings et al. 1998; Kishigami 2004).

2.2.1 Arctic Environments

Arctic Ecosystems and Species

The "Arctic" has been variously defined based on political, biological, and climatic boundaries (Chapin et al. 2005). Arctic land cover includes ice, barrens (polar desert and prostrate shrub tundra with less than 50% plant cover), and tundra (Chapin et al. 2005). The Arctic includes highly variable climatic conditions. Consequently, terrestrial ecosystems are characterized by a short productive summer season, while marine ecosystems include seasonal extremes in solar irradiance and ice cover. Compared with other biomes on Earth, terrestrial Arctic ecosystems foster low species diversity, and are generally comprised of fewer trophic levels, with fewer species at any given level (Meltofte 2013; Oksanen 2000). By virtue of this structure, changes in the abundance of any one species can have significant consequences, both directly and indirectly, on entire ecosystems.

In general, species richness in the Arctic is stratified by both longitude and latitude, with declining richness observed for most organism groups with increasing latitude (Meltofte 2013). Less than 5% of the global flora (3%) and fauna (2%) of the world occur in the Arctic. Approximately 1,800 species of vascular plants, 75 species of terrestrial mammals, and 240 species of terrestrial birds occur in the Arctic. Because of the low species diversity, some ecologically important species have large populations with broad geographic, often circumpolar, distributions. Responding to extreme seasonality, a distinguishing feature of Arctic biodiversity is the importance of migratory species, including most birds and marine mammals, caribou, and many key fish species (Meltofte 2013).

Seasonality is a key feature of the traditional Inuit food system. Patterns of country food consumption reflect animal migrations and seasonal distributions, as well as climatic and environmental factors relating to harvest, such as ice formation (Boas 1964). Seasonal fluctuations in diet were historically related both to the composition of species in the diet but also to the overall patterns of food consumption and meals. In Ulukhaktok (Northwest Territories), for instance. the summer diet was comprised of four daily meals (particularly raw/frozen char and caribou, and stews), while two meals were consumed daily during the summer (Geraci & T. G. Smith 1979).

Arctic Environmental Change

Arctic environments, wildlife species, and human societies are experiencing pressure from various anthropogenic stressors (e.g. climatic changes, species decline and the presence of toxic compounds). As part of a holistic system, these changing environmental conditions do not act in isolation from the broader economic and cultural conditions presently afflicting Inuit communities; rather, they may act synergistically to exacerbate food insecurity and poor diet quality, by promoting the transition away from country foods and fostering increased reliance on nutrient poor market foods.

Climate Change

The Arctic is among the most ecologically-sensitive regions on earth to climate variability (Seddon et al. 2016). Global warming has occurred more rapidly in the Arctic, than elsewhere on the planet (IPCC 2014), and Inuit have witnessed climate-mediated changes on both the abiotic (e.g. sea-ice conditions that impact harvesting activities) and biotic (e.g. health of wildlife populations) dimensions of their local food systems (Nancarrow et al. 2008; Wesche & Chan 2010). Downing & Cuerrier (2011) offer a synthesis of various community-based climate change studies in Canada's northern regions. Most changes are thematically related to weather (e.g. unpredictable weather, stronger winds and changes in prevailing wind direction, increased rainfall, decreased snowfall, and fewer extreme cold temperatures), ice and hydrologic systems (e.g. earlier break up/later freeze up of ice, thinning ice, melting glaciers, increased coastal erosion, decreasing lake and stream levels), and changes in animal populations (e.g. decreased wildlife health/quality/abundance, the appearance of new wildlife and plant species, migration) (Ford et al. 2014; Nancarrow et al. 2008; Nancarrow & Chan 2010; E. J. Peters 2003; Ford et al. 2008; Wesche & Chan 2010; Downing & Cuerrier 2011).

Global warming is internationally recognized as a significant threat to the conservation of biodiversity, and interactions between numerous threats (e.g. human harvesting, habitat fragmentation, and climate change) could lead to species extinctions (Thomas et al. 2004; Heller & Zavaleta 2009). Although Inuit have been sustained by harvesting Arctic wildlife for thousands of years (Bonesteel & Anderson 2008; Nuttall et al. 2005), the loss of Arctic biodiversity represents a critical challenge to food security and the sustainability of country food harvests (Brinkman et al. 2016; Theriault et al. 2005). However, climate-mediated changes can affect access and availability of country food species, in both positive and negative ways, depending on geography, availability of harvester travel equipment, and changes in the distribution of animals relative to the location of communities (Nancarrow & Chan 2010; C. J. Peters et al. 2008; Wesche & Chan 2010). As mentioned previously, environmental changes do not act in isolation from the broader sociocultural conditions in northern communities. For example, changing ice conditions affect the accessibility of hunting areas and may necessitate longer travel distances for harvesters; however, many harvesters may lack the financial resources and time to adapt to these changes (Ford & Beaumier 2011).

Contaminants

The matter of environmental contaminants in the diet and environment of northern Indigenous peoples has received considerable scholarly interest sine the late 1980s (Dewailly et al. 1989). Through extensive monitoring initiatives, including the Arctic Monitoring and Assessment Program (AMAP), it is now well understood that the Arctic, although largely isolated from industrial activity, acts as a sink to environmental contaminants (e.g. mercury, and persistent organic pollutants) from long range transport (Bidleman et al. 2003; Van Oostdam et al. 2005). Despite their generally low concentration at low trophic levels, these contaminants can be assimilated in wildlife where they become subject to bioaccumulation and biomagnification across trophic levels. Though advocated for the promotion of food security and dietary quality, the consumption of country food is recognized as the principle exposure vector for many persistent environmental contaminants in the Arctic (Van Oostdam et al. 2005; Donaldson et al. 2010; Chan 1998). The presence of contaminants in country food represents a particular case for risk-management, as country foods are beyond the safety monitoring, policy, and legislation, of the industrial agro-food industry (Kuhnlein & Chan 2000), and furthermore, country foods, despite their contaminant burden, confer significant cultural, nutritional, and economic benefits to Inuit (Binnington et al. 2016; Laird et al. 2013; Kuhnlein & Chan 2000). Though local consumption advisories may be issued for species or animal parts (e.g. ringed seal liver (Government of Nunavut, University of Ottawa, Nunavut Tunngavik Incorporated 2012)), ultimately the decision to consume country foods resides with individuals and households. In Salluit (Nunavik), for instance, the possible presence of contaminants in country food sources did not modify consumption patterns (Poirier & Brooke 2000). However, community perceptions and responses to country food contamination have been variable, and the perceived risk of contaminants, as well as cultural resistance to contaminant discourse (Friendship & Furgal 2012; O'Neil et al. 1997), may determine, more practicably than scientific food safety characterizations, the extent to which contaminants interact with food security in the the north.

2.2.2 Country Food

Arctic Indigenous Peoples have depended on the harvest of Arctic species (termed "country foods") for thousands of years (Nuttall et al. 2005). Despite rapid sociocultural change during the last several decades, Inuit continue to utilize a rich diversity of approximately 200 species of local fauna, including dozens of marine and land mammals, approximately seventy avian species, and roughly fifty species of each local plants, and fish/seafood, although fewer species are used frequently (Kuhnlein & Receveur 2007). In addition to socially prescribed variations in diet, including age and life-stage specific dietary preferences/requirements (e.g. pregnant women and elders), the species and the parts used are subject to considerable regional variation, based on species availability, climate, distance of wildlife populations from home (Boas 1964; Binford 1978).

Animal source food

The dependence of Indigenous Peoples on wild animal food in the Arctic is arguably more pronounced than in any other part of the world, due to the limited availability of edible wild plants in this region (Meltofte 2013). Animal source food (ASF), obtained from various modes of subsistence (e.g. maritime hunting, taiga and tundra hunting and fishing and reindeer herding) comprised the majority of traditional Arctic diets (Kuhnlein & Soueida

1992; Mann et al. 1962; Draper 1977; Young & Rawat 2012; Snodgrass 2013). Inuit communities were traditionally coastal and depended on marine environments for subsistence. At high latitude terrestrial ecosystems, marine environments provide a considerable expansion to the local diet and nutrient base (Chapin et al. 2004; Kozlov & Zdor 2003). For instance, sea mammal fats and fish (e.g. whale blubber and oil, ringed seal liver, arctic char flesh, etc.…) are rich sources (mean > 5 μg/100 g) of Vitamin D (Kuhnlein, Barthet, et al. 2006) and polyunsaturated fatty acids (Lucas et al. 2010). Ringed seal (*Pusa hispida)* was a year-round staple food; however, other important species included bearded seal, muskox, caribou, bowhead whale (*Balaena mysticetus*), beluga (*Delphinapterus leucas*), narwhal (*Monodon monoceros*), harp seal (*Pagophilus groenlandicus*), and various species of fish and shellfish (Boas 1964; Damas 1972; Kemp 1984). In the barrens, communities relied more heavily on fish, migratory and sedentary birds, terrestrial mammals, and berries (Chapin et al. 2005). Inuit country food use has changed considerably in recent decades in terms of the absolute quantity and the relative importance of different species, parts, and preparations (e.g. raw, cooked, and fermented). Historically, caribou (*Rangifer tarandus*) and Arctic char (*Salvelinus alpinus*), which are present-day staple foods, occupied a smaller seasonal role in the diet (Stevenson 1997).

The introduction of firearms, snowmobiles, and settlement into permanent settlements greatly changed the nature of country food procurement. Although the introduction of firearms and other modern technologies, are often perceived to contribute to unsustainable harvests, there is no indication that these technologies have led to resource depletion through wasteful practices or overexploitation (Collings 1997), and the effect of other external factors (i.e the introduction of non-Indigenous harvesters, and severe whether conditions, colonial education) and the necessity of these technologies in the context of relocation policies and centralized settlements, are often overlooked (Collings 1997).

Plants

Early literature contains few references about the use of plants among Inuit, beyond plant-use for winter, as a starvation food, or used a trade item (Høygaard 1941; Eidlitz Kuoljok 1969). Although various scholars have suggested that plants played a minor-to-negligible role in the Inuit diet (Boas 1964; Draper 1977), Schaefer and Steckle (1980) contend that plant-use in traditional diets is more important than has been described in ethnographies. Various species of seaweed, berries (e.g. crowberries (*Empetrum nigrum*), Artic blueberries (*Vaccinium uliginosum*), cloudberries (*Rubus chamaemorus*), tundra greens, and other plant matter (e.g. stomach contents of caribou), are used as food, medicine, and material (Boas 1964; Kuhnlein & Soueida 1992; Kuhnlein & N. J. Turner 1991; Black et al. 2008).

The importance of wild plant foods to human nutrition has been highlighted for several decades (Bharucha & Pretty 2010; Fleuret 2010; Scoones et al. 1992). Generally, wild plants are consumed to compliment diets dominated by starchy staples or animal source food (Eidlitz Kuoljok 1969; Høygaard 1941) and though, the contribution of wild plants to total dietary intake is very low (due to infrequent use, and small portion sizes), including in the most biodiverse regions of the world, they can contribute significantly higher micronutrient intake (Boedecker et al. 2014). Accordingly, wild plants are often considered an "underutilized potential" (Boedecker et al. 2014).

Nutrition in Traditional Inuit Diets

A predominant feature of the traditional Inuit diet is the low carbohydrate content (Draper 1977). Høygaard (Høygaard 1941) reported that the traditional Inuit diet (Tasiilaq, Greenland) provided approximately 2,800kcal, 299g of protein, 169g of fat, and 22g of carbohydrates. A high concentration of protein was an essential feature of the Inuit diet to provision the amino acids required for glucose synthesis (Draper 1977). Draper (1977) contends that despite its restricted composition, the traditional Inuit diet was capable of provisioning all the essential nutrients for nutritional health. Early accounts suggest that the traditional diet provisioned 500mg of calcium, 2g of phosphorous, 50,000 International Units of vitamin A, and approximately 36 mg of vitamin C (Høygaard 1941). As mentioned previously, however, insight into nutrition in the traditional Inuit diet, is limited by a lack of food composition information and systematic dietary assessments.

2.2.3 Market Food

Shifts in food systems occur as a result of diverse factors as colonialism, technological, lifestyle and climatic change. Colonial policies and programs initiated by the federal government during the mid-twentieth century – including, but not limited to forced relocation into permanent settlements, and the residential school system (Truth and Reconciliation Commission of Canada 2015) – systematically undermined the sovereignty of Inuit communities (Bonesteel & Anderson 2008), and accelerated the transition from traditional subsistence-based lifestyles to mixed-economies. Integration into wage economies in the north, and the omnipresent influences of industrialization, globalization, and capitalism, have fostered increase reliance on market foods, in particular, market foods of poor nutritional quality (Kuhnlein et al. 1996; Kuhnlein et al. 2004; Sharma et al. 2010; Sharma et al. 2009; Sheehy et al. 2013).

Despite the very costly and complex logistics of food retailing in communities of northern Canada (e.g. distance from food production centers, limited road access and isolation from major transportation routes) market foods are now routinely sold in remote community stores, either through private corporations or community co-operatives (Enrg Research Group 2016). Although there has been significant scholarly focus on the traditional dimension of the Inuit food system, comparatively little information is available on the market food system in the north. Unlike country foods, whose availability differs greatly between regions and communities, market food items available in Arctic communities are consistent geographically (Kuhnlein & Receveur 2007). The most frequently reported market foods in dietary surveys are generally nutrient-poor. These include, for instance: coffee and tea, white bread, biscuits, lard, crystal powdered drinks, evaporated milk, and soft drinks (Kuhnlein & Receveur 2007). In many communities fresh meats are unavailable, while those meats that are available are often frozen, preprocessed, or precooked (Kuhnlein & Receveur 2007).

Key features of the northern food retailing environment include the very high cost of food, the limited availability, diversity and poor quality of nutritious perishable foods, such as fresh fruits and vegetables – particularly during certain times of the year, and, with extreme weather events. The high cost of food in northern Canada is well documented, and together with poor quality, is perceived by Inuit as the principle barrier to purchasing nutritious market foods (Mead et al. 2010). The average price of market foods in Nunavik (northern Quebec) for instance, was 81% higher than in Quebec city in 2011 (Duhaime & Caron 2012). Inuit in Nunavut and the Inuvialuit Settlement Region spent an estimated CAD $19.70 per person per day on food (CAD $7,217 annually) (Pakseresht et al. 2014), roughly three times the amount spent by the average Canadian (CAD $ 6.44) (based on the annual average household expenditure of CAD $5,880, 2.5 person per household, for food purchased in-store) (Statistics Canada 2016)).

In Canada, northern food subsidy programs have been administered by the federal government since the 1960s (e.g. the federal Food Mail Program, 1999-2011) to promote availability and access to nutritious foods (e.g. fresh fruits and vegetables, dairy products) in northern remote communities. The Nutrition North Canada (NNC, 2011-present) federal subsidy program is currently available in eligible communities to offset the high cost of transporting food to remote northern communities (Government of Canada n.d.). NNC has been reviewed for its administration and reporting structure, as well as its effectiveness in meaningfully promoting access to nutritious foods in the North (Galloway 2014; Office of the Auditor General of Canada 2014; de Schutter 2012). Concern remains that the "extremely high" (Enrg Research Group 2016) cost of nutritious food remains prohibitive for many households.

While conventional metrics of food security seldom embody nuances of the traditional Inuit diet, they nonetheless provide meaningful insights into the economic challenges experienced by individuals, and households, in accessing a healthful diet. Between 40% and 70% of Arctic Indigenous women interviewed in three large cross sectional surveys (1993 to 2000), indicated that they could not afford to purchase sufficient food to meet the family's needs (Lambden et al. 2006). Similarly, The principal factors contributing to food insecurity documented in the 2007-8 Inuit Health Survey – unemployment, low income, and high food costs – collectively represent economic barriers to diet acquisition, whether through the direct purchase of food in stores, or through the acquisition of equipment and supplies for harvesting (Egeland 2010).

Nutrition

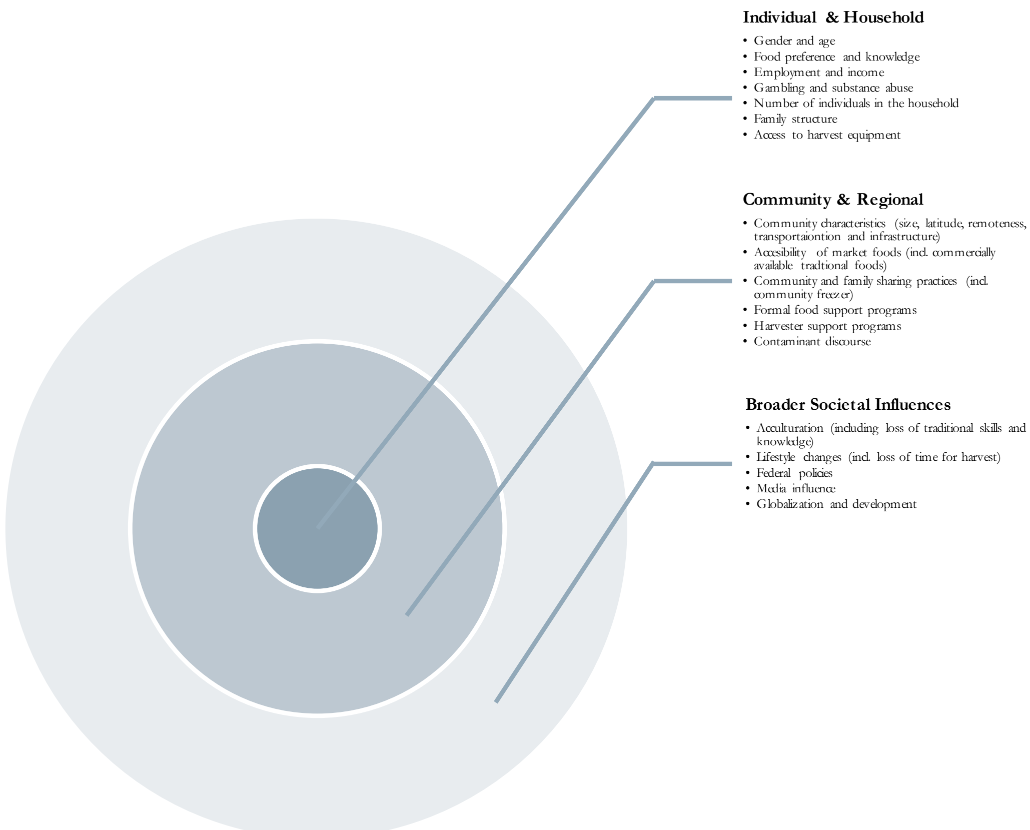
As recently as 1987, country foods provided nearly half (43.5% of total diet energy) of the total diet of Inuit men (based on September data from the Qikiqtaaluk region) (Kuhnlein 1995). Market foods, though largely unavailable to Inuit during the first half of the 20th century now constitute over 70-80% of the total diet (on the basis of energy) (Sharma et al. 2010; Sharma et al. 2009; Sharma 2010; Kuhnlein et al. 2004). This transition has greatly compromised dietary quality, and studies conducted in recent decades identify a range of nutrient adequacy issues for Inuit adults in Arctic Canada. Low intakes of dietary fiber, calcium, vitamins A, C, D and E, folate, and n–6 fatty acids are pervasive across northern Canada (Erber, Hopping, et al. 2010; Berti et al. 2004; Hopping, Mead, et al. 2010; Sharma et al. 2010; Sharma et al. 2013; Kuhnlein & Receveur 2007). Moreover, maximum recommended sodium intakes are commonly exceeded (Blanchet & Rochette 2008).(Blanchet & Rochette 2008)

Despite their modest contribution to total diet energy, country foods remain a significant proportion of total animal-source foods, and make significant contributions to several nutrients (e.g. protein, iron, niacin, riboflavin, thiamin) (Kuhnlein et al. 2004; Kuhnlein & Receveur 2007; Kuhnlein et al. 1996). Higher essential nutrient intakes are observed on days when CF are included in the diet, and consumption of a single portion of CF is sufficient to significantly increase intake of protein, vitamin D, vitamin E, riboflavin, vitamin B6, iron, zinc, copper, magnesium, manganese, phosphorus, and potassium (Kuhnlein et al. 2004; Kuhnlein & Receveur 2007).

2.2.4 Factors Influencing Diet

Food choice is a complex human behaviour premised upon sensory, hedonic, and biological factors, on the one hand, to sociocultural, economic, and environmental factors, on the other (Bisogni et al. 1996; Sobal et al. 1998; Stewart & Tinsley 1995). The relative importance of each factor depends on gender, culture, and population, and is variable through the life-course. Furthermore, many factors are inextricably linked. For instance, although sensory experience is an individual phenomenon, taste preferences are often steeped in cultural factors (Willows 2005). To effectively promote healthful diets and support food security, there is a need for a more comprehensive understanding of the many factors that influence diet among Indigenous Peoples, including deeper understanding of their interactions (Willows 2005).

Figure 2.2 Summary of Factors Influencing Food Choice in the North



Declining country food consumption among Inuit has been attributed to a number of sociological (e.g. acculturation, salaried employment) and environmental (e.g. species depletion, concern of contaminants, climate change) factors (Duhaime et al. 2002; Egeland et al. 2010; McEachern 1978). Employment and income, and consequently, the ability to acquire and maintain harvest equipment, influences the level of harvesting and country food consumption – in some cases, the high cost of harvest equipment is prohibitive to engagement in traditional harvest activities (Mackey & Orr 1987; Condon et al. 1995; Duhaime et al. 2002; T. G. Smith & Wright 1989). A return caribou hunting trip, for instance, can cost upwards of $340 in gas alone, excluding other costs such as oil and equipment maintenance (Ford & Beaumier 2011). Given that male hunters remain responsible for much the country food production, the presence/absence, and occupation, of males in the household has been identified in many studies as an important determinant of household country food access (Duhaime et al. 2002). Households with an active hunter, furthermore, report a lower prevalence of food insecurity, and severe food insecurity, compared to households without an active hunter (Huet et al. 2012). Conversely, belonging to a household with a single-parent mother heading the family has been negatively related to household country food supply (Duhaime et al. 2002).

When environmental and socioeconomic circumstances preclude the ability to hunt regularly, markets and informal exchanges or sharing practices are important mechanism to support country food access. Traditions of sharing and reciprocity in Inuit communities promote access to country foods, and have been studied for several decades (Kishigami 2004; Collings et al. 1998). These traditions have also been formalized into community food programs, such as communal freezers and community harvests, to promote access to country food and food security for elders and the most vulnerable members of the community (Duhaime et al. 2002; Organ et al. 2014). Country food markets also provide a means to to obtain country foods locally (Marquardt & Caulfield 1996; Searles 2016; Ford et al. 2016).

Lifestyle changes that include time constraints and the appeal of convenience have in some cases, situated prepared/convenience foods preferentially over country foods in some dietary surveys (Paci et al. 2004; Lardeau et al. 2011; Duhaime et al. 2002). In the Nunavik Health Survey, 60% of the respondents reported buying prepared/convenience foods at least some of the time. The main reasons given by the respondents to explain this kind of purchase was either a lack of time or because it was easier (64%) (Jetté 1995). Only 15% cited the inaccessibility of country foods as a reason for using convenience foods. Socioeconomic indicators of diet quality among Inuit have been limitedly investigated (Hopping, Erber, et al. 2010; Galloway & Johnson-Down 2015; Pakseresht et al. 2014; Erber, Beck, et al. 2010). Participants with higher SES (Material Style of Life) and higher levels of formal education spent significantly more on, and were more likely to consume, fruit and vegetables (Pakseresht et al. 2014; Erber, Beck, et al. 2010). In some studies, socioeconomic indicators do not appear to be related to higher reliance (frequency of consumption and expenditure) on non nutrient dense food intake (Erber, Beck, et al. 2010; Pakseresht et al. 2014), suggesting factors such as taste preference or availability may bear greater influence on food consumption.

2.3 Summary

Given the adverse-health effects of food insecurity and the nutrition transition, developing an awareness of food system change, and elucidating constraints in the food system that may mediate it, are recognized priorities of food system research. Wild foods remain inextricably linked to culture, health and wellness in various global populations but are increasingly burdened by climate change and other anthropogenic pressures. International efforts to develop more holistic and integrative approaches to human nutrition, food security, and natural resource management have been highlighted in recent literature (Hickey et al. 2016). However, much of the literature examining the convergence of biodiversity, sustainable ecosystems and human nutrition and health, has been conducted in the most biodiverse regions of the world, and less is known about how these factors are manifested in Arctic contexts.

While restricted access to wild foods is an important determinant of the nutrition transition, consideration of the traditional dimension alone, paints an incomplete picture of the nutrition transition. When the use of wild and traditional food is diminished, the maintenance of dietary adequacy is theoretically possible upon the consumption of market foods of high nutritional quality. In rural and remote Indigenous communities, however, high food prices, low per capita income, and limited availability of nutritious fresh/perishable foods, collectively challenge food security and foster higher reliance on a limited diversity of non-perishable, and highly-processed foods. While the economic dimensions of obesity, nutrition diet, have been investigated in various global region, there is a lack of research examining how these factors are articulated in northern food retail environments. Furthermore, there is a lack of research seeking to characterize how multiple stressors (e.g. environmental and economic factors) interact to affect food security and diet quality in both the Arctic, and in other global contexts.

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3 ESTIMATING WILDLIFE HARVEST BASED ON REPORTED CONSUMPTION BY INUIT IN THE CANADIAN ARCTIC

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A version of this chapter has been published in the journal Arctic, March 2017. Please refer to Appendix C, for the the copyright agreement and permission to reproduce this material.

Authors' contributions: TK formalized the research question based on research priorities identified during a regional food security workshop in the Inuvialuit Settlement Region (Inuvik, Northwest Territories). TK performed the analyses, interpreted the data, and drafted the manuscript. HMC oversaw and provided intellectual support during all stages of the research.

ABSTRACT

The harvest and consumption of wildlife are integral to the livelihood, culture and nutritional status of the Inuit of Northern Canada. When wildlife populations are perceived to be vulnerable harvest restrictions may be enacted to protect species conservation interests. Such restrictions may also have consequences for the nutrition and food security of Inuit communities. The objective of this study is to estimate the number of key species of wildlife needed to sustain the traditional diet of Inuit. Using responses from the Food Frequency Questionnaire of the 2007-2008 Inuit Health Study collected from a total of 806 men and 1275 women, we characterized annual country food consumption in five Inuit regions of northern Canada. Data regarding species average edible yield, and Inuit population demographics were compiled to estimate the total number of harvested animals. Caribou (Rangifer tarandus) was the species consumed with the highest prevalence (> 90%) and in the greatest amounts (29.6–122.8 kg/person/yr, depending on sex and region). The consumption rate for beluga whale (*Delphinapterus leucas*) was 5.9 – 24.3 kg/person/yr. and that for ringed seal (*Pusa hispida*) was 4.1 – 25.0 kg/person/yr, depending on sex and region. To sustain this consumption consumption, it is estimated that a mean total of 36526 caribou, 898 beluga whales, and 17465 ringed seals are required annually. These results provide a baseline for food security and resources management in the Canadian Arctic to balance Indigenous subsistence needs and wildlife conservation.

3.1 Introduction

The Arctic is populated by several key species of mammals, e.g., caribou (*Rangifer tarandus*), beluga whale (*Delphinapterus leucas*), and ringed seal (*Pusa hispida*), whose population health is increasingly threatened by the pervasive influence of human activities and climate change (Kutz et al. 2013). The Arctic is also inhabited by Northern Indigenous peoples, such as the Inuit, for whom the harvest and consumption of local wildlife, termed "country food", has for thousands of years provisioned subsistence (Nuttall et al. 2005). Inuit communities have witnessed a general decline in the health and population status of many wildlife species relevant to subsistence lifestyles (Campbell 2007; Kilabuk 1998; Dumond 2007). Although various factors including climate, habitat degradation, prevalence of disease and parasites, level of predation and harvest, have been attributed to the observed population declines, wildlife management regimes have often focused on quota and other non-quota harvest restrictions to conserve the wildlife species. Harvest restrictions have been implemented for various Canadian Arctic species. This includes harvest restrictions for caribou on Nunavut's Southampton Island and most of the Qikiqtaaluk region (Government of Nunavut, 2015a,b), as well as in Nunatsiavut, where the George River caribou herd has declined by over 80% in the last decade (Government of Newfoundland and Labrador, 2013). Additionally, quota systems have been implemented for the harvest of beluga whale, narwhal (*Monodon monoceros*), bowhead whale (*Balaena mysticetus*), walrus (*Odobenus rosmarus*), and polar bear (*Ursus maritimus*) in various Inuit regions (Gosselin et al., 2002;Stewart and Lockhart, 2005).

The threat of climate change, habitat loss/degradation, and observed declines in species abundance, have motivated a number of domestic, and international, conservation measures (e.g. agreements, legislation, and management regimes) to protect several key species of arctic mammals (e.g. polar bear). The precautionary approach (avert risks of serious or irreversible harm in the absence of scientific certainty) is increasingly accepted as a foundational principle of environmental management, and has been incorporated in various instruments of biodiversity conservation at national and international levels (Cooney, 2004). Although "intuitively sensible", reconciling the interests of biodiversity conservation and human livelihoods, through a precautionary approach, raises significant equity issues and can yield negative impacts on those intimately dependent on the utilization of biological resources to support livelihoods (Cooney, 2004).

Although harvest restrictions have often been implemented for wildlife populations perceived to be vulnerable, they have not always been supported by scientific evidence (Diduck et al. 2005) and quota systems have had mixed success in achieving conservation objectives (Wilder 1995). For some species of wildlife in the Canadian Arctic, population status, health and seasonal range data are poor for effective harvest management (Dumond 2007). Furthermore, the degree to which Aboriginal subsistence harvests place stress on wildlife populations, has not to our knowledge been explicitly defined in the literature for the Inuit context. For some species, like beluga whales in the Inuvialuit Settlement Region, the total Inuit harvest has been deemed far below the magnitude at which negative population outcomes would be observed (DFO 2000).

While the effectiveness of quota systems to conserve wildlife populations remains unclear, the consequences of restricting Inuit subsistence harvests are apparent. The harvesting and consumption of local wildlife by Inuit contributes importantly to physical health, food security, cultural identity and spiritual well being (Condon et al. 1995; Borré 1991; Schuster & Wein 2011; Kuhnlein et al. 2004; Lambden et al. 2007). Country food contributes significantly to nutritional status, such that up to 25% higher intakes of protein are reported on days when country food is consumed, with higher intakes of micronutrients (niacin, riboflavin, vitamin B6, B12, selenium, zinc, iron, phosphorous), and lower intake of carbohydrates and saturated fat, relative to days when it is not consumed (Egeland et al. 2011; Blanchet & Rochette 2008; Kuhnlein & Receveur 2007). Beyond their rich nutritional qualities, several studies have identified country foods preferentially over market foods in terms of their affordability, palatability, and importance to Inuit culture and identity (Condon et al. 1995; Borré 1991; Wein & Freeman 1992). Harvest restrictions are likely to exacerbate Inuit food insecurity issues(food insecurity was identified in 62.6% of Inuit households of the Inuit Health Survey (Huet et al. 2012)), with implications for diet quality and risk of diet-related chronic diseases.

Wildlife managers and Inuit community organizations must interpret the projected outcomes of various management regimes and implement actions to buffer against the most adverse effects. To responsibly do so, they must recognize the need of stakeholders involved, and it is in this respect that despite "constitutionally entrenched" rights to harvest (Hummel & Ray 2008), the food security and nutritional status of Indigenous communities may not always be adequately accounted for within wildlife management regimes.

Preserving the integrity of Indigenous food systems, the cultural institutions, and traditional knowledge embedded within, involves recognition by wildlife managers that humans are integral ecosystem members (Chapin et al. 2004). Implementing conservation policies and practices that reconcile the sometimes conflicting values of conserving wildlife and using wildlife for subsistence is challenging (Bennett et al. 2007). Although the sustainability of wildlife populations is relevant to both government (wildlife management and nutrition/public health) and Inuit beneficiaries, Inuit disproportionately experience the consequences of conservation measures and wildlife population threats. In allocating harvest quotas and implementing harvest regulations, it should be considered that Inuit require access to these resources for the maintenance of nutritional adequacy and food security – without which they become susceptible to adverse outcomes from consumption of low nutrient dense market foods (Kuhnlein et al. 2004; Egeland et al. 2011). Inuit Land Claim Agreements include an extensive wildlife article detailing Inuit harvesting rights and standards for government restrictions on harvest. For instance, Article 5 (Wildlife) of the Nunavut Land Claims Agreements details harvesting rights/priorities/privileges and the establishment of a system of wildlife management in the Nunavut Settlement Area (Nunavut Final Agreement, 1993). Inuit have the right to harvest a stock or population up to the full level of his or her economic, social, and cultural needs. As part of the wildlife co-management process, a determination of the annual allowable harvest for selected species may be established (Natcher et al. 2012).

To assist Inuit community organizations, wildlife managers and public health professionals in the development of conservation programs that optimize wildlife population sustainability, while mitigating adverse affect to the dietary quality of the Inuit, reliable data on current harvest levels and how they are related to the diet is required. Unfortunately, there are few data sets available to relate the level of harvest to the consumption level in different regions of the Arctic. The purpose of this study is to establish estimates of country food use for selected species of wildlife (prioritized for the significance they occupy in the Inuit diet and data availability) in 5 Inuit regions in Canada. Translating dietary data regarding country food consumption to the equivalent wildlife harvest requirement situates issues of food security within a forum that is relevant to communities, wildlife managers and nutrition/public health professionals.

3.2 Study Population and Location

Country food consumption data used in the present study was derived from the Canadian International Polar Year Inuit Health Survey (IHS). The Inuit Health Survey, conducted between the late summer and fall of 2007 and 2008, collected comprehensive baseline data about the health, and living conditions, of Inuit adults across three jurisdictions within the Canadian Inuit Nunangat (Inuit Regions of Canada): Nunatsiavut, Nunavut and the Inuvialuit Settlement Region (ISR) (Fig 3.1). Results from Nunavut are also presented according to the territories' three administrative regions (Kivalliq, Qikiqtaaluk, and Kitikmeot). Nunavik (northern Quebec) Inuit were not included in the 2007-2008 IHS, as a separate health study was conducted in Nunavik in 2004 (Rochette & Blanchet., 2007). Complete study design and methodology for the IHS has been described elsewhere (Saudny et al. 2012). Briefly, a cross sectional study was conducted in which 2796 households were randomly selected to participate. From these households, Inuit adults, aged 18 and older (men and non-pregnant women) were eligible to participate. The Inuit Health Survey was designed in a participatory manner, with representatives from the three participating Inuit jurisdictions. It was approved by both the McGill University Faculty of Medicine Institutional Review Board and the University of Ottawa Health Sciences and Science Research Ethics Board (file number H05-15-16).

Figure 3.1 Map of the participating Inuit regions of the 2007-2008 Inuit Health Survey: Inuvialuit Settlement Region, Nunavut (Kivalliq, Qikiqtaaluk, and Kitikmeot) and Nunatsiavut

Map showing the Inuit regions that participated in the Inuit Health Survey of 2007–08. (From west to east): the Inuvialuit Settlement Region; Kitikmeot, Kivalliq, and Qikiqtaaluk, the three subregions of Nunavut; and Nunatsiavut. Adapted from the Map of Inuit Nunangat (https://www.itk.ca/maps-of-inuit-nunangat) and used with permission of the Inuit Tapiriit Kanatami (ITK).

In total, 2595 adults from 1901 households (68% of households approached) took part in the IHS, yielding an approximate participation rate of 12% of people from each community. The survey employed a number of methodologies (e.g., questionnaires, clinical tests, blood samples), however, the present study includes only data from the food frequency questionnaire (FFQ). Completed food frequency questionnaires were available from 208 men and 304 women in Kivalliq, 271 men and 412 women in Qikiqtaaluk, 143 men and 215 women in Kitikmeot, 86 men and 180 women in the ISR, 98 men and 164 women in Nunatsiavut. Not all respondents of the FFQ reported consumption of beluga whale, ringed seal, and/or caribou. The subset of consumers (defined as those reporting > 0 g of a particular country food per day) for each species of country food was retained for analysis of harvest requirements.

Table 3.1 Regional characteristics: population distribution by age and sex

Population	Regions included in the IHS					
	Nunavut [a]				Inuvialuit Settlement Region [c]	Nunatsiavut [d]
	Nunavut	Kivalliq [b]	Qikiqtaaluk [b]	Kitikmeot [b]		
0 - 12 years old	8 873	2 688	4 438	1 743	1 125	495
Male	4 538	1 373	2 268	890	555	270
Female	4 328	1 318	2 165	853	570	225
13- 17 years old	3 458	1 028	1 748	678	505	220
Male	1 773	518	903	350	250	115
Female	1 683	508	845	333	250	95
>= 18 years old	19 585	5 235	10 745	3 600	4 125	1 895
Male	10 100	2 695	5 540	1 855	2 095	1 000
Female	9 490	2 540	5 205	1 745	2 030	900
Total by region	31 905	8 955	16 940	6 010	5 775	2 615
Aboriginal Identity [d]						
Male		90	79	89	72	93
Female		91	82	90	75	90

[a] Nunavut includes Kivalliq, Qikiqtaaluk, Kitikmeot and the Nunavut data represents the sum of the 3 sub-regions

[b] Data from Statistics Canada, 2011 Census of Population – regional data

[c] Data from Statistics Canada, 2011 Census of Population – community data pooled by region

[d] Aboriginal identity defined as the percentage of respondents self-identifying as Aboriginal in the 2006 census community profiles (Robinson & Bennett 2002)

3.3 Methods

To estimate the harvest needs of country foods necessary to meet current regional diets in the Canadian Arctic, data regarding Inuit country food consumption, Inuit population demographics, and the average edible yield of species consumed as country food were compiled.

3.3.1 Determination of Harvest Requirement

Data regarding the consumption of country foods was derived from the Food Frequency Questionnaire (FFQ) of IHS. The interviewer-completed questionnaire (English and Inuit languages) solicited information regarding the frequency, usual serving size, and seasonal-variability of a comprehensive, and locally adapted, list of country foods. Participants were asked to recall how often each food item was consumed both "in season" and "out of season" in the previous year. These season designations were based on community previously completed harvest calendars (such as the Nunavut Wildlife Harvest Survey). Frequency was recorded per day, per week, per month, or per season and calculated the average consumption over the last year. Serving sizes were estimated using three-dimensional graduated food model kits from Santé Québec and pictures (when needed). We focused on consumption results of caribou (*Rangifer tarandus*), beluga whale (*Delphinapterus leucas*), and ringed seal (*Pusa hispida*) based on their importance in the Inuit diet. Only data from the consumers, defined as individuals reporting consuming more than 0 g/day of a particular country food, was included in the analysis.

Adult consumption results were converted to a daily consumption equivalent (g/person/day) based on estimates of portion size (standard portion model, Santé Québec) and food density. Annual amounts consumed of different body parts from each species were summed to estimate the total weight of that species over the past 12 months; e.g., total caribou consumption (kg/person/year) is the sum of caribou meat + caribou organs + caribou fat + other parts consumed in that year. As food frequency data was not collected for children, we estimated consumption of children aged 0–12 years (inclusive) at one third of an adult equivalent, and that of adolescents (13–17 years) at two thirds of an adult equivalent (Berkes & Farkas 1978).

Employing a proportional projection, we adjusted the results from the IHS to estimate the total Inuit consumption of each country food by region. In brief, the estimated per capita consumption (kg/person/year) and percent consumers (# of consumers of the item/total respondents) was multiplied by the estimated Inuit adult population (Table 3.1). Multiplication was done separately for males and females and these products were summed to get the total projected consumption.

$$Y_i = \left(y_i * N\left(\frac{c_i}{n}\right)\right)_f + \left(y_i * N\left(\frac{c_i}{n}\right)\right)_m$$

Y_i = Estimated regional consumption (kg/region/year) of country food species 'i'

y_i= Reported per capita consumption (kg/person/year) of country food species 'i', by sex

N_r = Estimated Inuit population in the region (total regional population reported in 2011 census, multiplied by the percent respondents in the 2006 census identifying as Aboriginal), by sex

n_r = Total number of respondents for the the IHS FFQ, in the region, in by sex

c_i =The reported number of consumers (>0g/day) of country food 'i' reported in in the IHS by region, and sex

For females (f), and males (m), respectively

We repeated this process for each species (caribou, beluga whale, ringed seal) and again, repeated it for children and adolescent consumption. Total children, adolescent and adult results were summed for each species, to yield an estimated annual consumption by region (kg/region).The total regional consumption of country food (kg/region/year) was then converted into subsistence harvest estimates (animals/region/year) based on the average edible weight of each species. There exists no universal standard of reference regarding the average edible yield of northern-harvested animals due to insufficient field studies, regional and seasonal weight variations, and challenges related to defining 'edible' portions, which is non-universal and culture specific (Ashley 2002; Usher 2000). Our determination of wildlife edible weight was thus derived from review of literature, considering the strength of the study methodology, the year in which the study was published, and the study location. The total regional consumption (kg/region/year) was converted to harvest requirements (Total number of animals required to meet present Inuit diets/region), by dividing the total projected regional consumption by the most appropriate edible weight yield values reported in the literature (Table 3.2).

Table 3.2 Edible yield of selected traditional mamals

Species	Edible Yield (Kg-edible/animal)	
	Range [a]	Value Used [b]
Beluga Whale	106[c] – 481[d]	335[e]
Ringed Seal	13[e] – 59[f]	16[g]
Caribou	36[e] – 50[h]	45[i]

[a] Range of edible weights reported in the literature
[b] Value employed in the calculation of harvest requirements in the present paper
[c] (Berger 1977) [d] (Ewan Cotterhill & Associates 1986)[e](Usher 2000) [f] (Pattimore, 1985), [g] Based on average of (Usher 2000) and (Loring 1996), [h] (Veitch 1996), [i](Ashley 2002)

3.3.2 Assumptions

A number of assumptions were made for the derivation of regional estimates. Whenever there is a range of values in the literature, we tend to use the parameters that would yield the most conservative estimate. Interpretation of the results presented herein must therefore be considered within the constraints of these assumptions.

First, the edible weight yields used to translate total regional consumption (kg/region) to wildlife harvest equivalents (number of animals harvested/region) assume an inherent age-sex structure to the harvest. This harvest structure may however, be inconsistent with that of the local Inuit harvester context. This assumption will influence the total body mass of the harvested animal, in turn, dictating the edible weight yield.

Second, the consumption of each edible portion of different animal parts reported in the IHS, was summed for each participant (ex: caribou ribs + caribou meat, etc.) to yield an estimated total consumption by species. This approach assumes there is no specific preference for any particular animal part (e.g., beluga muktuk (skin)). As a result, the estimated harvest requirement may be underestimated, if more animals are harvest because of certain preferable parts.

Third, the preparation method will influence the moisture content, thus the resulting weight of country food consumed. Food frequency questionnaires of the IHS collected consumption data according to the relevant edible portion (e.g., beluga muktuk), at times embedding various preparation methods (e.g., fresh, cooked or frozen) into the same grouping by edible portion. The moisture content of raw and cooked edible portions can differ by up to 10% (Kuhnlein et al., 1996). The difference in weight resulting from different cooking methods (e.g., baking vs. boiling) was deemed insignificant in relation to individual differences in consumption. When respondents reported consuming dried portions of country foods, however, we converted dry weights to fresh weights using moisture content differentials reported in the literature for caribou and beluga: raw caribou meat = 71 g moisture/10 g portion; dried caribou meat = 32 g moisture/100 g portion; dried beluga meat = 22 g moisture/100 g portion; raw beluga muktuk = 68 g moisture/100g portion; raw beluga blubber = 22 g moisture/100 g portion (Kuhnlein and Soueida, 1992).

Fourth, as data regarding country food consumption of those aged less than 18 years was not collected during the IHS, child and adolescent food intake was estimated according to previous standards described by Berkes & Farkas (1978). Consumption of children (0–12 years) and adolescents (13–17 years) were assumed to represent one-third, and two-thirds, respectively, of adult consumption. The prevalence of country food consumption for children and adolescents was adjusted in order to simulate the relative lower intake of country food among children and adolescents (Quinn et al. 2012). We have assumed therefore the prevalence of country food consumption of children and adolescents to equate 25% and 75%, respectively of that reported by adults in the IHS (Quinn et al. 2012).

Fifth, the country food requirements reported herein assume all available country food is consumed, with no consideration of consumer wastage.

The results reported herein can thus be readily adjusted by an appropriate conversion factor to account for projected wastage losses at the consumer level. Finally, the self-reported use of country food, as recorded in the 2007–08 Food Frequency Questionnaire of the Inuit Health Survey, was used as a snapshot of baseline country food use among Inuit at that time. It is important to emphasize that this estimate does not represent preferred/idealized or recommended diets to satisfy nutritional or cultural requirements for country food.

3.4 Results

3.4.1 Country Food Consumption

Adult consumption (kg/person/year) for beluga whale, ringed seal, and caribou, were computed based on IHS FFQ response for both men and women, in each of the 5 regions (Table 3.3). It must be noted that median and 95th percentile consumption statistics reported in Table 3.3 are meaningful in describing individual-level responses, however, the 95% CI of the mean is the most representative result from which determination of regional subsistence harvest requirements should be derived. A consistent trend observed across all regions was the high prevalence of caribou consumption, with no region reporting less than 94% consumption prevalence. Caribou was also the country food consumed in highest quantities, with annual mean consumption ranging between 29.6 – 101.3 kg/person for women and between 49.7 – 122.8 kg/person for men, according to region (Table 3.3). Table 3.3 also shows regional differences in the pattern of country food use.

3.4.2 Harvest Requirements

Detailed regional harvest requirements of beluga whale, ringed seal and caribou necessary to satisfy contemporary Inuit diets are summarized in Table 3.4. Median and 95th percentile results describe regional harvests projected from the corresponding IHS individual-level consumer results, whereas the 95% CI of the mean provide the most likely harvest estimate for the region.

Based on mean country food consumption results reported in the IHS, and the edible yield of 335 kg edible parts/beluga (Table 3.2), an average beluga whale will provide the meat/muktuk for 17 – 57 women, or 14 – 28 men, respectively, depending on region. In the scenario of highest beluga whale consumption considered here (133.2 kg/man, the 95% percentile in the Inuvialuit Settlement Region), an average beluga whale will satisfy the dietary requirement of as few as three people annually. These consumption statistics, together with population demographics (Table 3.1) and average species edible yield (Table 3.2), suggest that mean regional requirements of the beluga whale harvest range from 59 whales per year in Kitikmeot to 313 in Qikiqtaaluk and 337 in Kivalliq (Table 3.4). For ringed seal, based on the edible yield of 16kg edible parts/seal (Table 3.2) mean consumption results of the IHS suggest that a ringed seal will provide meat/organs for 1 – 4 women, according to region. For men in regions consuming low levels of ringed seal, a ringed seal may satisfy the diet of a little over two men annually, but for higher consuming regions, an average male consumer would require upwards of one and a half seals annually. In the highest scenario of consumption, we considered (81.1 kg/man, the 95% percentile in Qikiqtaaluk), an individual requires roughly five ringed seals annually. Based on these consumption statistics, mean regional harvest requirements range between 386 ringed seal per year in the Inuvialuit Settlement Region, to 11 687 ringed seal per year in Qikiqtaaluk (Table 3.4). For caribou, based on the representative edible yield of 45kg edible parts/caribou, our results suggest that in low caribou consuming regions, a caribou will satisfy the dietary need of 1 – 2 average men or women annually. However, in higher consuming regions an average individual would require between 2 – 3 caribous annually. Consumption of caribou by individuals at the 95^{th} percentile (286.4kg/person in Kivalliq and Kitikmeot) would necessitate upwards of 6 caribou annually. These consumption statistics correspond to mean regional harvest requirements of 1865 caribou per year in Nunatsiavut to 14270 caribou per year in Kivalliq (Table 3.4).

Table 3.3 Reported adult consumption equivalent of selected country food by region and sex (Kg/person/year)

Region		Consumption [a] (kg/person/year) of Select Country Foods											
		Beluga Whale				Ringed Seal				Caribou			
		Consumers [b] [n (%)]	Mean (95% CI)	Median	95th %	Consumers [b] [n (%)]	Mean (95% CI)	Median	95th %	Consumers [b] [n (%)]	Mean (95% CI)	Median	95th %
Nunavut [c]													
	M	466 (74.9)	19.4 (17.0 - 21.8)	7.5	83.0	501 (80.5)	19.6 (17.5 - 21.8)	8.8	76.9	605 (97.3)	87.0 (79.9 - 94.3)	47.4	265.5
	F	682 (73.3)	13.0 (11.2 - 14.8)	3.5	70.0	678 (72.8)	11.8 (10.3 - 13.3)	3.3	58.1	898 (96.5)	69.4 (64.0 - 74.8)	31.8	240.3
Kivalliq													
	M	187 (89.9)	24.3 (20.2 - 28.4)	12.6	91.2	145 (69.7)	13.6 (10.7 - 16.6)	6.7	46.5	207 (99.5)	122.8 (109.0 - 136.6)	91.1	286.4
	F	254 (83.6)	20.2 (16.7 - 23.7)	7.2	94.0	154 (50.7)	9.5 (6.3 - 12.6)	2.1	52.9	295 (97.0)	101.3 (90.7 - 112.0)	75.1	271.6
Qikiqtaaluk													
	M	201 (74.2)	17.8 (14.2 - 21.3)	6.5	76.8	251 (92.6)	25.0 (21.7 - 28.3)	14.3	81.1	258 (95.2)	49.7 (41.6 - 57.9)	19.8	218.8
	F	299 (72.6)	10.0 (7.6 - 12.4)	2.7	46.0	368 (89.3)	14.9 (12.7 - 17.0)	6.6	63.9	390 (94.7)	35.8 (30.2 - 41.4)	10.9	189.1
Kitikmeot													
	M	78 (54.5)	11.9 (7.2 - 16.7)	4.7	51.4	105 (73.4)	15.1 (10.4 - 19.8)	3.3	79.0	140 (97.9)	102.7 (87.7 - 117.6)	64.1	259.5
	F	129 (60.0)	5.9 (3.7 - 8.1)	1.5	16.9	156 (72.6)	6.8 (4.3 - 9.2)	1.7	31.5	213 (99.1)	86.8 (75.6 - 97.9)	59.7	254.1
Inuvialuit													
	M	80 (93.0)	28.8 (19.4 - 38.2)	10.3	133.2	20 (23.3)	9.3 (5.4 - 13.1)	8.1	25.9	84 (97.7)	51.9 (39.1 - 64.8)	33.4	182.0
	F	163 (90.6)	11.5 (7.7 - 15.2)	3.4	43.7	26 (14.4)	10.1 (2.1 - 18.2)	1.4	40.9	173 (96.1)	29.6 (23.4 - 35.9)	13.9	107.0
Nunatsiavut													
	M	-	-	-	-	75 (76.5)	13.3 (8.3 - 18.4)	3.8	71.2	98 (100.0)	52.6 (39.7 - 65.6)	24.7	210.7
	F	-	-	-	-	94 (57.3)	4.1 (2.5 - 5.8)	1.3	17.2	163 (99.4)	32.1 (25.1 - 39.1)	15.9	127.6

[a] Data from Inuit Health Survey, FFQ questionnaire, Individuals aged 18 years+

[b] Consumers defined as individuals who consume > 0g of respective country food per day

[c] Nunavut includes *Kivalliq, Qikiqtaaluk*, *Kitikmeot* and the Nunavut data represents the sum of the 3 sub-regions

Table 3.4 Estimation of regional harvest requirements (# animals) for selected country foods based on dietary consumption

Region (population[a])	Harvested Requirements (# of animals)								
	Beluga Whale			Ringed Seal			Caribou		
	Median	95th %	Mean (95% CI)	Median	95th %	Mean (95% CI)	Median	95th	Mean (95% CI)
Nunavut[b] (29270)	262	3614	768 (669 – 868)	6364	69639	16326 (14422– 18216)	18248	116085	35945 (32055 –38863)
Children[c] (13075)	57	790	168 (146 – 189)	1391	15208	3564 (3155 – 3979)	3986	25368	7855 (6244 –8492)
Adults[d] (16645)	204	2825	600 (523 – 678)	4973	54431	12762 (11287 – 14237)	14263	90717	28090 (25811 – 30370)
Kivalliq (8099)	152	1392	337 (279 – 394)	1053	10777	2616 (1955 – 3277)	10585	35442	14270 (12265 – 15831)
Children[c] (3362)	28	257	62 (51 – 73)	193	1987	481 (359 – 603)	1952	6540	2631(1900 – 2919)
Adults[d] (4737)	124	1135	275 (227 – 322)	860	8789	2135 (1596 – 2674)	8633	28902	11638 (10365 – 12912)
Qikiqtaaluk (13617)	104	1386	313 (247 – 380)	6158	42361	11687 (10088 – 13286)	3329	44113	9256 (7539 – 10748)
Children[c] (4973)	16	216	49 (38 – 59)	958	6594	1818 (1570 – 2067)	518	6868	1441 (983 – 1673)
Adults[d] (8645)	88	1171	264 (208 – 321)	5200	35768	9869 (8519 – 11219)	2811	37245	7815 (6555 – 9075)
Kitikmeot (5392)	19	226	59 (36 – 82)	447	10000	1975 (1329 – 2620)	5309	22015	8131 (6777 – 9252)
Children[c] (2170)	3	40	10 (6 – 15)	79	1771	350 (235 – 464)	942	3908	1443 (1011 – 1642)
Adults[d] (3221)	16	186	49 (30 – 67)	368	8229	1625 (1093 – 2156)	4367	18107	6688 (5766 – 7611)
Inuvialuit (4226)	64	831	189 (128 – 251)	223	1276	386 (165 – 607)	1743	10650	3005 (2255 – 3709)
Children[c] (1195)	7	94	21 (14 – 28)	25	146	44 (19– 69)	197	1210	341 (215 – 421)
Adults[d] (3031)	57	737	168 (113 – 222)	198	1130	342 (147 – 538)	1546	9439	2664 (2040 – 3288)
Nunatsiavut (2386)	-	-	-	211	3653	801 (496 – 1107)	890	7446	1865 (1395 – 2306)
Children[c] (646)	-	-	-	23	402	88 (55– 122)	97	809	202 (127– 250)
Adults[d] (1740)	-	-	-	188	3251	713 (441 – 985)	793	6637	1662 (1269 – 2056)

[a] Estimated Inuit population based on Statistics Canada (2011) Census of Population and reported prevalence (%) of Aboriginal identity Statistics Canada (2006) Census: Community profiles

[b] Nunavut includes *Kivalliq, Qikiqtaaluk*, *Kitikmeot* and the Nunavut data represents the sum of the 3 sub-regions

[c] Based on children's consumption estimations of one-third (children 0-12years) and two-thirds (adolescents 13-17years), respectively of adult consumption equivalents reported in the IHS (2007-2008) with 75% prevalence of adult consumption

[d] Based on adult consumption values reported in the FFQ of the IHS (2007-2008)

3.5 Discussion

To our knowledge, this study represents the first systematic effort to estimate regional harvest requirements of country food across several Inuit regions of northern Canada. Most of the previous initiatives estimated basic Inuit harvest needs using reported harvester data (see for instance Miller, 1983; Jingfors, 1986). Estimates by the Federal Court of Canada suggest that Inuit require between 5-7 caribou per person, annually (Miller 1983). Similarly, estimates by Jingfors (1986), suggest a slightly lower requirement of 3.1 caribou per person annually. Harvest estimates may be converted to edible food weights to yield the 'potential' edible yield (see Berkes et al. 1994), however, the actual consumption often remains unknown (Ashley 2002) and furthermore, the accuracy of this conversion has scarcely been validated through concurrent dietary studies (Guyot 2006). Moreover, harvester recall methods, may yield lower estimates of country food use, when compared to the amount country food reported in dietary recalls and food frequency interviews for many species (namely smaller, and non-staple species) (Guyot 2006). Despite considerable effort to characterize wildlife harvests for various Aboriginal groups across northern Canada, seldom have Aboriginal wildlife harvests been documented within the context of their contribution to diet (Berkes & Farkas 1978; Berkes et al. 1994). Existing harvest data sets moreover, have traditionally suffered from a lack of systematic sampling techniques, and derived almost exclusively from harvesters, suffer from a number of inherent methodological limitations – namely, the influence of "strategic bias", and harvester recall failure (for a review see Usher and Wenzel 1987). The current approach of estimating harvest requirement for country food, based on food use patterns should provide more relevant results to the context of food security.

Our estimated harvest requirements are based exclusively on diet, and do not consider the requirements for trade, sale and sport. Omission of economic harvests may result in an underestimation of total regional harvest requirements, and therefore, it is important that the results presented herein be understood within the exclusive context of harvest for country food use. Table 3.5 presents a comparison of our country food estimates with results reported in regional harvest surveys. Although the data were collected in different years and different methodologies were used, the comparison provides a means of crude validation of our estimates. It is remarkable that the range reported in previous harvest surveys are very similar to our estimates, and many even fall within the 95% CI of our estimated mean (Table 3.5). Our estimates are based on an individual's recall of food use over the previous year, and therefore, do not reflect the desire, or actual need, of the individual. A low consumption rate may reflect limited country food availability in the household, rather than inherent dietary preference. Indeed, the food frequency questionnaire of the Inuit Health Survey identified a lower intake (daily frequency of consumption) of country food among food insecure participants (Huet et al. 2012). Thus, results presented herein must be understood as relevant to satisfying reported diets, rather than desired, or optimal, diets. More fundamentally, inherent limitations exist in the use of health survey data (e.g., the order in which questionnaires are administered to participants, questionnaire length, misinterpretation of questions by participants), and the use of the food frequency questionnaire to estimate country food consumption (e.g., recall bias, estimation of portion sizes) (Duhaime et al., 2002; Pakseresht and Sharma, 2010). Despite systematic errors regarding consumption frequency and serving size (Bogers et al., 2003), researchers still regard the food frequency questionnaire a valid and reproducible tool for estimating long-term diet (Willet et al., 1985; Silva et al., 2013), including in the Inuit population (Duhaime et al., 2002; Pakseresht and Sharma, 2010).

The key factor used for the conversions of dietary consumption to harvest requirements is the mean edible weight for each species (Table 3.2). Harvest data sets however, have been often incomplete, inconsistent, and poorly reported, without reference to location, season, sample size or sample type (Ashley 2002). Moreover, many wildlife edible weight estimates have been based on average adult weights from sports hunters (Berger 1977; Ashley 2002), yet, the size and weight of Inuit harvests may reflect preferential harvest selection, or opportunity and encounter. Additionally, many species exhibit an inherently large range in the reported edible weight yield (Ashley 2002). Sources of variance in edible weight estimates have been previously reviewed (Usher 2000). Notably, whole body weights and body composition of animals can vary substantially by year, season, life-cycle stage, and geographic location (Berger 1977). The blubber content of ringed seals, for instance can vary between 31% - 51% of total body weight over the year (Ryg et al. 1990).

Consistent with previous studies, we found that country food remains an integral dimension of the contemporary Inuit diet (Duhaime et al. 2002; Kuhnlein et al. 2004), with consumption of over 88 traditional food items (species and parts) reported (data not presented). Our results reaffirm the role of caribou as a staple food of the Inuit diet: it was the food consumed most frequently and in greatest quantities across all regions (Table 3.3). Mean annual caribou consumption (range = 29.6–122.8, Table 3.3) is higher in all Inuit Health Survey regions than the 19.9 kg/person previously reported for the Nunavik region by Duhaime et al. (2002). Differences in patterns of country food use across regions is complex and can be attributed to a number of cultural, socio-economic, political, environmental and biological factors that govern the preference, availability and accessibility of country food for harvest and consumption (Natcher et al. 2011). The conservative approach that we used in our assumptions will likely result in an over-estimate of number of animals required. Our Inuit partners also cautioned that the reported food use only reflected the abundance of the species in the year (or the previous year) of the study. It is important to consider the high annual fluctuations in the availability of wildlife species. Multiple sources of information need to be collected and cross-referenced to provide the most reliable regional-specific estimate of harvest requirement. Traditional knowledge is also important to be included in harvest management.

The rapid environmental changes in the Arctic have resulted in a decline of availability of country food that can have significant impact on the diet quality of the Inuit (Rosol et al., 2016). Local governments, supported by an established body of literature, have advocated country foods as an effective strategy to promoting healthy lifestyles, nutritious diets and food security in the Arctic (Nienstedt et al. 2012; Chan et al. 2006). While it has been postulated that the food requirements of northern Aboriginal families can be satisfied principally by local sources (Paci et al. 2004), no research presently exists to substantiate whether this notion is intrinsically possible, or ecologically sustainable. Our results provide a basis to evaluate the sustainability of Inuit subsistence harvests, particularly when interpreted in the context of available wildlife population data and can be used for the development of informed conservation policies.

Table 3.5 Comparison of harvest estimates from this study [a] and annual harvest estimates reported in the Nunavut Wildlife Harvest Study [b] and the Inuvialuit Harvest Study [c]

	Beluga Whale		Ringed Seal		Caribou	
Region	Harvest Survey	This study [a]	Harvest Survey	This study [a]	Harvest Study	This study [a]
Nunavut	679	669 – 868	25 086	14422– 18216	24 522	32055 –38863
Kivalliq	451	279 – 394	1806	1955 – 3277	10210	12265 – 15831
Qikiqtaaluk	248	247 – 380	23048	10088 – 13286	10440	7539 – 10748
Kitikmeot[d]	7	36 – 82	840	1329 – 2620	4089	6777 – 9252
Inuvialuit	130	128 – 252	1085	165 – 607	3113	2040 – 3288

[a] 95% CI of estimated mean

[b] Priest and Usher (2004): five-year average (1996–2001)

[c] Usher and Wendt (1999): ten-year average (1988–1997)

[d] Many Kitikmeot communities reported no beluga harvest data in the five study years.

It is clear that there exists mutual relevancy between wildlife managers, harvesters, country food consumers, and health/nutritional professionals. However, there is a pronounced ideological dichotomy and/or lack of common data platforms for human food security and nutrition information and wildlife population information. Our results may provide additional insights for communities, public health and wildlife organizations to develop sustainable food security initiatives in the North. Future wildlife management issues related to country food species in the Arctic will be best undertaken if they directly involve community-stated needs and preferences for country food and are articulated within a context that is relevant to both the wildlife management and public health sectors. Further research is needed both to clarify the effects of harvest restrictions on Inuit food security and to quantify the stress that the subsistence harvests place on wildlife populations.

3.6 Acknowledgements

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4 CARIBOU (*RANGIFER TARANDUS*) AND INUIT FOOD SECURITY

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Authors' contributions: TK conceived of the research question, compiled, analyzed and interpreted the data and drafted the manuscript. MF, assisted with the study design and provided feedback on the drafted manuscript. SS. provided support with the creation of the map. HMC and SDW provided feedback on the drafted manuscript.

ABSTRACT

Caribou (*Rangifer tarandus*) has remained fundamental to the diet and culture of Arctic Indigenous Peoples for thousands of years. In recent decades, however, several caribou herds across the circumpolar north have experienced dramatic declines. The objectives of this study are to investigate the role of caribou for the food and nutrient security of Inuit across northern Canada, and to evaluate the conservation management status of caribou herds/populations harvested by Inuit. A mixed-methods approach was used. Dietary data were derived from the 2007-8 International Polar Inuit Health Survey, which included dietary information for Inuit adults (n=2097) residing in thirty-six communities (latitude of 54°10'N to 76°25'N), spanning five jurisdictions of the Canadian north. Information regarding the range, abundance, status, and management of caribou herds/populations was collected through document analysis, followed by consultation with northern wildlife experts (n =4). While caribou contributed modestly to total diet energy (3 – 11 %) across the five Inuit regions, it was the number one source of iron (14 – 37%), zinc (18 – 41%), copper (12 – 39%), riboflavin (15 – 39%) and vitamin B12 (27 – 52%), as well as a top source of protein (13 – 35%), vitamin B6 (7 – 23%), and phosphorous (7 – 22%). Restrictions on Inuit subsistence harvest (harvest quotas or bans) are currently enacted on six caribou herds, with potential implications for the food and nutrition security of up to twenty-five Inuit communities across Canada. A holistic approach that integrates human and ecosystem health is needed to promote the sustainable management and harvest of caribou, while maintaining the food security of Inuit living in a rapidly changing Arctic environment.

4.1 Introduction

Wild foods obtained from hunting, fishing, and gathering provide important economic, cultural, and nutritional benefits to over one billion people globally, including Indigenous Peoples and many of the world's most vulnerable and marginalized populations (Nasi et al. 2008; Burlingame 2000; Bharucha & Pretty 2010; Golden et al. 2011; Sarti et al. 2015; Hickey et al. 2016; Kuhnlein et al. 2009). However, the harvest of wild food for human consumption represents one of the most important global threats to wildlife populations (Bowen-Jones et al. 2003; Wilkie et al. 1998; Fa & Brown 2009; Brashares et al. 2004; Heinsohn et al. 2004). It is estimated that between 23 to 36% of species used by humans for food and medicine are threatened with extinction (Butchart et al. 2010). Biodiversity loss is a major issue of ecological significance, with consequences for whole ecosystem functioning and the provisioning of ecosystem services (i.e. the benefits humans derive from ecosystems, such as food) to humankind (Cardinale et al. 2012). Despite international resolutions to support the conservation and sustainable use of biological resources (e.g. the Convention on Biological Diversity (United Nations 1992)), biodiversity at the global scale has continued to decline over recent decades (Butchart et al. 2010). Moreover, climate change is recognized as an significant challenge to the conservation of biodiversity, and interactions among and between numerous threats, such as human harvesting, habitat fragmentation, and climate change, could lead to species extinctions (Thomas et al. 2004; Heller & Zavaleta 2009).

The Arctic is among the most ecologically-sensitive regions on earth to climate variability (Seddon et al. 2016). Global warming has occurred more rapidly in the Arctic, than elsewhere on the planet (Change 2014), and Inuit have witnessed climate-mediated changes on both the abiotic (e.g. sea-ice conditions that impact harvesting activities) and biotic (e.g. health of wildlife populations) dimensions of their local food systems (Nancarrow et al. 2008; Wesche & Chan 2010). Although Inuit have been sustained by harvesting Arctic wildlife (termed "country food") for thousands of years (Bonesteel & Anderson 2008; Nuttall et al. 2005), the loss of Arctic biodiversity represents a critical challenge to food security and the sustainability of country food harvests (Brinkman et al. 2016; Theriault et al. 2005). Despite rapid lifestyle changes in the latter half of the 20th century – including the settlement into permanent communities, the development of a wage economy, and the introduction of market foods to remote northern communities – the harvest of country food remains a critical facet of life in Inuit communities (Kuhnlein et al. 2006; Sheikh & Egeland 2011; Kuhnlein & Receveur 2007; Borré 1991). The contemporary Inuit diet comprises over one hundred wildlife and plant species (Kuhnlein & Soueida 1992; Kuhnlein & Turner 1991; Kuhnlein & Receveur 2007); however, caribou (*Rangifer tarandus*), which is consumed by over 90% of Inuit adults (Kenny & Chan 2017), can be deemed a "cultural keystone species" (Garibaldi & Turner 2004), a species integral a people's diet, cuisine, society.

Caribou and human histories have converged in the north for thousands of years (Stewart et al. 2004; Gordon 2005). In recent decades however, caribou populations across the circumpolar north have exhibited dramatic declines (Gunn et al. 2011; Vors & Boyce 2009). The cause of these declines is complex and generally represents the cumulative effect of many interrelated factors – from habitat degradation and climate change, to increasing predator populations and anthropogenic pressures (Gunn et al. 2011; Wilson et al. 2014). Moreover, elucidating the cause of caribou declines is complicated by the inherently cyclical nature of caribou population abundance (Gunn et al. 2011). While hunting by humans can exacerbate caribou declines, it is not believed to be the definitive cause (Vors & Boyce 2009).

Inuit hunters have long negotiated their relationship with caribou based on Indigenous knowledge and practice and the sustainability of traditional Indigenous food systems is implicitly recognized based on historical continuity and ecological harmony in traditional territories (Kuhnlein 2012). While Inuit Land Claims Agreements affirm the right of Inuit to harvest a wildlife stock or population to meet economic, social, and cultural needs, recent caribou population declines have motivated the implementation of institutional conservation measures, including quota restrictions and harvest moratoria (see for example Government of Nunavut 2014; Government of Newfoundland and Labrador - Department of Environment and Climate Change 2013). As part of the wildlife co-management process, an annual allowable harvest for selected species may be established (Natcher et al., 2012). While Inuit may be consulted and involved (to varying degrees) in decisions to restrict, or limit, subsistence harvests, ultimately, harvest restrictions can become barriers to country food access that can exacerbate food insecurity (Chan et al. 2006). Inuit experience the highest documented prevalence of food insecurity among all Indigenous Peoples in a developed country (Rosol et al. 2011; Egeland 2011).

Although millions of people depend on wildlife for food security and dietary adequacy, human nutrition remains one of the most important, yet often overlooked, ecosystem services (Declerck et al. 2011). The literature on reconciling wildlife conservation and food security has largely favored the "bushmeat" context in the humid tropics of the Americas, Asia, and Africa (see for example Fa et al. 2003; Davies & Brown 2008; Golden et al. 2011). Inuit face similar challenges in supporting food security and the sustainable harvest of wildlife – particularly, in the context of global environmental change.

This aim of this research is to develop a holistic understanding of human nutrition and wildlife status / management across the Canadian Inuit Nunangat (Inuit regions of northern Canada). The specific objectives of this research are to: i. demonstrate the importance of caribou to the nutrition security (i.e. the appropriate quantity and combination of food and nutrients to ensure an active and healthy life (Haddad et al. 1994)) of Inuit, by relating caribou consumption to nutrient intakes; and, ii. examine the status of northern caribou herds/populations by compiling trends in northern caribou populations, including the relevant wildlife management policies.

4.2 Methods

We employed a mixed-methods approach, drawing on qualitative and quantitative research methods. Dietary data were derived from a cross sectional health survey of Inuit adults (Saudny et al. 2012) conducted across five jurisdictions of the Canadian Inuit Nunangat (Inuit regions of Canada). Information regarding the range, abundance, status, and management of northern caribou herds/populations was obtained through document analysis (Bowen 2009), and verified through consultation with northern wildlife experts (n= 4). Northern wildlife experts were identified based on their affiliation to Inuit wildlife co-management bodies, and/or territorial governments. We distinguish between Inuit subsistence harvests, and resident, sport, and commercial harvests, as they are subject to distinct harvesting rights and management regimes.

4.2.1 Contribution of Caribou to Nutrition Security

The Inuit Health Survey (IHS) was a cross-sectional health survey of Inuit adults conducted between the late summer and fall of 2007 and 2008. Detailed survey methodology and design, including the participatory research process, has been reported elsewhere (Saudny et al. 2012). Households (n=2,796) in 36 communities (latitudes between 54°10'N and 76°25'N), spanning five administrative jurisdictions (the Inuvialuit Settlement Region (ISR), Nunavut (Qikiqtaaluk, Kivalliq and Kitikmeot) and Nunatsiavut) were randomly selected to participate. From each household, Inuit men and non-pregnant Inuit women (18 years and older) were eligible. Informed consent was obtained from all individual participants. Ethical approval for the IHS was granted by McGill University (Faculty of Medicine Institutional Review Board). The University of Ottawa (Health Sciences and Science Research Ethics Board, file number H05-15-16) provided ethical approval for secondary analysis of data. Scientific Research Licenses for the IHS were obtained from relevant northern research institutions (the Aurora Research Institute (Northwest Territories) and (Qaujisaqtulirijikkut (NU)).

Dietary assessments

Dietary assessments were conducted in-person by trained interviewers in English and Inuit Languages. Diet was assessed using a single 24h recall, based on an adapted form of the USDA multi pass approach (Blanton et al. 2006). Participants were asked to recall all foods (both country food and market food) consumed on the day preceding the interview (beginning and ending at midnight) and estimate portion sizes with the help of three-dimensional graduated food model kits (Direction de Santé Québec, Institut de la Statistique du Québec 2013). The Canadian Nutrient File (Health Canada 2015) was used to calculate energy and nutrient intakes. Nutrient composition information for foods not included in the CNF was available from an additional in-house food file (McGill School of Dietetics and Human Nutrition) (Egeland et al. 2011). All missing nutrient values were imputed following the methodology outlined by Schakel et al. (1997).

Analyses

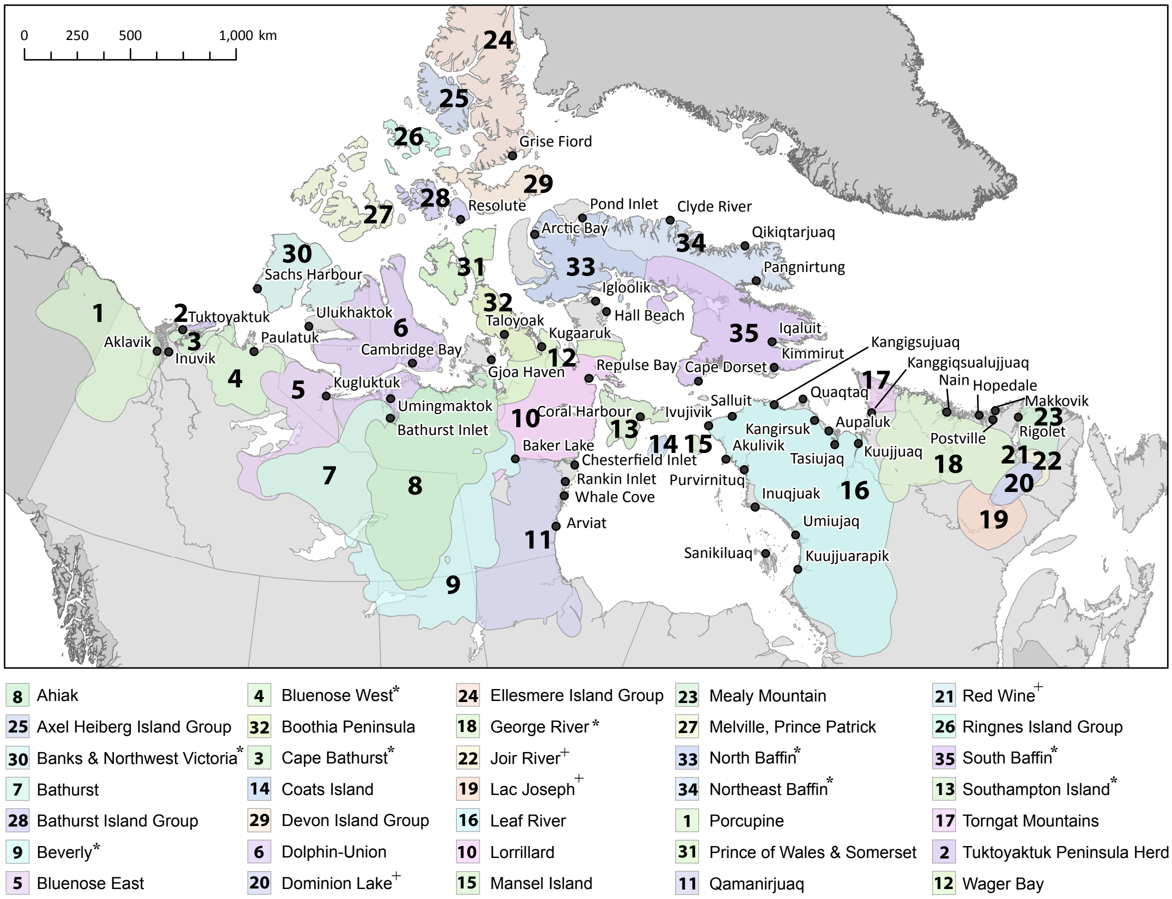
Data management and nutrient calculations were performed with SAS statistical software (version 9.4; SAS Institute, Cary, NC). The population proportion method (Krebs-Smith & Kott 1989) was used to calculate the contribution of caribou to nutrient intakes by region.

4.2.2 Status and Management of Northern Caribou (*Rangifer tarandus*)

Document analysis (Bowen 2009) was used to identify the range, status, trends, and management of northern caribou herds/populations. Locations of Inuit communities and caribou ranges were mapped (Figure 4.1) to identify caribou herd/population relevant to Inuit subsistence at differing scales (territory, region, and community). "Relevance" was defined by community proximity to the herd's annual range and/or documented use of the herd by the community. Kendrick and Manseau (2008) previously reported based on results from Arviat and Baker Lake, that depending on community location and season, most harvesting activities occurs within a small radius of the community (10 – 20km), with few harvesters travelling long distances (300-500km) (Kendrick & Manseau 2008).

Organizational and institutional reports, maps, newspapers, press releases, and various public records for each herd/population were systematically searched to identify: i. the most recent abundance estimates; ii. herd/population status; iii. the relevant management entities and management plans; and iv. the current management status, including current restrictions on Indigenous harvest. Comprehensive information on the trends, distribution, and status of northern caribou was summarized in the Canadian Biodiversity: Ecosystem Status and Trends 2010 Technical Thematic Report No. 10, (Gunn et al. 2011). Wildlife experts (i.e. professionals from Inuit, or territorial, wildlife co-management bodies) in each Inuit region (n = 4) were consulted in-person, by telephone, or by e-mail, to validate status and management results.

Figure 4.1 Range and distribution of northern Caribou (*Rangifer tarandus*) herds/populations and Inuit communities across the Canadian Inuit Nunangat



** Denotes caribou populations where a quota or ban on Inuit subsistence harvest is currently implemented.*
+Inuit communities are not known to currently harvest from the herd

4.3 Results

4.3.1 Contribution of Caribou to Nutrition Security

Caribou contributed between 5.6 - 11.2% of the Inuit population's total energy intake (by region) and ranked within the top five dietary sources of energy in the ISR and all three Nunavut regions (Figure 4.2). In Nunatsiavut, caribou contributed less than five percent (3.2%) of total energy intake at the time of the study. Caribou was the top dietary source of protein in Nunavut (up to 35% of total intake) and the ISR, and the second-most important in Nunatsiavut (Figure 4.2). Caribou was the top dietary source of iron in all regions, and contributed between 14.3 – 36.5% of total iron intake by region (Figure 4.3). Caribou was likewise the most important dietary source of zinc (17.7 – 41.3%), copper (12.1 – 38.5%), riboflavin (15.4 – 39.3%), phosphorous (7.3 – 22.1%), vitamin B12 (26.6 – 52%), and vitamin B6 (7.0 – 22.9%) across all regions (Figure 4.3). Caribou ranked within the top three dietary sources of potassium in both Nunavut and the ISR (8.8 – 17.4%). Nutrients for which caribou contributed less than 10% of total intake across all regions (data not presented) included vitamin C (<3%), vitamin D (<2%), selenium (<10%), vitamin E (<10%) and MUFA (<10%).

Figure 4.2 Contribution of caribou (*Rangifer tarandus*) to intake of dietary energy and selected nutrients among Inuit adults (n 2095) in five regions of northern Canada

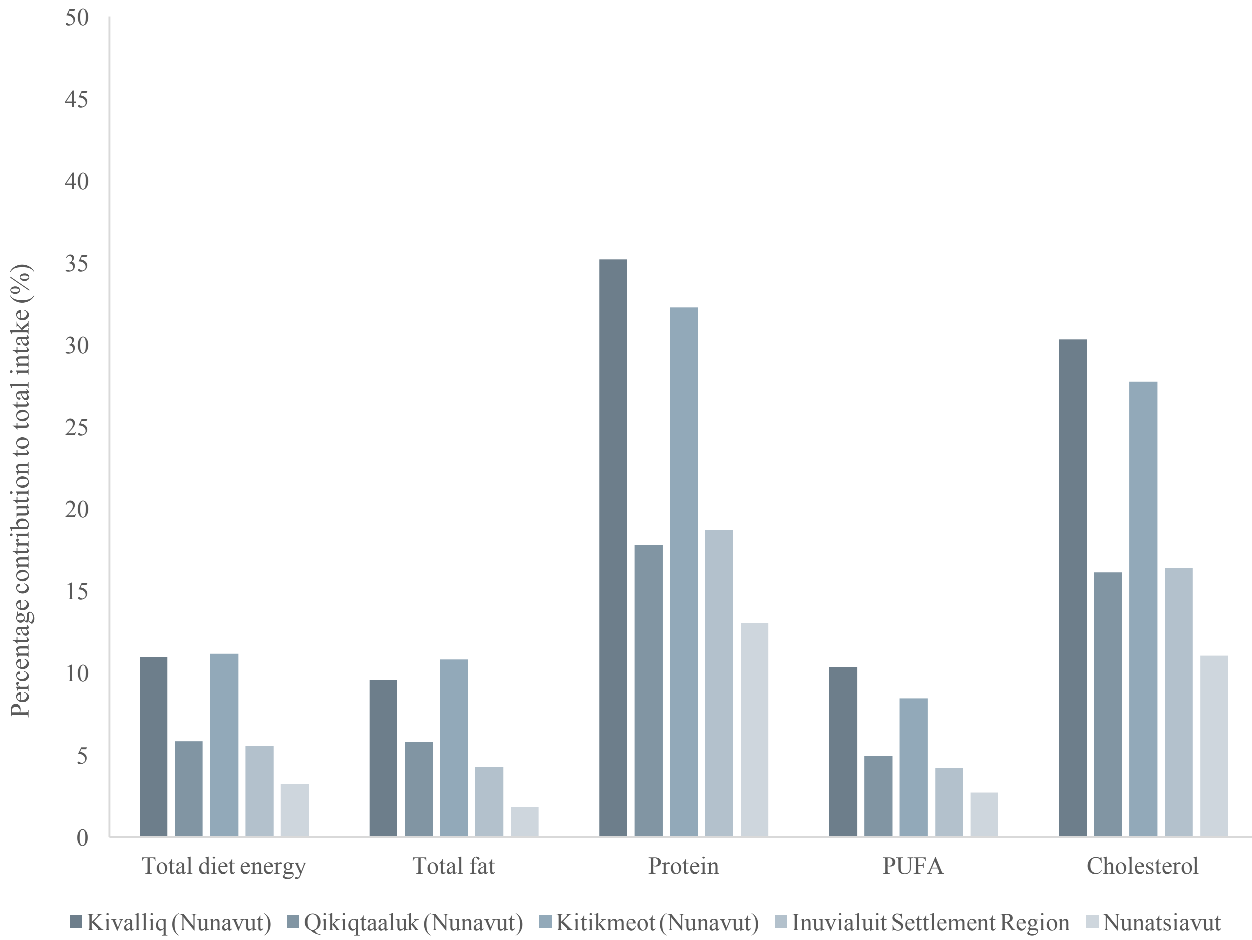
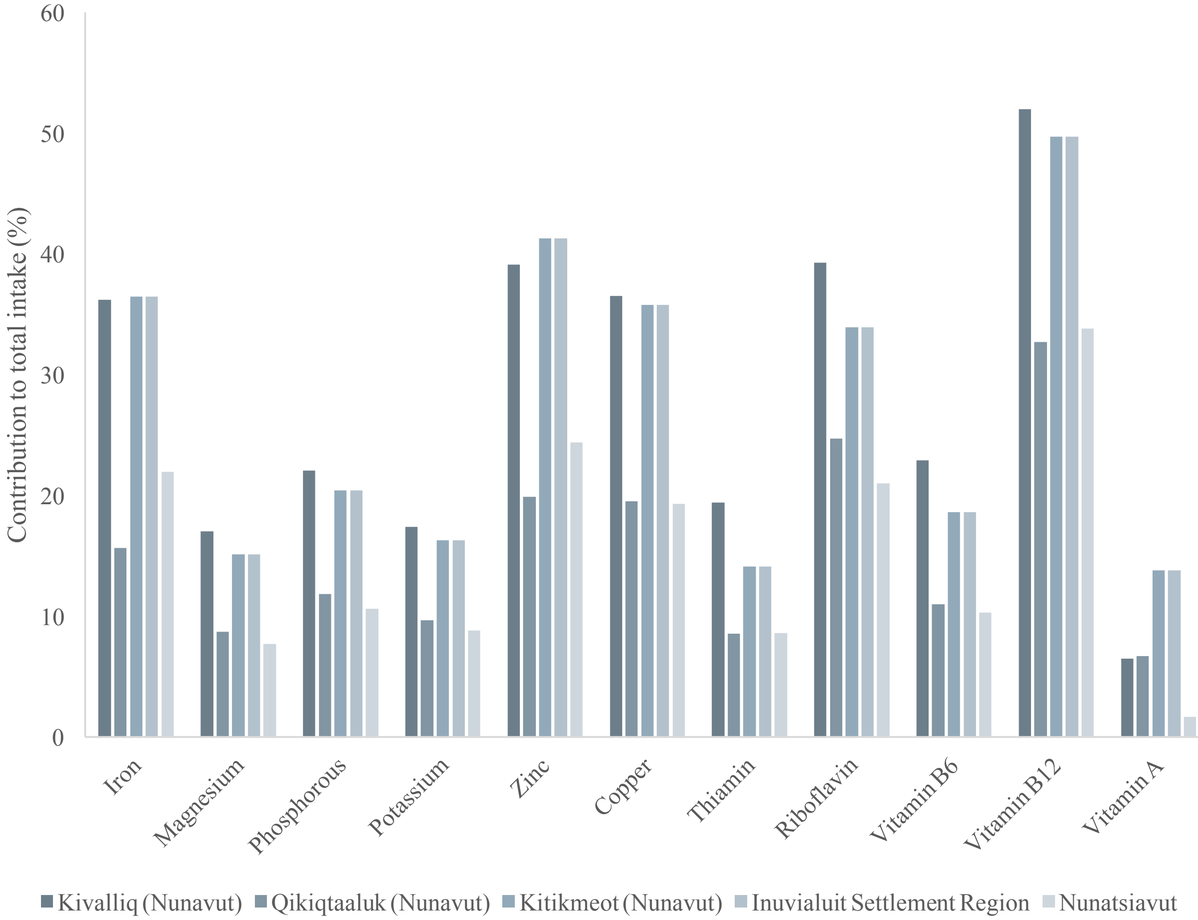


Figure 4.3 Contribution of caribou (*Rangifer tarandus*) to intake of micronutrients among Inuit adults (n 2095) in five regions of northern Canada



4.3.2 Caribou Annual Ranges and Inuit Communities

Caribou (*Rangifer tarandus*) / subspecies / ecotypes / populations-herds
Caribou represents the broad, species-level, designation of several genetically, morphologically, and/or behaviorally distinct subspecies, ecotypes, and populations/herds, of *Rangifer tarandus* (Hummel & Ray 2008; Wilson et al. 2014). Four subspecies of *Rangifer tarandus* occur across Inuit Nunangat: i. barren-ground (*R. t. groenlandicus*), ii. porcupine (*R. t. granti*), iii. Peary (*R. t. pearyi*), and, iv. woodland (*R.t. caribou*) caribou. Additionally, Dolphin and Union caribou (*R. t. groenlandicus/pearyi*) are recognized as a distinct population of the barren-ground caribou subspecies. Caribou are generally designated (and managed) as discrete subpopulations or herds; however, this classification is complicated by the intersecting herd ranges, with many distinct herds only having been recognized within the last few decades (Gunn et al. 2011).

Seven migratory barren-ground caribou (*R. t. groenlandicus*) herds occur across Inuit Nunangat (Figure 4.1, from west to east): Cape-Bathurst, Bluenose-West, Bluenose-East, Bathurst, Ahiak, Beverly and Qamanirjuaq. Additionally, Porcupine caribou (*R. t. granti*), among the largest migratory herds in North America, occurs between Alaska, Yukon, and the western Northwest Territories (NT). Five major populations of sedentary barren-ground caribou (Tuktoyaktuk Peninsula, Wager Bay, Lorillard, Boothia Peninsula, North Melville Peninsula) occur on the mainland of Nunavut and the ISR, in addition to three populations on the southern Arctic islands of the Hudson Bay (the Southampton, Coats, and Mansel island populations). Dolphin and Union caribou (*R. t. groenlandicus/pearyi*) are endemic to Victoria Island and the northern mainland of the Kitkmeot region (Nunavut). Peary caribou (*R. t. pearyi*) inhabit the islands of the Canadian Arctic Archipelago (namely the Queen Elizabeth Islands, Banks Island and northwest Victoria Islands, and Prince of Wales–Somerset islands), in addition to the Boothia population on the Kitikmeot (NU) mainland. Woodland caribou (*R.t. caribou*) occur in the eastern subarctic regions of Nunavik and Nunatsiavut, where two migratory woodland caribou herds (George River, and, Leaf River) inhabit the Ungava Peninsula, a single population of montane woodland caribou inhabits the Torngat Mountains (Torngat population), and three populations of sedentary woodland caribou occur in Labrador (Mealy Mountain, Joir River Subpopulation; Red Wine, Dominion

Lake Subpopulation; and the Lac Joseph population) but are generally beyond the current harvest range of Inuit in Nunatsiavut (McCarthy, personal communication).

Regional/community dependence on specific herds

Mainland communities of the Inuvialuit Settlement Region (Aklavik, Inuvik, Paulatuk, Tuktoyaktuk) harvest principally from the Porcupine, Cape Bathurst, Bluenose West, Bluenose East and the Tuktoyaktuk Peninsula herds (Figure 4.1). Sachs Harbour (Banks Island) and Ulukhaktok (Victoria Island) are situated within the range of the Peary Caribou and Dolphin and Union caribou; however, harvest restrictions on caribou have been implemented locally through community-based management plans for several decades (Figure 4.1; Appendix). Communities from the Kivalliq region (Arviat, Whale Cove, Rankin Inlet, Baker Lake, Chesterfield Inlet, Repulse Bay and Coral Harbour) harvest principally from the Qamanirjuaq, Beverly, Lorillard, Ahiak, Wager and Southampton herds (Figure 4.1; Table 4.1). Communities on Baffin Island (Qikiqtaaluk Region) harvest principally from the three sub-populations of Baffin caribou (North Baffin, Northeast Baffin, and South Baffin). Finally, communities in Nunavik and Nunatsiavut harvest principally from the George River and Leaf River herds; however, a ban on caribou harvest is in place for the George River herd between 2013 - 2018. To a lesser extent, Nunatsiavut communities may harvest from the Torngat Mountain herd (Figure 4.1).

Many communities are situated at the confluence of overlapping herd ranges and therefore, harvest from multiple herds throughout the year (Figure 4.1). For instance, Inuvialuit in Tuktoyaktuk (NT) harvest caribou from the Tuktoyaktuk Peninsula, the Cape Bathurst, and the Bluenose west herds. Likewise, Baker Lake (NU) is situated within the overlapping ranges of up to five caribou herds (Beverly, Qamanirjuaq, Wager Bay, Lorillard, and Ahiak herds). Conversely, some communities, such as Arviat (NU) are situated within proximity to the migration route of a single herd (Qamanirjuaq herd), and thus harvesting is limited to very specific seasons.

Table 4.1 Risk for adverse human nutrition and food security outcomes based on caribou (*Rangifer tarandus*) status

Risk[1]	Caribou Herd/Population	Inuit communities potentially affected [2]
High Risk (harvest ban)	Cape Bathurst	ISR (NT) = Aklavik, Inuvik, Tuktoyaktuk
	George River	Nunatsiavut (Labrador): Nain, Hopedale, Makkovik, Postville, Rigolet
	Peary Caribou (Banks Island subpopulation [3])	ISR (NT): Sachs Harbour, Ulukhaktok
Medium risk (harvest quota)	Bluenose-West [4]	ISR (NT): Aklavik, Inuvik, Paulatuk, Tuktoyaktuk
	Southampton Island	Kivalliq (NU): Coral Harbour, Repulse Bay, Chesterfield Inlet and Rankin Inlet Qikiqtaaluk (NU): Cape Dorset
	Baffin Island (North, Northeast and South, Baffin herds)	Qikiqtaaluk (NU): Arctic Bay, Pond Inlet, Clyde River, Kimmirut, Cape Dorset, Iqaluit, Pangnirtung, Qikiqtarjuaq, Igloolik, Hall Beach
Low risk (declining population status or population stable at historic low, or species at risk)	Bathurst	Kitikmeot (NU): Kugluktuk, Bathurst Inlet, Umingmaktok
	Beverly	Kitikmeot (NU): Bathurst Inlet, Umingmaktok Kivalliq (NU): Arviat, Baker Lake, Chesterfield Inlet, Whale cove, Rankin Inlet
	Bluenose-East [5]	Kitikmeot (NU): Kugluktuk
	Dolphin and Union Caribou	ISR (NT): Ulukhaktok, Paulatuk Kitikmeot (NU): Cambridge Bay, Kugluktuk, Bathurst Inlet, Umingmaktok
	Leaf River	Nunavik (all communities)
	Peary caribou (High Arctic and Low Arctic subpopulations)	Qikiqtaaluk (NU): Resolute Bay, Grise Fiord, Arctic Bay Kitikmeot (NU): Kugaaruk, Taloyoak, Gjoa Haven, and Cambridge Bay
	Torngat Mountain	Nunatsiavut (Labrador): Nain Nunavik (Quebec): Kangiqsualujjuaq
	Tuktoyaktuk Peninsula	ISR (NT): Tuktoyaktuk
Very low risk (Stable or increasing population status)	Porcupine	ISR (NT): Inuvik, Aklavik
	Lorillard	Kivalliq (NU): Chesterfield Inlet Baker Lake
	Wager Bay	Kivalliq (NU): Repulse Bay, Baker Lake, Chesterfield Inlet
Unknown (population status is unknown)	Ahiak	Kitikmeot (NU): Gjoa Haven, Umingmaktok Cambridge Bay Kivalliq (NU): Baker Lake
	Qamanirjuaq	Kitikmeot (NU): Bathurst Inlet, Umingmaktok Kivalliq (NU): Rankin Inlet, Arviat, Baker Lake, Chesterfield Inlet, Whale cove

Acronyms: ISR = Inuvialuit Settlement Region; NT = Northwest Territories; NU = Nunavut

[1] Risk is defined by management of Inuit subsistence harvests as: harvest ban (high risk), quota-based harvest restrictions (medium risk) and declining population status / population at historic low / species at risk (low risk). Detailed information on caribou abundance, population, and management status is summarized in the Appendix.
[2] Based on community-proximity to herd and/or documented use of the herd by the community
[3] The Banks Island Peary caribou subpopulation includes the Minto herd in Northwest Victoria Island. A Harvest Ban is enacted on Victoria Island (Ulukhaktok, NT), while a quota restriction on Banks Island (Sachs Harbour, Northwest Territories)
[4] Sachs Harbour and Ulukhaktok are allocated tags for the Bluenose-West herd through the co-management process, however, these tags are generally redistributed to the other ISR communities.
[5] Although Paulatuk (NT) is allocated harvest tags for the Bluenose-East herd, the herd is typically beyond the community's usual harvest range

4.3.3 Caribou Status

A detailed summary of abundance estimates, population trends, and management status of northern caribou herds/populations across the Inuit Nunangat is presented in the supplemental material. Abundance estimates from censuses conducted during recent decades shows evidence of dramatic population declines for several caribou herds, including: the Cape-Bathurst, Bluenose-West, and Southampton herds (Nagy & Johnson 2006; Campbell 2006; McFarlane et al. 2016). A notable exception, the Porcupine herd is currently experiencing a period of increasing population abundance (197,000 animals in 2013) (Appendix). Dolphin and Union caribou are stable from historic lows (Dumond & Lee 2013). Peary caribou have been listed under the federal Species at Risk Act (SARA) since 2011, with the High Arctic and Banks Island populations designated as "endangered", and the Low Arctic population designated as "threatened" (Government of Canada 2016; Species at Risk Committee 2012).

The interpretation of status trends is complicated by both the inherent density-dependent dynamics of caribou populations, coupled with the lack of comprehensive longitudinal data and differing survey methodologies over time (Gunn et al. 2011). For some herds/populations, lack of comprehensive longitudinal data (i.e. irregular survey frequency, differing methodologies, limited scope of surveys) precludes the possibility of assessing population trends over time. The level of detail in reporting estimates varies considerably, and the assessment of trends in caribou status is challenged by the disparity in monitoring for some northern caribou herds, the absence of historical information on many herds, and the lack of standard protocols across time and regions (Gunn et al. 2011; Giroux et al. 2012). For instance, the abundance of Ahiak and Qamanirjuaq herds are currently unknown or thought to be declining (Appendix).

Caribou management and harvest restrictions

While hunting for most caribou herds across Inuit Nunangat is presently closed or restricted for non-Indigenous harvest – including resident, outfitted/sport, and commercial harvests - the specifics of these dynamics are beyond the scope of the present research. At present, restrictions on Inuit subsistence are implemented for six caribou populations, including complete harvest bans on both the George River (2013 – 2018) and Cape Bathurst (since 2007) herds harvest (Table 4.1). Harvest of the Southampton Island herd (since 2012), the three Baffin Island herds (since 2015), as well as the Bluenose-West herd (since 2007), is currently restricted through a total allowable harvest (TAH). Restrictions on Indigenous Peoples' harvest (e.g. Wek'èezhìı) are currently implemented for both the Bathurst (since 2014) and Bluenose East (since 2016) herds in the Northwest Territories; however, no formal government restrictions currently exist for these same herds in Nunavut. Harvest restrictions are currently implemented through community-based management plans for Peary caribou on Banks Island (harvest quota in Sachs Harbour (ISR) since 1990), and Victoria Island (a harvest ban on in Ulukhaktok (ISR) since 1993). Similarly, Resolute Bay hunters implemented voluntary harvest limitations for Peary caribou for several years (1986 to 1996).

4.4 Discussion

Impact of caribou restrictions on Inuit nutrition security

While caribou populations experience natural population fluctuations (Gunn 2003), declines of recent decades may be more dramatic than those documented in recorded history (Gunn et al. 2011). In light of emerging concerns regarding caribou access across the north, we have reported on the critical role of caribou to the nutritional security of Inuit. Caribou, despite its modest energetic contribution to total diet (<12% of total diet energy), was the principle source of several micronutrients, including, iron, zinc, copper, riboflavin, vitamin B12, vitamin B6, phosphorous and potassium. Previous research has documented that country foods contribute markedly to vitamin and mineral intake (Kuhnlein et al. 2004); however, consistent with the international literature, the nutritional contribution of wild foods is generally not reported at the species level (Penafiel et al. 2011).

Harvest restrictions are currently enacted on several caribou herds harvested by Inuit across the Canadian north (Table 4.1), including harvest bans for both the Cape Bathurst, and George River, herds, harvested by communities in the ISR, and Nunatsiavut Regions, respectively (Figure 4.1). While subsistence-based societies have long adapted to fluctuating species populations and changing harvest conditions (Sabo 1991; Berkes & Jolly 2002), it remains unclear to what degree harvesters substitute one species for another (Hansen et al. 2013). From a human health perspective, barriers to caribou access, whether through species decline (i.e. availability) and/or harvest regulations (i.e. accessibility), are likely to cause cascading effects on human health, through the loss of critical micronutrients in the diet. Although many nutrients (e.g. protein) may be provisioned from consumption of alternate country food species (Wesche & Chan 2010; Rosol et al. 2016; Nancarrow & Chan 2010) and/or market foods, certain micronutrients may be limitedly available and/or "unaffordable" in the northern food supply. For instance, if caribou was substituted (weight for weight) with goose (*Branta canadensis*) meat, zinc and vitamin D levels would be substantively diminished (Rosol et al. 2016). Similarly, a 100g serving of ground beef (cooked) provides less than half the iron, a third of the vitamin B12, and much less riboflavin, copper, and thiamin than a 100g serving of caribou meat (Health Canada 2015). Furthermore, the high cost nutritious market foods in remote community stores can be a barrier to food security and healthful diets for many households (Lambden et al. 2006; Chan et al. 2006). For instance, the average price of ground beef ($ CAD 17.04/kg) in the Qikiqtaaluk Region (NU) (Nunavut Bureau of Statistics 2016) was 38% higher than the national average ($ CAD 12.36 /kg) in 2016 (Statistics Canada 2016). Constraints to country food access must therefore be situated within the context of the "nutrition transition", a pattern by which country foods are increasingly replaced by low-cost, energy-dense / nutrient-poor market foods (e.g. sugar-sweetened beverages, chips and pasta) due to a confluence of factors (Kuhnlein et al. 2004; Egeland et al. 2011; Sheikh & Egeland 2011).

Impact of harvest restrictions on Inuit health

The human health effects of wildlife depletion and harvest regulations have been limitedly investigated through empirical research methods in both Canadian and international contexts (Golden et al. 2011). To our knowledge, no previous research has investigated the dietary responses of Inuit to constrained country food access. As caribou is the primary source of iron and several micronutrients (zinc, copper, riboflavin and B6) necessary for the synthesis of red blood cells (erythropoiesis), caribou restrictions may represent a risk for the development of anemia and other nutrient deficiencies, such as zinc deficiency, associated with diseases such as diabetes and immunological effects (Prasad 1993). Women of childbearing age, as well as pregnant and lactating women, who are at increased risk of iron deficiency and inadequacies of magnesium and zinc (Duhaime et al. 2002; Berti & Soueida 2008), may be at increased risk of adverse health outcomes from restrictions on caribou harvests. In practice, however, risk of food insecurity and malnutrition from restricted species access will depend on a number of individual and community-level factors (Wesche & Chan 2010), such as household income, employment in the wage economy, community location, harvesting trends, dependence on individual species, and both access to and utilization of alternate local food species. Inuit communities situated at the confluence of overlapping herd ranges (Figure 4.1), for instance, may be protected from restrictions enacted upon a single herd. Similarly, access to seafood in coastal communities may buffer against some of the negative dietary effects of caribou declines.

Inuit harvesting rights and wildlife co-management

In their recent synthesis of food security research in the North American Arctic, Loring and Gerlach (2015) identified governance and policy challenges as primary drivers of food insecurity, with a need to support the rights of local peoples to pursue food security on their own terms (Loring & S. C. Gerlach 2015). The importance of harvesting local foods been described as a fundamental pillar of the 'right to food' for Inuit (Inuit Tapiriit Kanatami & Inuit Circumpolar Council 2012), and although Canada presently lacks the human rights framework to integrate the 'right to food' within its national constitution (de Schutter 2012), federal support for the United Nations Declaration on the Rights of Indigenous Peoples has recently been affirmed (United Nations General Assembly 2007).

The establishment of Inuit Land Claims Agreements formally recognizes the rights of Inuit over the protection, use, and development of renewable resources (Berkes et al. 2007). Management of wildlife across the Canadian Arctic is currently administered as a collective responsibility, shared between federal (including fulfillment of international treaties), territorial, and Indigenous governments at various levels (land claim areas, regions, and communities). Generally, harvest is unrestricted for Inuit, unless decided by co-management boards which may institute a total allowable harvest (TAH) for selected species (Natcher, Felt & McDonald 2012). Although extensive, Inuit harvesting rights are ultimately superseded by federal and territorial policies pertaining to biodiversity conservation, and may thus be subject to implementation or overturn by such governments. Despite many successful achievements in co-management (Brook et al. 2009; Natcher, Felt, Chaulk, et al. 2012), ideological, epistemological, and cultural challenges may permeate efforts to integrate distinct world-views and political systems (Murphy 2011; Fa et al. 2003; Kendrick & Manseau 2008). For instance, the cultural relationships held by Inuit to animals as autonomous, sentient beings may be incongruous with conservation and management notions of these same animals as wildlife resources, subject to careful management and protection (Tyrrell 2007; Castro et al. 2016). It is important to note that traditional Inuit culture has defined customary rules to inform the utilization (or non-utilization) of wildlife resources, and community-based management may be preferred to formal legal processes and intervention of government at larger scales (Natcher, Felt, Chaulk, et al. 2012).

Integrating conservation into food security

While the sustainability of wildlife populations is mutually relevant to wildlife conservation and human health interests, the challenge of reconciling these seemingly disparate interests can adversely impact both biodiversity and human food security. Harvester support programs are often included as part of regional and territorial food security and poverty reduction strategies (See for example Nunavut Food Security Coalition 2014; Territorial Anti-Poverty Action Plan 2015). However, encouraging harvests may impose stress on wildlife populations that are already experiencing long-term declines, compounded by climate change and habitat degradation (2012). In Nunavut, for instance, it is unknown whether the implementation of a community-based harvesting program could represent an unreasonable long-term risk to caribou populations, as wildlife status (i.e. abundance, productivity and natural mortality) is not being monitored with sufficient regularity to detect trends in a timely manner (Giroux et al. 2012). Wildlife monitoring in remote Arctic regions is expensive and methodologically cumbersome, and often competes with alternate conservation needs, such as habitat management and protection (Boyce et al. 2012). Furthermore, sector-based, species-by-species management, and dichotomized perceptions of conservation and Indigenous food security, ultimately undermines human food security (Loring & C. Gerlach 2010).

Limitations

Several important study limitations warrant address. First, dietary data in the present study were derived from the 24h recall of the 2007-8 Inuit Health Survey and reflect species availability and accessibility (e.g. seasonal availability, species abundance, and conservation measures) during the study period. Dietary data may have been asynchronous with the timing of caribou harvest and / or caribou availability may have been restricted due to declining population status. For instance, caribou contributed less than 5 % of total energy intake for Inuit in Nunatsiavut (Figure 4.2), where George River caribou have now reached critically low numbers (Government of Newfoundland and Labrador - Department of Environment and Climate Change 2016). Second, we have mapped caribou herd ranges and community locations, and, where possible, have confirmed the utilization of the herd through document analysis and/or direct consultation with northern wildlife experts. However, results from the study have not been confirmed at the community level. Community insights and Indigenous knowledge regarding the status and management of northern caribou populations would greatly enrich this and other interdisciplinary studies of food security in the north. Nevertheless, this research provides a foundation for further community-scale inquiry into the diet and health dimensions related to species conservation in the Canadian north. Finally, while focus of the present article was on the food security and nutritional implications of caribou status, it must be stated that the value of caribou to Inuit, and indeed to other Indigenous peoples across the circumpolar north, far exceeds mere dietary nutrients. For many Inuit, there exists no replacement for the cultural value of caribou (Wilson et al. 2014).

4.5 Conclusion

A food system approach to management that explicitly includes the human dimensions of the ecosystem can link specific goals for the conservation of individual species to broader goals of human health. From a food systems perspective, ecosystem conservation and food security are highly connected objectives and priorities. Barriers to caribou access are likely to initiate cascading effects on human health through the loss of critical micronutrients in the diet. Thus, instruments of wildlife conservation must be considered in terms of their implications for food security and public health. Likewise, public health initiatives that promote the harvest of country foods must respect the ecological limits of species sustainability. Future initiatives to support food security in the Arctic will necessitate a transdisciplinary food systems approach that includes the active participation of Indigenous organizations and the wildlife and public health/nutrition sectors. Further research is required to determine the dietary and human health impacts of specific types of wildlife restrictions, and elucidate the conditions that favor consumption of nutrient-poor market foods when access to nutrient-rich country foods is restricted. The fundamental importance of caribou to Indigenous diets, coupled with the amplified responses of arctic species and ecosystems to climate change, may serve as a sentinel for changes in other regions where harvest of wildlife constitutes an integral dimension of nutrition and food security.

4.6 Acknowledgements

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4.7 Supplemental Material

Table 4.2 Status of caribou (*Rangifer tarandus*) in Inuit Nunangat (Inuit regions across Canada)

Herd / Population	Communities within proximity to herd range *	Range overlap	Estimated Population Abundance (Year)	Population trend & conservation status	Harvest Restriction (Inuit subsistence only) +
Barren Ground Caribou (*R. t. groenlandicus*)					
Ahiak	**Kitikmeot (NU):** Gjoa Haven*, Umingmaktok* Cambridge Bay* **Kivalliq (NU):** Baker Lake* **Other:** NT*, Saskatchewan*	Bathurst, Qamanirjuaq, Beverly	71,000 (2011) [1]	**Uncertain** [2,3] *survey frequency too irregular to determine long-term status*	**No restriction** [1,4]
Beverly	**Kitikmeot (NU):** Bathurst Inlet*, Umingmaktok* **Kivalliq (NU):** Arviat*, Baker Lake*, Chesterfield Inlet*, Whale cove*, Rankin Inlet* **Other:** NT*, Saskatchewan*, Manitoba* and Alberta*	Bathurst, Ahiak, Qamanirjuaq, Lorillard, Wager Bay	124,000 (2011)[1,5]	**Declining** [2,3] *55% lower than 1994 (276,000)* [6]	**No restriction** [4]
Qamanirjuaq	**Kitikmeot (NU):** Bathurst Inlet*, Umingmaktok* **Kivalliq (NU):** Rankin Inlet*, Arviat*, Baker Lake*, Chesterfield Inlet*, Whale cove* **Other:** NT*, Saskatchewan*, Manitoba* and Alberta*	Beverly, Ahiak, Wager Bay, Lorillard, Cape Churchill	264,000 (2015) [7]	**Stable Decline/ Uncertain** [2, 8] *30% lower than 1994 (496,000)*[6]	**No restriction** [4]
Bathurst	**Kitikmeot (NU):** Kugluktuk, Bathurst Inlet*, Umingmaktok* **Other:** NT* and northern Saskatchewan*	Bluenose-East, Ahiak, Dolphin and Union, Lorillard, Wager Bay, Beverly,	16,000 - 22,000 (2015) [9]	**Declining** [10] *Estimated at 350,000 in mid-1990s*[11]	**NU = No restriction** **NT = Quota restriction** [10]
Cape Bathurst	**ISR (NT):** Aklavik*, Inuvik*, Tuktoyaktuk* **Other:** NT*	Bluenose-West, Tuktoyaktuk Peninsula	2,427 (2012) [11]	**Stable from historic decline** [10] *Estimated at 20,000 in 1992* [12]	**Harvest ban** (since 2007) [4]
Bluenose-West	**ISR (NT):** Aklavik*, Inuvik*, Paulatuk*, Tuktoyaktuk*, Sachs Harbour* (allocated tags), Ulukhaktok*(allocated tags) **Other:** NT*	Cape Bathurst, and Bluenose-East	15,000 (2015) [13]	**Stable from decline** [2] *Estimated at 112,000 in 1992* [12]	**Quota restriction** (since 2007) [4]
Bluenose-East	**Kitikmeot (NU):** Kugluktuk* **ISR (NT):** Paulatuk* **Other:** NT*	Bluenose-West, Bathurst, Dolphin and union	35,000- 40,000 (2015) [13]	**Declining** [13] *Except for a brief increase 2006 - 2010 followed by decline* [13] Estimated at 68,295 in 2013 [12]	**NU = No restriction** [13] **NT = Quota Restriction**[14]
Tuktoyaktuk Peninsula	**ISR (NT):** Tuktoyaktuk*	Cape Bathurst	~ 1,700 (2015) [15]	**Declining (slow)** [15]	**Non-quota restriction** [4, 17]

Herd / Population	Communities within proximity to herd range [*]	Range overlap	Estimated Population Abundance (Year)	Population trend & conservation status	Harvest Restriction (Inuit subsistence only) [+]
				Estimated at 2,753 in 2009 [16]	*Seasonal restriction (no hunting) during herd migration*
Southampton Island	**Kivalliq (NU):** Coral Harbour[*], Repulse Bay[*], Chesterfield Inlet[*] and Rankin Inlet[*] **Qikiqtaaluk (NU):** Cape Dorset[*]	-	12,297 (2015) [18]	**Stable from decline** [19] *50% decline between 1997* in 2005 *(30,38 and* 20,582) [19]	**Quota restriction** (Since 2012) [20]
Coats Island		-	5000 (2010) [21]	**Unknown** [2] *Experiences rapid population fluctuations*	**-**
Lorillard	**Kivalliq (NU):** Chesterfield Inlet[*] Baker Lake[*]	Wager Bay, Ahiak, Beverly, Bathurst, Qamanirjuaq, Dolphin and Union, Baffin Island herds	12,156 (2003) [19]	**Stable** [19]	**No restriction**
Wager Bay	**Kivalliq (NU):** Repulse Bay[*], Baker Lake[*], Chesterfield Inlet[*]	Lorillard, Beverly, Qamanirjuaq, Ahiak, Bathurst, Dolphin and Union, Baffin Island herds	20,931 (2002) [19]	**Stable** [19]	**No restriction**
Baffin Island Herds	**Qikiqtaaluk (NU):** Arctic Bay[*], Pond Inlet[*], Clyde River[*], Kimmirut[*], Cape Dorset[*], Iqaluit[*], Pangnirtung[*], Qikiqtarjuaq[*], Igloolik[*], Hall Beach[*]	Wager Bay, Lorillard	3,462 - 6,250 (2014) [22]	**Declining** [22] *90-95% decline since 1990s estimate of ~120,000 – 330,000*	**Quota restriction** (since 2015) [23]
Dolphin and Union (R. t *groenlandicus x Pearyi*)					
Dolphin and Union	**ISR (NT):** Ulukhaktok[*], Paulatuk[*] **Kitikmeot (NU):** Cambridge Bay[*], Kugluktuk[*], Bathurst Inlet[*], Umingmaktok[*]		27 787 (2007) [24] 14,730 (2015 draft) [25]	**Stable / declining** [24, 26] *too little information to assess long-term trend* COSEWIC (2004) = special concern SARA = special concern NT SARA (2015) = species of risk	**No restriction**
Peary Caribou *(R. t Pearyi)*					
Banks Island subpopulation *Includes Minto herd (Northwest Victoria Island)*	**ISR (NT):** Sachs Harbour[*], Ulukhaktok[*]	Dolphin and Union	1195 Banks Island (2001) [27] 150 Minto Inlet/Northwest Victoria Island (2010) [28]	**Stable from historic low** *Banks Island = 12,098 in 1972* [27] *Northwest Victoria Island = 2,600 in 1987* [2] *SARA = Endangered* *NT SARA = Threatened* *COSEWIC = Threatened*	**Banks Island = Quota restriction** (since 1990) [29] **Victoria Island = Harvest Ban** (since 1993) [29]

Herd / Population	Communities within proximity to herd range *	Range overlap	Estimated Population Abundance (Year)	Population trend & conservation status	Harvest Restriction (Inuit subsistence only) +
High arctic subpopulation *Western Queen Elizabeth Island groups (Ellesmere Island, Axel Heiberg, Ringnes Island, Devon Island, Prince Patrick, Melville)*	**Qikiqtaaluk (NU):** Resolute Bay *, Grise Fiord*, Arctic Bay* **Kitikmeot (NU):** Taloyoak*, Gjoa Haven*	-	NU = 4,000 (2001-2008) [30]	**Declining** *COSEWIC status: Threatened* *SARA status: Endangered*	**No restriction**
Low arctic subpopulation *Prince of Wales; Somerset, Boothia Peninsula;*	**Kitikmeot (NU):** Kugaaruk, Taloyoak, Gjoa Haven, and Cambridge Bay	-	NU = 4,000 (2001-2008) [30]	**Declining** *COSEWIC = Threatened* *SARA = Endangered*	**No restriction in Nunavut**
Woodland Caribou *(Rangifer t. caribou)*					
George River	**Nunatsiavut (Labrador):** Nain*, Hopedale, Makkovik, Postville, Rigolet, **Nunavik (Quebec)** **Other:** Québec and Newfoundland & Labrador	Leaf River, Torngat Mountain, Lac Joseph	8,938 (2016) [31]	**Declining** [31] *99% decline since early 1990s (775,000)* [31]	**Harvest ban** (2013 – 2018) [32]
Leaf River	**Nunavik (Quebec):** Kuujjuaq, Tasiujaq, Tasiujaq, Aupaluk, Kangirsuk, Quaqtaq, Kangiqsujuaq, Salluit, Ivujivik, Akulivik, Puvirnituq, Inukjuak, Umiujaq, Kuujjuarapik, Kangiqsualujjuaq **Other:** FN northern Quebec	George River	332,000 (2015)[33]	**Declining** *Estimated at 430,000 in 2011*[33] *Estimated at 628 000 at 2001*[34]	**No restriction**
Torngat Mountain	**Nunatsiavut (Labrador):** Nain **Nunavik (Quebec):** Kangiqsualujjuaq	George River	< 1000 animals [35]	**Declining** *Estimated at 5,000 in 1980* [36]	**Non-quota restriction** [37] *Hunting permitted within the Torngat Mountain National Park (not on Provincial lands)*
Boreal Population *Includes Mealy Mountain Red Wine and Lac Joseph subpopulations‡*	**Nunatsiavut (Newfoundland):** Rigolet*	George River	Mealy Mountain = 2,200 (2005) [38] Red Wine = 97 (2001) [39] Lac Joseph = 1400 (2009) [38]	**Declining** COSEWIC: Threatened ESA of NL (2002): Threatened	**Harvest ban** [37]
Porcupine caribou (*R. t. granti*)					
Porcupine herd	**ISR (NT):** Inuvik*, Aklavik* **Other:** NT, Yukon, Alaska	Central Arctic herd	197, 000 (2013) [40]	**Increasing** [40] *Estimated at 169,000 in 2010* [40]	**No restriction** *Voluntary bulls-only harvest*

Acronyms: NL = Newfoundland Labrador, Canada; NT = Northwest Territories, Canada; NU = Nunavut, Canada; COSEWIC = Committee on the Status of Endangered Wildlife in Canada; WAMC = Wildlife Advisory Management Council (NT); SARA = Species at Risk Act, Public Registry (Federal); ESA = Endangered Species Act (Newfoundland Labrador)

Notes: * Asterisk denotes communities whose harvest of the herd is confirmed through community reports, and/or expert knowledge; otherwise the relationship is inferred from the community's proximity to the herd's annual range+ Current restriction on Indigenous Peoples' harvest (does not consider harvest restrictions on commercial, sport or resident harvest)
‡ Joir River Subpopulation and Dominion Lake Subpopulation

Complete citations for the supplemental material follow the manuscript references

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5 POTENTIAL IMPACT OF RESTRICTED CARIBOU (*RANGIFER TARANDUS*) CONSUMPTION ON ANEMIA PREVALENCE AMONG INUIT ADULTS IN NORTHERN CANADA

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ABSTRACT

Background: Caribou (*Rangifer tarandus*) is the top dietary source of iron and several micronutrients necessary to red blood cell production (erythropoiesis) in the contemporary diet of Inuit adults across Canada. However, caribou populations across the circumpolar north have experienced dramatic declines in recent decades. Restricted access to caribou, whether through species decline or harvest regulations, is likely to negatively impact the nutrition and health of Inuit communities.

Methods: We used data from the Inuit Health Survey, a cross-sectional survey of 2,550 Inuit adults in thirty-six communities across northern Canada (conducted in 2007-8) to examine the relationship between caribou consumption, hemoglobin (Hb), and blood biomarkers of nutrient intake and contaminant exposure. Multivariable linear regression was used to investigate the potential public health impact of a theoretical restriction in caribou consumption, by estimating the response of Hb concentrations (and the attendant change in anemia prevalence), to theoretical changes in caribou consumption (with and without substitution of caribou with other country food meat).

Results: Mean (95 % CI) daily caribou meat consumption differed by an order of magnitude 4.3 (3.9 - 4.7), 72.7 (69.9 – 75.6), and 236.7 (224.7 - 248.7) grams/day between terciles of caribou consumption. Mean (95% CI) hemoglobin levels increased from 129.1 (128.1 - 130.2) g/L to 132.5 (131.3 - 133.7) g/L between the highest and lowest terciles of caribou consumption. In multivariable regression analyses, average daily caribou meat consumption was positively associated (<0.001) with hemoglobin levels. This relationship translated into approximately 4 g/L hemoglobin increase in participants in the third tercile of caribou consumption. The overall prevalence of anemia observed in the study population was 26.5% (24.5 % – 28.3 %) and a simulated restriction in caribou consumption (i.e. caribou=0) increased the overall prevalence of anemia by approximately 6%. The maximum negative effect of caribou restrictions was related to a complete restriction on caribou consumption, coupled with the substitution of caribou with other country food meat (35.4% prevalence).

Conclusions: Strategies to promote the sustainable harvest of caribou are urgently required to ensure the health and food security of the Inuit in a rapidly changing Arctic environment.

5.1 Background

Anemia is a major international health issue affecting an estimated 1.62 billion people globally (95% CI: 1.50–1.74 billion), almost a quarter (24.8%) of the world's total population (McLean et al. 2008). Moreover, anemia is disproportionately represented in people of lower socioeconomic strata (WHO 2015), and Indigenous Peoples, worldwide (Khambalia et al. 2011). Among Inuit (Arctic Indigenous People) in northern Canada, the prevalence of anemia is several times higher than the average prevalence (approximately 8%) observed in most developed countries (DeMaeyer & Adiels-Tegman 1985), and corresponds to a moderate (25-30 % prevalence) to severe (40-43% prevalence) public health problem (Jamieson & Kuhnlein 2008; Jamieson et al. 2016; Plante et al. 2011).

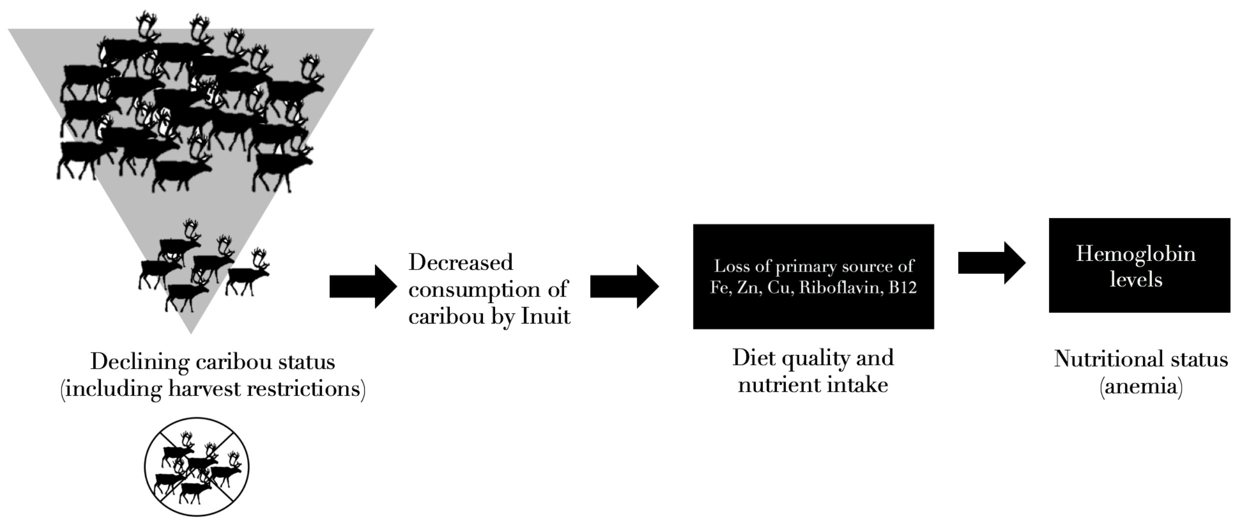
Approximately half of all cases of anemia on a global scale are assumed to be caused by dietary iron deficiency, related to inadequate iron intake, poor iron bioavailability, high iron needs, or high loss of iron (Petry et al. 2016). However, the etiology of anemia is multifactorial and context-specific (e.g. population, region, and general environmental), with nutrient deficiencies, malaria, infections, inflammatory disorders, blood disorders, and low socioeconomic status, counted among its most frequent causes (Petry et al. 2016).

The declining use of country foods (i.e. wild foods harvested by Inuit using cultural knowledge, and traditional practices) may place Inuit at increased risk for both iron deficiency (ID) and anemia (Jamieson et al. 2013). Despite rapid sociocultural change in the last several decades, country foods obtained from hunting, fishing, and trapping remain fundamental to the Inuit food system (Kuhnlein & Receveur 2007). While Inuit utilize a diversity of local species (including both plant, and animal species) for culture and subsistence, dietary studies show that caribou (*Rangifer tarandus*) generally represents the most frequently, and abundantly, consumed country food. Over ninety percent of participants in the Inuit Health Survey reported consuming caribou over the previous year, with a mean annual consumption of 29.6 - 122.8 kg of caribou per person, according to sex, and region (Kenny & Chan 2017). Caribou is also the number one source of iron (up to 36.5% of total population iron intake) and several micronutrients (including zinc, copper, vitamin B_6, and vitamin B_{12}) involved in erythropoiesis (Chapter 4).

However, many caribou populations across the circumpolar north have experienced dramatic declines (70-97%) in recent decades (Russell & Gunn 2013; Russell et al. 2015; Gunn et al. 2011; Vors & Boyce 2009), and their precarious status has prompted government restrictions on Inuit subsistence harvests in various regions of the Canadian north (see for example Government of Nunavut 2014; Government of Newfoundland and Labrador - Department of Environment and Climate Change 2013). While Inuit have long endured fluctuating cycles of species abundance, the declining use of country foods, related to both species declines and harvest restrictions, may place communities at increased risk of food insecurity. From a human health perspective, barriers to caribou access, whether through species decline (i.e. availability) and/or harvest regulations (i.e. accessibility), are likely to cause cascading effects on human health through the decline of critical nutrients in the diet. Although many nutrients (e.g. protein) may be provisioned from consumption of alternate country food species (Wesche & Chan 2010; Rosol et al. 2016; Nancarrow & Chan 2010) and/or market foods, certain micronutrients may be limitedly available and/or "unaffordable" in the northern food supply. For instance, when caribou is substituted for other country food species (e.g. muskox (*Ovibos moschatus*)), intake of zinc, and in some cases iron and vitamin D, is markedly reduced (Rosol et al. 2016). Furthermore, the high price of animal-source foods in remote northern community stores, may favour the substitution of caribou with low-cost foods such as grains and starches (Chapter 7)

The human health impacts of wildlife restrictions among Arctic Indigenous Peoples are unknown. The goal of this research is to model the potential human health impact of restricted caribou consumption for Inuit adults in northern Canada. As caribou is a major source of nutrients important in the prevention of anemia, the specific objectives of this research are to: (i) examine the relationship between caribou consumption, hemoglobin (Hb), and blood biomarkers of nutrient status and contaminant exposure; and (ii) examine the theoretical public health impact of restricted caribou consumption, by modelling the response of Hb to caribou intake using multivariable regression. We hypothesize that caribou consumption is positively associated with blood Hb concentrations; thus, restricting caribou intake will lead to an increased prevalence of anemia in the study population (Figure 5.1).

Figure 5.1 Relationship between caribou status, consumption, and potential implications for human health



5.2 Methods

5.2.1 Study Setting and Participants

Dietary data and blood biomarkers were derived from the 2007-8 International Polar Year (IPY) Inuit Health survey (IHS). The study sample comprised of 2,550 self-identified Inuit adults (men and non-pregnant women) who completed the food frequency questionnaire (FFQ) and provided valid blood samples.

Figure 5.2 Map of the participating Inuit regions[1] of the 2007-8 Inuit Health Survey

[1]*Nunavut is comprised of the Kitikmeot, Kivalliq and Qikiqtaaluk regions*

Survey Design

Detailed methodology for the IHS, including the participatory survey design, has been reported elsewhere (2012). The survey took place between the late summer and fall of 2007 and 2008 in thirty-six communities (latitude of 54°10'N to 76°25'N) across Nunatsiavut, Nunavut, and the ISR (Figure 5.2). Households (n=2,796) in each community were selected to participate through a stratified random sampling design and, ultimately, 68% (1,901) agreed to participate. All non-pregnant Inuit adults (18 years and older) from the households were eligible to participate in the survey. Informed consent was obtained from all participants. Ethical approval for the IHS was granted by McGill University (Faculty of Medicine Institutional Review Board) and scientific Research Licenses were obtained, where necessary, from northern research institutions (the Aurora Research Institute (Northwest Territories) and (Qaujisaqtulirijikkut (NU)). The University of Ottawa (Health Sciences and Science Research Ethics Board, file number H05-15-16), granted ethics approval for secondary analysis of the data.

5.2.2 Dietary Assessment

Dietary assessments were conducted in-person, by trained interviewers, in English and Inuit Languages. A semi-quantitative food frequency questionnaire (FFQ) was administered to estimate the frequency (number of times per day, week, and month) and usual serving size of each country food item (species, and in some cases, distinct parts such as organs and fat) consumed during the previous year, both in and out of harvest season. The FFQ was developed with input from the IHS steering-committees, based on a revised version of the Centre for Indigenous People's Nutrition and Environment's Inuit traditional FFQ. Average (annual average) daily consumption (grams per day, g/d) was calculated for each participant as the product of daily intake frequency and serving size, adjusted for seasonality, according to wildlife harvest calendars. Consumption results were truncated at the 90th percentile to correct for unrealistic reporting. Average daily caribou meat consumption (g/d) was calculated for each participant as the sum of caribou (raw) meat, and caribou dry meat.

Caribou dry meat was converted to fresh weight by correcting for the moisture content differential between raw and dried caribou meat (0.73% and 0.27%, respectively (Health Canada 2015)). Total meat from all other country food species, including meat from both terrestrial mammals (e.g. muskox meat) and marine mammals (e.g. ringed seal meat), was summed as "total other country food meat" and included as a model covariate.

5.2.3 Biochemical Assessment

As described in greater detail elsewhere (Jamieson et al. 2012; Laird et al. 2013; Jamieson et al. 2016), blood biomarkers of nutrient status and contaminant exposure were quantified from fasting (8 – 16 hours preceding the interview) venous blood samples. Blood samples were collected by certified nurses in vacutainer tubes with clot activator and polymer gel for serum separation (Becton Dickinson), or EDTA-coated vacutainers for whole blood hematology. Hb from venous blood samples (morning participants) and blood drops from a finger prick (afternoon participants) was determined using the azide methemoglobin method with a HemoCue 201+ portable photometer (HemoCue; Lake Forest, California). Serum ferritin (SF) and high-sensitivity C-reactive protein (hs-CRP) were quantified by automated chemiluminescence assay (Liaison Ferritin; Diasorin, Italy) and by auto-analyzer (Beckman

Coulter; Brea, California), respectively (Jamieson et al. 2016). Soluble transferrin receptor (sTfR) levels were determined by ELISA (R&D Systems; Minneapolis, Minnesota) for a subsample of the population (n=1039). *Helicobacter pylori* (*H. pylori*) seropositivity was ascertained from detection of serum IgG antibodies against H. pylori by Immunoenzymatic methods (Calbiotech) at the Montreal General Hospital. Serum 25(OH)D was quantified using the LIAISON total 25(OH)D assay (DiaSorin) at McGill University (detection limit of 0.5 mg/L) as described elsewhere (Hayek, Egeland, and Weiler 2011). Fatty acid composition was measured from 200 mL of red blood cells (RBC) stored in 200 mL of a 1:1 solution of methanol and distilled water plus 8.4 mg BHT (Becton Dickinson) based on RBC membranes by Lipid Analytical Laboratories (University of Guelph Research Park). RBC phospholipid FA analyses were expressed as a percentage of total FAs weight. Selenium, mercury, cadmium and lead were quantified in whole blood by an inductively coupled plasma–mass spectrometer (Elan DRC II (Perkin-Elmer SCIEX) for selenium, mercury and cadmium; ELAN 6000 (Perkin-Elmer SCIEX) for Pb) at the Laboratoire de Toxicologie, Institut national de santé publique, (Québec, QC) (Laird, Goncharov, Goncharov, et al. 2013; Laird, Goncharov, Egeland, et al. 2013).

5.2.4 Anemia Classification

Anemia was classified according to the World Health Organization (WHO) (WHO 2015) Hb cutoff values of 130 g/L for men and 120 g/L for non-pregnant women. Cutoff values were adjusted downward (- 0.3 g/L) for current cigarette smokers (WHO 2015).

5.2.5 Covariates

Model covariates are summarized in Table 5.1, including demographic (age, sex, region) and socioeconomic characteristics (e.g. education (post-secondary education), income (> CAD $ 40,000), smoking (current smoker), as well as other factors known or suspected to be involved in the development of anemia among Inuit adults (e.g. consumption of country food meat (non-caribou)), food insecurity and *H. pylori* seropositivity (Jamieson et al. 2012). Food security status was assed using a modified version of the United States Department of Agriculture (USDA) Food Security Survey Module) (Health Canada 2012b); food insecurity was classified based on two or more affirmative responses on the 10-item adult scale as recommended by Health Canada (Health Canada 2012a).

5.2.6 Statistical Analysis

Demographic characteristics, country food consumption, and blood biomarkers were described using descriptive statistics (mean (95% CI)). Participants were stratified into terciles based on average daily caribou consumption (g/day) and multiple comparisons, (with Bonferroni correction) were used to compare means between terciles. Multivariable linear regression (Hidalgo & Goodman 2013) was used to test the hypothesis that caribou consumption was positively associated with blood Hb concentrations. Model covariates (Table 5.1) were selected *a priori* based on known, or suspected relationships to Hb in the Inuit population. When necessary, model parameters were logarithmically (ln) transformed to improve normality of the respective distributions. Significance was set at $\alpha=5$ % for all statistical tests. All statistical analyses were performed with Stata SE® (version 14; StataCorp LP, College Station, Texas).

Following the approach described by Golden et al. (2011), we investigated the potential human health impact of a theoretical restriction in caribou consumption, by estimating the response of Hb levels to changes in caribou consumption using the multivariable model described above. The population change in anemia prevalence was estimated by subtracting the expected impact of restricted caribou consumptions from baseline Hb concentrations observed in study population. Four scenarios were formulated to evaluate the impact of different levels of restricted caribou consumption and adaptation. Scenario 1 represented a complete restriction on caribou consumption (i.e. caribou intake = 0). Scenario 2 represented a complete restriction on caribou consumption, and substituted caribou meat with the equivalent weight of other country food meat. Finally, scenarios 3 and 4 represented a fifty-percent reduction in caribou consumption, considering both no substitution of caribou meat (scenario 3), and replacing caribou with intake of other country food meat (scenario 4).

5.3 Results

5.3.1 Participant Characteristics

Participant characteristics are presented according to terciles of caribou consumption in Table 5.1. Overall, the mean ± SD age of study participants was 42 ± 15 years. The percentage of participants who reported to be current smokers was 70%. The proportion of women decreased from 67% to 55.5% between terciles one and three. Likewise, the percentage of physically inactive participants decreased between terciles one and three (39% to 28%). Participants in higher terciles of caribou consumption were more likely to report incomes above CAD $40, 000, and *H. pylori* seropositivity. A higher percentage of participants from the Kivalliq and Kitikmeot regions were in the highest tercile of caribou consumption. By contrast, fewer participants from Nunatsiavut, the Qikiqtaaluk region, and the Inuvialuit Settlement Region were represented in the highest tercile of caribou consumption.

Table 5.1 Demographic, lifestyle, and socioeconomic characteristics according to terciles of caribou consumption: IPY 2007-2008 Inuit Health Survey

Participant characteristics	Terciles of caribou consumption[1]					
	Tercile 1		Tercile 2		Tercile 3	
	Mean /n	SD/ %	Mean/n	SD / %	Mean/n	SD / %
Age (year)	43	15	41	14	41	15
Female (%)	491	67	437*	60	402*	56
Kivalliq (Nunavut)	138	24	137	24	288*	51
Qikiqtaaluk (Nunavut)	355	49	235*	32	139*	19
Kitikmeot (Nunavut)	46	13	118*	33	196*	54
Inuvialuit Settlement Region	100	37	110	41	57*	21
Nunatsiavut	86	34	125*	49	45*	18
Post-secondary education (%)	138	20	155*	22	122	17
Married (%)	429	61	475	66	471	65
Current smoker (%)	500	71	482	67	525	73
Physically inactive (%)	280	39	261	36	202*	28
Food insecurity (%)[2]	340	65	282*	57	287	62
BMI (kg/m2)	27.6	6	28.6*	6	28.9*	7
Income > CAD $ 40 000 (%)	140	22	192*	30	176*	28
H. pylori seropositive (%)[3]	481	69	485	68	522*	75

*Multiple comparisons between terciles (tercile 1 vs. terciles 2 and 3, respectively) with Bonferroni correction. $P < 0.05$

[1] Participants were stratified into terciles based on average (annual average) daily caribou intake g/day, as estimated by the food frequency questionnaire.

[2] Food insecurity includes both moderate and severe food insecurity

[3] Based on percent inhibition from blood sample

Table 5.2 Average daily consumption of country food1, by tercile of caribou consumption (average daily intake - g/day) (n=2175)

	Terciles of caribou consumption[2]					
	Tercile 1		Tercile 2		Tercile 3	
	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)
Caribou						
Caribou fresh weight[3]	5.6	5.1 – 6.1	72.7*	69.9 – 75.6	506.8*	483.2 – 530.4
Caribou meat [4]	4.3	3.9 - 4.7	51.1*	48.5 - 53.8	236.7*	224.7 - 248.7
Caribou dry meat	0.5	0.4 - 0.6	8.0	7.2 - 8.7	99.9*	90.8 - 108.9
Total country food	107.8	97.5 - 118.0	205.0	194.5 - 215.5	596.4	576.1 - 616.7
Other country food meat [5]	45.9	40.7 - 51.0	108.3*	102.9 - 113.8	416.0*	401.8 - 430.1
Fish and other seafood [6]	41.0	35.8 - 46.1	62.1*	56.7 - 67.5	97.3*	90.4 - 104.2
Fat and muktuk	11.2	8.8 - 13.6	15.6	13.1 - 18.0	37.2*	32.6 - 41.7
Plant and berries	3.1	2.6 - 3.6	4.5*	4.0 - 5.0	6.1*	5.5 - 6.7

*Multiple comparisons between terciles (tercile 1 vs. terciles 2 and 3, respectively) with Bonferroni correction, adjusting for age, sex and region of residence. $P < 0.05$

[1]Average daily country food consumption (g/person/day) was based on the food frequency questionnaire and averaged across seasons

[2] Participants were stratified into terciles based on average (annual average) daily caribou intake g/day

[3] Caribou fresh weight calculated based on the sum of caribou meat and caribou dry meat (corrected for moisture content difference)

[4] Caribou meat - including raw, baked, cooked and aged, preparations

[5] Aggregated total of meat from all other (non-caribou) country food species, including birds, land mammals (e.g. muskox meat) and marine mammals (e.g. ringed seal meat)

[6] Does not include marine mammals

5.3.2 Blood Biomarkers

Most concentrations of blood nutrients and contaminants remained stable between terciles (Table 5.3). Mean (95% CI) concentrations of % eicosapentonoic acid (EPA), magnesium, selenium, and mercury were lower in the third tercile, relative to tercile 1. Mean (95% CI) Hb levels were higher in terciles two 132.5 (131.3 - 133.7) g/L, and three 132.9 (131.8 -134.1), relative to tercile one 129.1 (128.05 - 130.23) (Table 5.4). Similarly, mean (95% CI) serum ferritin concentrations were higher in terciles two 58.5 (54.1 – 63.0) g/L, and three 57.5 (53.1 - 61.9) g/L, relative to tercile one 50.1 (46.3 - 53.9) g/L (Table 5.4).

Table 5.3 Blood biomarkers of contaminants and nutrients by tercile of caribou consumption: IPY 2007-2008 Inuit Health Survey (n=2175)

	Terciles of caribou intake					
	Tercile 1		Tercile 2		Tercile 3	
	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)
Serum vitamin D (nmol/L)	59.4	56.9 – 62.0	58.6	56.0 - 61.2	55.6	53.3 - 57.8
Plasma vitamin B_6 (ng/mL)	3.5	2.9 - 4.0	2.9	2.4 - 3.4	2.8	2.1 - 3.5
Total n-3 fatty acids (%)	5.8	5.6 - 6.1	5.7	5.5 - 5.9	5.6	5.3 - 5.8
RBC EPA (%)	1.7	1.6 - 1.9	1.5	1.4 - 1.6	1.5*	1.4 - 1.6
RBC DHA (%)	2.5	2.4 - 2.6	2.6	2.5 - 2.7	2.4	2.3 - 2.5
RBC magnesium (mg/L)	52.0	50.9 - 53.1	51.3	50.4 - 52.2	50.8*	49.9 - 51.7
Blood selenium (μg/L)	331.7	318.3 - 345.6	306.3	294.3 - 318.9	314.4*	301.7 - 327.7
Blood mercury (μg/L)	7.4	6.7 - 8.2	6.3	5.8 - 6.8	6.9*	6.3 - 7.5
Blood lead (μg/L)	34.7	32.7 - 36.8	32.8	31.1 - 34.6	38.1	36.0 - 40.2
Blood cadmium (μg/L)	1.7	1.6 - 1.8	1.5	1.4 - 1.6	1.7	1.5 - 1.8

Acronyms: DHA = Docosahexaenoic acid; EPA = Eicosapentaenoic acid; RBC = red blood cell

*Multiple comparisons between terciles (tercile 1 vs. terciles 2 and 3, respectively) with Bonferroni correction, adjusting for age, sex and region of residence. $P < 0.05$

Table 5.4 Blood biomarkers of anemia and iron status by tercile of caribou consumption (n=2175)

	Terciles of caribou intake[1]					
	Tercile 1		Tercile 2		Tercile 3	
	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)
Hemoglobin (g/L) (n=2175)	129.1	128.1 - 130.2	132.9*	131.8 - 134.1	132.5*	131.3 - 133.7
Serum ferritin (ng/mL) (n=2095)	50.1	46.3 - 53.9	58.5*	54.1 – 63.0	57.5*	53.1 - 61.9
Serum soluble transferrin receptor (mg/L) (n=986)	1.5	1.4 - 1.6	1.4*	1.3 - 1.4	1.4*	1.4 - 1.5
Serum hs-C-reactive protein (mg/L) (n=2086)	3.1	2.7 - 3.5	2.7	2.3 – 3.0	2.7	2.4 - 3.0

Abbreviations: hs=high sensitivity

*Multiple comparison between terciles (tercile 1 vs. terciles 2 and 3, respectively) with Bonferroni correction, adjusting for age, sex and region of residence. $p<0.05$

5.3.3 Modelled Change in Hemoglobin and Anemia

In multivariable regression, Hb was positively associated ($P<0.001$) with caribou consumption after adjustment for covariates (Table 5.1), with 0.008 g/L Hb increase per daily gram of caribou consumed (Table 5.5). This translated into approximately 4 g/L Hb increase in participants in the third tercile of caribou consumption (i.e. who reported consuming ~500g/day of caribou, on a wet weight basis). The consumption of other (i.e. non-caribou) country food meat was negatively associated (<0.001) with Hb (Table 5.5). Hb decreased by 0.007 g/L per daily gram consumption of other country food meat, which translated into about 0.5 g/L of Hb decrease in participants of the higher tercile of caribou consumption (approximately 80 grams).

Table 5.5 Multivariable linear regression[1] coefficients for hemoglobin, with both dietary and non-dietary determinants as independent variables[2]. Inuit adults: International Polar Year Inuit Health Survey, 2007–2008

	Coefficient	SE	P
Constant	123.741	3.093	0.000
Caribou consumption (g/day)[3]	0.008	0.003	0.009
Other CF consumption (g/day)[4]	-0.008	0.004	0.020
Age (years)	-0.139	0.030	0.000
Male sex	14.243	0.818	0.000
Region	0.869	0.300	0.004
Current smoker	-0.457	0.873	0.601
BMI (kg/m^2)	0.204	0.061	0.001
Postsecondary education	0.919	0.512	0.073
Married	1.233	0.788	0.118
Income above CAD $ 40 000	-0.011	0.015	0.459
H. pylori seropositivity (% inhibition)	-0.263	0.815	0.747
Food insecure	-2.096	0.813	0.010

Acronyms: BMI= body mass index; CF = country food

[1] Model R^2 = 0.23; Model adjusted R^2= 0.22

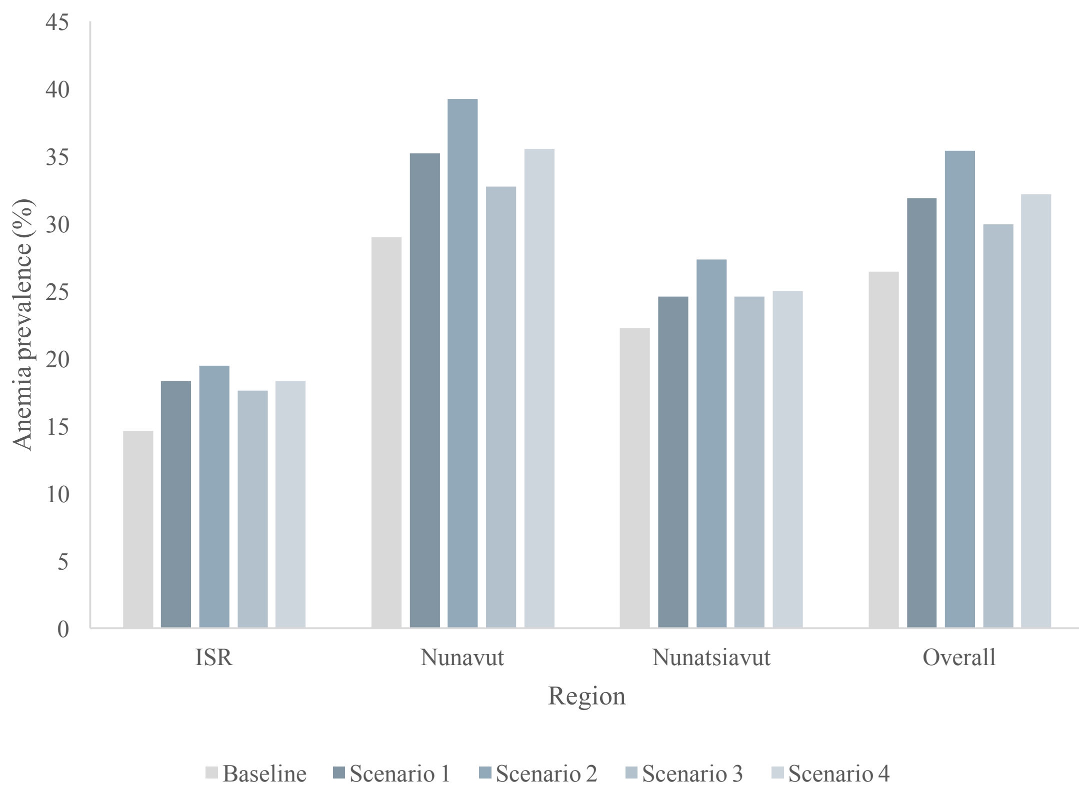
[2] Sex, region, smoking status, marital status, post-secondary education, income, and food insecurity (includes both moderate and severe food security) were treated as binary or dummy variables

[3]Average daily caribou meat consumption (g/person/day) was based on the food frequency questionnaire and was averaged across seasons. Average caribou meat consumption was expressed on a fresh weight basis as sum of caribou meat and caribou dry meat (corrected for moisture content difference)

[4] Other country food consumption represented the aggregated total of meat from all other (non-caribou) country food species, including birds, land mammals (e.g. muskox meat) and marine mammals (e.g. ringed seal meat)

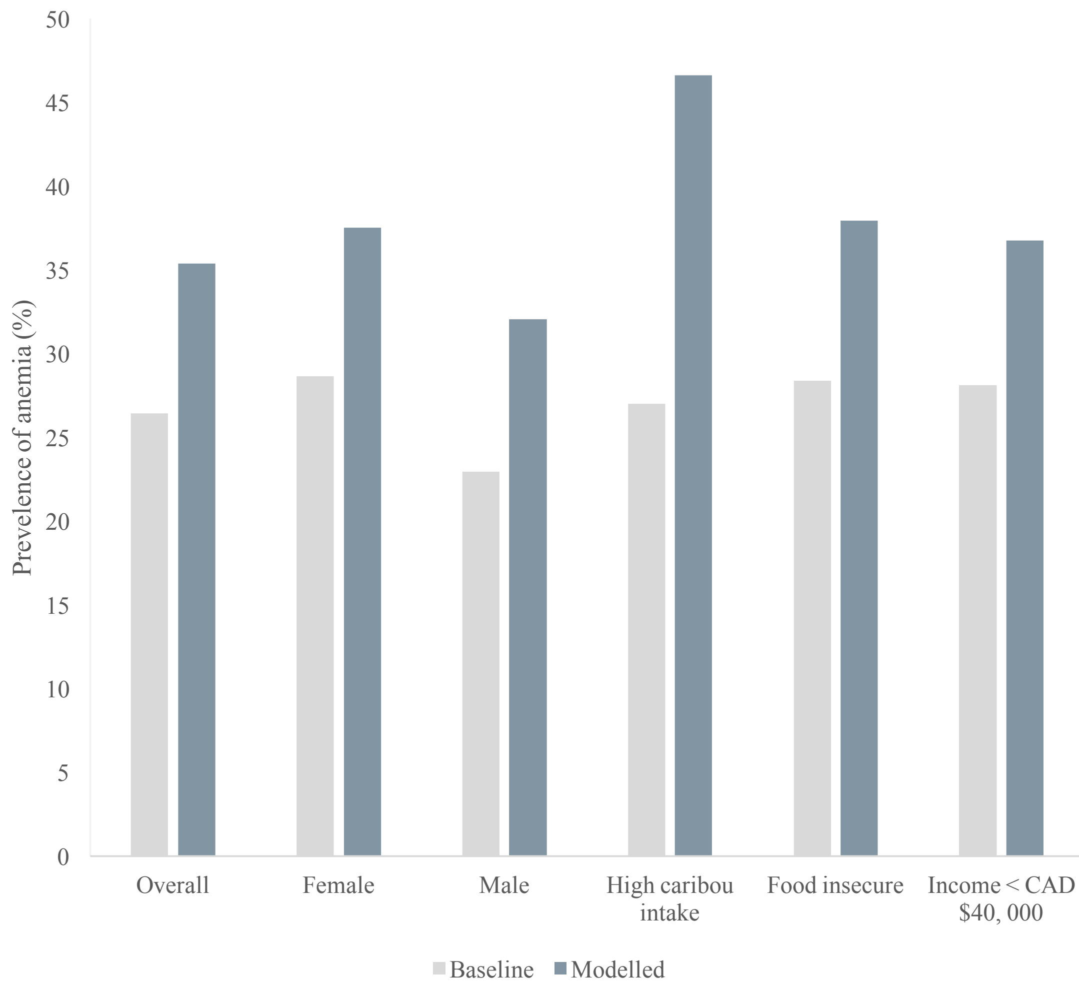
The overall prevalence of anemia in the study population was 26.5% (24.5 % – 28.3 %) (Figure 5.3). The impact of various scenarios of restricted caribou consumption are presented in Figure 5.3, based on the observed relationship between Hb and consumption of caribou meat, and other country food meat with (Table 5.5). A complete restriction on caribou consumption (i.e. restricting caribou to zero in the models) was associated with an overall 31.9% prevalence of anemia in the study population (18.4% in ISR to 35.2% in Nunavut). A complete restriction on caribou consumption, coupled with the substitution of caribou meat with other country food meat, represented the maximum negative effect of caribou restrictions on the population distribution of Hb levels (Figure 5.3). This scenario leads to an overall increase in anemia prevalence of approximately 9% (35.4% prevalence) and was higher among females (37.5% prevalence), participants in the highest tercile of caribou consumption (46.6%), and participants with annual incomes below CAD $40,000 (36.9%) (Figure 5.4).

Figure 5.3 Modelled change in prevalence of Anemia among Inuit adults in Canada (by region) from different scenarios of theoretical caribou consumption restrictions



Description of model scenarios:
Baseline: Observed prevalence of anemia in Inuit adults who participated in the 2007-8 Inuit Health Survey, according to WHO cutoff values for hemoglobin, adjusted for smoking
Scenario 1: Complete restriction on caribou consumption (caribou = 0)
Scenario 2: Complete restriction on caribou consumption (caribou = 0) and substitution of caribou with other country food meat
Scenario 3: Fifty-percent restriction in caribou consumption
Scenario 4: Fifty-percent restriction in caribou consumption and substitution of caribou with other country food meat

Figure 5.4 Modelled change in prevalence of anemia according to dietary and socioeconomic factors, from a theoretical restriction of caribou consumption, and the substitution of caribou with other country food meat.



*Food insecure status combines both moderate and severe food insecurity

5.4 Discussion

Inuit experience the highest documented prevalence of food insecurity (i.e. the state of inadequate access to sufficient, safe/nutritious and culturally preferred foods) among all Indigenous Peoples in a developed country (Rosol et al. 2011; Egeland 2011). The 2007-2008 Inuit Health Survey (Saudny et al. 2012), the most comprehensive food security assessment of Inuit adults residing in the northern Canada, reported that 62.6% of Inuit households experienced food insecurity, representing the lack of financial means to purchase food (Rosol et al. 2011; Egeland 2011; Huet et al. 2012). By contrast, recent national statistics (Canadian Community Health Survey) indicate that 8.3% of Canadian households experienced food insecurity in 2011-2012 (Roshanafshar & Hawkins 2015).

Food insecurity is an important social determinant of health for Inuit (Inuit Tapiriit Kanatami 2014), which, in addition to economic food access, is predicated upon access to locally harvested country food (Inuit Tapiriit Kanatami & Inuit Circumpolar Council 2012; Paci et al. 2004; Lambden et al. 2007). Although country foods remain vital to the health and wellness of Arctic Indigenous Peoples (Kuhnlein & Receveur 2007), the public health implications of species declines and harvest restrictions in the Canadian Arctic have not been well studied. In Madagascar, wildlife consumption ("bush meat") contributed approximately 0.7 g/dL to Hb levels in children, and a modelled restriction in bush meat access resulted in an estimated 29% increase in the number of cases of childhood anemia (Golden et al. 2011). Nevertheless, even at the international scale, studies on the impact of wildlife depletion and harvest restrictions on food security and human health are limited.

Previous studies have reported a positive association between country food consumption, serum ferritin (Jamieson et al. 2012), and Hb (Jamieson et al. 2016) levels in Inuit adults. The positive association between average daily (annual average) caribou consumption (g/day), serum ferritin, and Hb suggests that barriers to consuming caribou (whether through species decline and/or harvest regulations) may pose cascading effects on human health through the development of anemia. While caribou may be substituted for other country food species (e.g. moose or geese), micronutrient levels in the alternate diet may be diminished and result in deficiencies in some individuals (Wesche & Chan 2010; Rosol et al. 2016).

Most concentrations of blood nutrients and contaminants remained stable between terciles of caribou consumption in this study. However, we observed that mean concentrations of %EPA, magnesium, selenium, and mercury were lower in the highest tercile of caribou consumption relative to the lowest tercile. It is noteworthy that although country foods are rich sources of heme iron (Health Canada 2015), consumption of total other country food meat (i.e. non-caribou country food meat) was negatively associated with Hb in this study. Frequency of marine mammal consumption has been documented as an independent negative predictor of Hb concentrations in the Inuit population of Canada (Jamieson et al. 2016). It is postulated that high red blood cell EPA status, corresponding to higher intake of marine mammals (Lucas et al. 2010), may contribute to anemia in this population (Jamieson et al. 2016). Higher intakes of n-3 fatty acids may alter platelet function and/or hemostasis and lead to increased gastrointestinal blood loss (Petersen et al. 1996). Thus, high intakes of caribou may reflect lower intakes of marine mammals, contributing to improved iron status and Hb concentrations.

It is important to note that the etiology of anemia among Inuit is not fully understood (Jamieson & Kuhnlein 2008), and recent evidence recognizes non-dietary/nutritional factors (e.g. poverty, food insecurity, lead exposure, *H. pylori* infection, inflammation, chronic blood loss, and impaired iron absorption and/or utilization) (Jamieson et al. 2016). There is concern that exposure to heavy metals (e.g. lead and mercury) from consumption of country foods may expose individuals to unsafe levels of environmental contaminants and represent concern for anemia (e.g. lead interference with heme biosynthesis). Lead exposure among Inuit has been investigated as a potential cause of anemia and has been found to be negatively associated with Hb in men (Jamieson et al. 2016).

Public health interventions for the treatment and prevention of iron deficiency anemia generally include iron supplementation and fortification. Nutrient supplementation strategies such as "Sprinkles" (Zlotkin et al. 2005), for instance, have been included in strategies to prevent anemia in Indigenous children of northern Canada (Christofides, Schauer & Sharieff 2005; Christofides, Schauer & Zlotkin 2005). While anemia among premenopausal Inuit women is largely attributed to low iron /depleted iron stores (Plante et al. 2012; Jamieson et al. 2016), the vast majority of anemia cases among Inuit men and post-menopausal women are unexplained by iron status (Jamieson et al. 2016). The clinical significance of anemia among Inuit has not, to our knowledge, been established or described in the literature.

Limitations

Several important study limitations warrant mention. First, this study is based on cross sectional data, and, therefore, causality cannot be inferred directly. Second, caribou consumption estimated from the FFQ reflects the average diet during the twelve months preceding the interview, while blood biomarkers reflect a single time point (in the late summer/fall). Accordingly, the relationship observed between caribou consumption and blood biomarkers may differ throughout the year. Third, data from the Inuit Health Survey is aggregated at the regional level, which precluded the possibility of linking human health measures to status of northern caribou populations. Data for all regions was thus combined and modelled at the population level; however, this may have obscured region, age, and sex risk factors (Jamieson et al. 2016).

Nevertheless, this is the first study, to our knowledge, that has attempted to establish empirical links between country food consumption and human health in the Arctic. Inuit have witnessed climate-mediated changes on various aspects of the traditional food system, including changes in the accessibility, availability, and condition, of key country food species (Wesche & Chan 2010; Nancarrow et al. 2008). While hunting pressures by humans can exacerbate caribou declines, they are not generally recognized as the ultimate cause of wildlife declines (Vors & Boyce 2009). However, the health consequences of these declines would be experienced directly by Inuit and other northern Indigenous Peoples who rely on caribou for food security and nutritional adequacy.

5.5 Conclusion

The prevalence of anemia is high in the Inuit adult population of Canada and restricted access to caribou has the potential to further exacerbate this issue. Conservation scientists and health practitioners must therefore implement integrated solutions that ensure the sustainability of caribou populations over the long term. Preventing anemia will also necessitate broader support to address systemic inequalities (e.g. education, food insecurity and infection) among Inuit (Jamieson et al. 2016).

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6 DIETARY SOURCES OF ENERGY AND NUTRIENTS IN THE CONTEMPORARY DIET OF INUIT ADULTS: RESULTS FROM THE INUIT HEALTH SURVEY

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ABSTRACT

Objective: To characterize the major components of the contemporary Inuit diet, and identify the primary sources of dietary energy and essential nutrients.
Design: Dietary data were derived from the 24-hour recall collected by the Inuit Health Survey (IHS) from 2007 to 2008. The population proportion method was used to determine the percentage contribution of each group to the total energy and nutrient intakes. Unique food items/preparations (93 country foods and 1591 market foods) were classified into 8 country food groups, and 41 market food groups. Nutrient composition of each food item was obtained from the Canadian Nutrient File.
Setting: 36 communities, across three Inuit regions of northern Canada (Nunatsiavut, Nunavut and the Inuvialuit Settlement Region) in 2007 and 2008.
Subjects: A representative sample (n= 2095) of non-pregnant Inuit adults (>=18 years), randomly selected through a stratified random sampling survey design.
Results: Despite their modest contribution to total energy intake (16.4 – 19.6%, by region) country foods represent a major source of many nutrients, including protein (23-52%), iron (28.1 – 54.2%), niacin (24 – 52%), vitamins D (up to 73%), B6 (18 – 55%), and B12 (50 – 82%). By contrast, the three most popular energy-yielding market foods (i.e. sweetened beverages, added sugar, and bread), collectively, contributed approximately 20% of total energy, while contributing minimally to most micronutrients. A notable exception was the contribution of these foods to calcium (13.2 – 21.4%), vitamins E (17 – 35%) and C (as much as 50%). Solid fruits were consumed by less than 25% of participants across all regions while vegetables were reported by 38-59% of respondents.
Conclusions: Although country food use has declined considerably in recent decades, country foods remains a critical dimension of the contemporary Inuit diet

6.1 Introduction

From the Arctic to the South Pacific, Indigenous Peoples have experienced a rapid nutrition transition (Popkin 1998; Popkin & Gordon-Larsen 2004) characterized by the adoption of a "western" diet (i.e. high in saturated fats, sugar, and processed foods) and the decline of traditional / subsistence-based ways of life (Albala et al. 2006; Port Lourenco et al. 2008; Kuhnlein et al. 2004; Hughes & Lawrence 2005). Across the globe, this dietary shift has been paralleled by an increased prevalence of obesity, diabetes, and other diet-related chronic diseases (Albala et al. 2006; Port Lourenco et al. 2008; Kuhnlein et al. 2004; Hughes & Lawrence 2005). Inuit are a traditionally semi-nomadic subsistence culture of Indigenous People residing across the circumpolar north (Bonesteel & Anderson 2008). In the latter half of the 20th century, Inuit endured significant lifestyle changes, involving the settlement into permanent communities, the development of a wage economy, and the introduction of market foods to remote northern communities (Akande et al. 2015). The diet transition among Inuit is characterized by the decreased consumption of "country foods" (foods harvested from northern ecosystems, through cultural practices, tradition, and detailed environmental knowledge) and the increased presence of "market foods" (foods shipped to northern communities from the south and purchased in stores) in the diet (Kuhnlein et al. 2004; Sharma et al. 2010; Egeland et al. 2011).

The harvest and consumption of country food remains fundamental to Inuit cultural identity (Borré 1991; Searles 2002; Pufall et al. 2011), food security, and dietary adequacy (Schaefer et al. 2011; Jamieson et al. 2012; Power 2008). However, the transition towards higher intakes of market food has led to excessive intakes of energy, carbohydrates, and fat, coupled by inadequate intakes of several micronutrients (namely dietary fiber, calcium, folate, and vitamins A, D, and E) (Kuhnlein et al. 2004; Egeland et al. 2011; Sharma 2010; Sharma et al. 2010; Erber et al. 2010). This transition is associated with high rates of food insecurity (Egeland et al. 2011) and has been linked to increasing incidence of obesity, and bears important risks for the development of diabetes and chronic disease (Kuhnlein et al. 2004; Sheikh & Egeland 2011). Inuit experience moderate and/or severe food insecurity, at almost four times the rate of non-Aboriginal Canadians (27% relative to 7%, based on data from males aged 12 years and older) (Gionet & Roshanafshar 2013).

With few exceptions (see for example Kuhnlein et al. 2007) available literature on the Inuit diet in Canada generally consists of community-level studies, and involves small sample sizes. Limited consideration has traditionally been given to the importance of regional similarities and differences in dietary patterns and nutrient intakes (Blanchet et al. 2002; Akande et al. 2015). A notable exception, Kuhnlein et al. 2007 provide a comprehensive description of dietary adequacy in three populations of Arctic Indigenous adults (n 3329) across Canada, between 1993 to 1999 (Kuhnlein et al. 2007). To our knowledge, however, there has been no representative description of Inuit dietary habits across the Canadian north in the last decade. While there are unique qualities that define Inuit communities at the local level, food system disturbances (e.g. environmental change) are often expressed, and modelled by scientists, at larger scales (Wesche & Chan 2010). Likewise, strategies and interventions to improve food security and nutrition in Inuit communities may necessitate broader regional, territorial, or federal, support (see for example the federally-administered Nutrition North Canada program(Government of Canada n.d.) and the Nunavut Food Security Strategy and Action Plan (Nunavut Food Security Coalition 2014)).

The 2007-2008 International Polar year (IPY) Inuit Health Survey (IHS) was developed in response to the disparity in available information regarding the health status of Inuit residing across the Canadian Inuit Nunangat (homeland of Inuit of Canada). The IHS collected comprehensive baseline data for 2,595 Inuit adults in 36 communities, spanning three jurisdictions of Inuit Nunangat (Nunatsiavut, Nunavut and the Inuvialuit Settlement Region; Figure 6.1). Health status for Inuit in Nunavik (the fourth Inuit region in Canada) was assessed during the 2004 Qanuippitaa? How are we? Nunavik Health Survey (Rochette & Blanchet 2007).

The purpose of this study was to describe region-level population diets for a large sample of Inuit adults across the Canadian north. Specifically, our objectives were to: 1) identify principal dietary sources of energy and selected nutrients; 2) examine the relative contribution of country food and market food to energy and nutrient intake.

6.2 Methods

6.2.1 Study Design and Sample

Dietary data were derived from the Canadian International Polar Year Inuit Health Survey (IHS). The Inuit Health Survey, conducted between the late summer /fall of 2007 and 2008, collected comprehensive baseline data about the health and living conditions of Inuit adults across three Inuit regions (Nunatsiavut, Nunavut and the Inuvialuit Settlement Region) spanning the Canadian north (latitude of 54°10'N to 76°25'N). Complete methodology and design for IHS has been published elsewhere (Saudny et al. 2012). The survey was cross-sectional, and employed a stratified random sampling of households in 33 coastal communities, and 3 in-land communities (Figure 6.1). A total of 2,796 households were randomly selected to participate. From the households, non-pregnant Inuit adults, 18 years and older, were eligible to participate. The survey was developed in a participatory manner, with steering committees representing the participating Inuit jurisdictions. A certificate of Ethical Acceptability for the IHS was granted by the McGill Faculty of Medicine Institutional Review Board. Scientific Research Licenses were obtained from relevant northern research granting institutions (Aurora Research Institute and the Nunavut Research Institute). Ethical clearance for secondary analysis of data was granted by the University of Ottawa Health Sciences and Science Research Ethics Board (file number H05-15-16). Informed written consent was obtained from all participants.

Figure 6.1 Map of the participating Inuit regions1 of the 2007-08 Inuit Health Survey

[1]Nunavut is comprised of the Kitikmeot, Kivalliq and Qikiqtaaluk regions

6.2.2 Dietary Assessment

As described elsewhere (Egeland et al. 2011; Jamieson et al. 2012), dietary assessments were conducted in-person by trained interviewers in English and Inuit Languages. Diet was assessed by administering a single 24-hour dietary recall (beginning at midnight, and ending at midnight), based on an adapted form of the USDA Automated Multiple-Pass method (Blanton et al. 2006). Three-dimensional graduated food model kits (Direction de Santé Québec, Institut de la Statistique du Québec 2013) were available to aid participants in the estimation of portion sizes. Due to survey logistical constraints, a single 24-hour recall was collected from each participant. While this method does not capture inter-individual variations in dietary intake, it is appropriate for estimating population mean intakes (Guenther et al. 1997). Dietary data were entered using CANDAT Software (Godin London).

A total of 1591 (including 93 country foods) unique food and beverage (hereafter referred to as "food(s)") items and/or preparations, corresponding to unique food codes in the Canadian Nutrient File (CNF) were reported in the dietary recalls. Alcoholic beverages (12 unique items), which are legislatively prohibited in some Inuit communities, were excluded from all analyses. All food and beverages reported as consumed in the IHS were coded hierarchically, by item similarity and food group (major and sub groups) (Table 6.1a-b, Appendix). Similar food items in each recall were collapsed into a single item (e.g. 'potato chips" aggregated all potato chips of various seasonings), and compiled as a daily sum for the item (g/person/day). Food groups were based on the USDA Food and Nutrient Database for Dietary Studies 5.0 classification scheme (Ahuja et al. 2012), with some exceptions, to reflect culinary usage (e.g. butter was categorized as a "fat and oil" as opposed to a dairy product) and the dietary habits of Inuit. Due to database limitations, foods reported as mixed dishes/recipes (e.g. pizza, sandwiches) could not be disaggregated into component ingredients. Thus, a "mixed dishes" grouping was included, and classified according to the dish's primary ingredients (e.g. primarily meat dishes; and primarily grain dishes). Potatoes were excluded from the vegetables grouping, and included with "grains and starches". Efforts were made to group market foods based on nutritional similarities (e.g. high sugar beverages, such as fruit drinks and cola, were collectively grouped). However, food fortification practices in Canada (Canadian Food Inspection Agency 2014), such as the mandatory fortification of flour (thiamine, riboflavin, niacin, folic acid, iron), as well as the fortification of Vitamin c (mandatory), folic acid (voluntary) and iron (voluntary), in fruit-flavoured drinks, can complicate these relationships.

Country foods were classified by species (e.g. caribou, beluga whale) and body part (e.g. meat, fats, and organs). Bannock, a homemade biscuit (often considered traditional), was included with market grains and starches. The importance of food items/sub groups to total diet was characterized by: (i) mean population consumption (averaged for all participants, by region), and, (ii) the percentage of recalls reporting consumption of a particular food.

6.2.3 Dietary Sources of Energy and Nutrients

The Canadian Nutrient File, national food composition database (Health Canada 2015) was used to calculate energy and nutrient intakes. Nutrient composition information for foods not included in the CNF was available from an additional in-house food file (McGill School of Dietetics and Human Nutrition), as described elsewhere (Egeland et al. 2011). Missing nutrient values for all foods were imputed following procedures described by Schakel et al. 1997 (Schakel et al. 1997). The USDA Food and Nutrient Database for Dietary Studies (FNDDS) 5.0 was used to supplement missing nutrient information for market foods (Montville et al. 2013; Ahuja et al. 2012). Missing nutrient values for country foods (not in the FNDDS) were imputed and/or manually calculated, based on similar food items (considering the species, body part, and preparation method).

6.2.4 Analysis

Data management and statistical analyses were performed with SAS statistical software (version 9.4; SAS Institute, Cary, NC). The percentage contribution of each food sub group to total energy and nutrient intake was calculated for the entire population, according to the population proportion method (Krebs-Smith & Kott 1989; Block et al. 1985). Nutrients analyzed include energy, selected macronutrients (protein, fat, carbohydrates, total sugar, saturated fat), dietary fiber, vitamins (A, C, D, E, B12, thiamin, riboflavin) and minerals (calcium, iron, magnesium, zinc, copper, selenium, sodium). Dietary supplements, which were consumed by < 10% of all IHS respondents (IHS, unpublished results), were not included in the calculation of total nutrient intakes.

6.3 Results

A total of 2 595 Inuit adults (~1.3 participants per household) agreed to participate in the Inuit Health Survey (IHS). Complete 24-hour dietary recalls were available from a total of 2097 participants (1 292 women and 805 men). Characteristics of the study sample are summarized in Table 6.1. The mean (± standard deviation, SD) age of participants was 43 ± 15 and 41 ± 15 years for men, and women, respectively. The mean (± SD) BMI for men was

27.2 ± 5.5, and 29.2 ± 7.0 for women – both of which fall within the "overweight" class (BMI = 25 - 30 kg/m^2) defined by World Health Organization. The mean (± SD) energy intake was 2 351 ± 1 355 kcal, 1 962 ± 1028 for men, and women, respectively.

6.3.1 Top Food Items

Across all regions, the most popular country foods, in terms of percentage of recalls that reported the item, were caribou (18 - 40%, by region) and fish (7-22%, by region) (Table 6.2a). Country food meat was reported by nearly half (47.6%) of all participants in Nunavut, approximately thirty-five percent (34.8%) of participants in the ISR, and almost one quarter of all participants (24.6%) in Nunatsiavut (Table 6.2a). A notable difference in the consumption of country food fat was observed between regions (22% of respondents in Nunavut, and approximately 1% of respondents in Nunatsiavut), coincident with the consumption of marine mammals (Table 6.2a).

The most frequently reported market foods items, were coffee and tea (>85% of respondents), (granulated) sugar (>65% of respondents), sweetened beverages (44 – 64% of recalls), and bread (50 – 80% of recalls) (Table 6.2b). Dairy products were reported by the majority of participants (62 -72 %, by region), but region-level differences were observed in the consumption of fluid milk vs. powdered milk and non-dairy coffee whitener, with higher consumption of the former in Nunatsiavut. Store-bought meats (including other proteins) were reported by 68 – 90% of participants, according to region. Solid fruits were consumed by less than twenty-five percent of participants across all regions (Table 6.2b), while solid vegetables (namely, onions, carrots, and other root vegetables) were reported by 38-59% of respondents on the day prior to the interview.

Table 6.1 Characteristics of the study sample by region; Inuit Health Survey, 2007–2008 (n 2095)

	Nunavut			Inuvialuit Settlement Region			Nunatsiavut		
	Total (n 1568)	Men (n 620)	Women (n 948)	Total (n 267)	Men (n 86)	Women (n 181)	Total (n 260)	Men (n 97)	Women (n 163)
Age in years, mean (SD)	40.7 (14.7)	41.5 (14.6)	40.1 (14.7)	44.2 (15.8)	46.9 (15.6)	42.9 (15.8)	44.3 (13.9)	46.0 (15.5)	43.2 (12.8)
< 40 years (%)	51.4	49.4	52.7	38.6	30.2	42.5	35.4	32.0	37.4
>= 40 years (%)	48.6	50.6	47.3	61.4	69.8	57.5	64.6	68.0	62.6
BMI									
Average BMI	27.9	26.9	28.7	30.5	28.9	31.2	29.3	27.9	30.1
BMI > 25 - 29.99 (%)	26.3	31.9	22.5	26.7	32.5	24.0	33.5	35.4	32.3
BMI > 30 (%)	33.1	24.0	39.1	49.0	41.3	52.6	41.2	31.3	47.2
Diet energy									
Total diet energy[1] in kcal, mean (SD)	2092 (1352)	2328 (1356)	1937 (1349)	2334 (125)	2692 (127)	2164 (124)	2002 (96)	2196 (99)	1886 (94)
% Total diet energy from country foods[2]									
among participants < 40 years	12.5	14.6	11.2	6.5	8.1	6.0	2.7	2.8	2.7
among participants > =40 years	25.6	27.6	24.1	19.2	21.7	17.8	9.3	13.0	6.8

[1]Total diet energy excludes consumption of alcohol;

[2]Country foods are wild foods harvested locally through cultural practice, tradition and knowledg

Table 6.2 Mean[1] consumption (grams/person/day) of country food by respondents of the 24hr recall; Inuit Health Survey, 2007–2008 (n 2095)

	Nunavut (n 1568)			Inuvialuit Settlement Region (n 267)			Nunatsiavut (n 260)		
	% of recalls	Mean	SD	% of recalls	Mean	SD	% of recalls	Mean	SD
Country food, by part									
Country food – meat[2]	47.6	116.4	194	34.8	82.4	156	24.6	49.6	124
Country food – fat[3]	21.6	45.7	134	12.4	25.7	142	1.2	0.3	4
Country food – organs[4]	2.1	2.0	25	2.2	1.9	16	1.5	0.7	7
Country food, by animal / species									
Birds	1.5	3.1	29	5.2	11.7	68	5.0	10.4	59
Fish (country food only)	14.3	42.9	143	22.1	61.8	153	7.3	20.1	104
Caribou	39.3	97.4	187	29.2	68.1	144	18.1	36.0	109
Other land mammals	1.5	2.8	28	1.1	4.9	50	0.4	0.3	5
Seal and walrus	9.1	18.4	85	1.1	0.8	10	1.9	3.9	33
Beluga whale	11.0	30.6	116	9.7	23.4	141	0.0	0.0	0
Narwhal	4.3	12.0	72	0.7	1.1	13	0.0	0.0	0
Berries	3.1	6.2	44	0.7	2.2	24	1.5	0.2	2

[1] Population mean (consumers and non-consumers), by region

[2]Total meat does not include fish

[3]Total fat includes muktuk (whale blubber and skin)

[4]Total organs includes bone marrow and offal

Table 6.3 Mean[1] consumption (grams/person/day) of market food by respondents of the 24hr recall; Inuit Health Survey, 2007–2008 (n 2095)

	Nunavut (n 1568)			Inuvialuit Settlement Region (n 267)			Nunatsiavut (n 260)		
Market food groups / Sub groups[2]	% of recalls	Mean	SD	% of recalls	Mean	SD	% of recalls	Mean	SD
Dairy products	62.0	48.5	132	69.3	65.0	128	72.3	93.5	185
Milk	17.6	32.7	120	25.1	41.5	12	60.0	81.8	82
Coffee whitener and milk powder	40.4	5.3	16	34.1	3.4	9	6.9	1.0	6
Cream	5.7	1.8	11	10.5	4.9	21	1.9	0.9	9
Cheese	13.5	5.7	21	21.0	8.6	25	23.5	7.5	19
Yoghurt	1.4	2.7	42	5.6	6.6	30	1.9	2.2	19
Added fat	51.7	10.4	22	68.5	14.7	21	72.7	11.4	14
Table fat	33.5	3.7	9	56.2	7.2	12	63.5	7.0	10
Vegetable oil	10.3	1.8	9	14.2	2.4	8	16.5	2.0	7
Lard and shortening	13.8	3.5	15	10.9	2.4	9	2.7	0.5	4
Salad dressing & mayonnaise	7.0	1.4	9	16.1	2.7	9	12.7	1.9	6
Market meat and alternatives	67.6	144.3	180	87.3	228.8	220	90.0	247.8	225
Poultry	18.9	36.8	97	25.8	47.5	109	34.6	53.1	97
Pork	18.8	17.3	76	22.8	21.7	62	27.3	24.0	59
Beef	17.1	23.4	72	23.2	27.4	66	26.5	32.3	87
Processed meat	16.4	14.2	45	20.2	17.0	54	25.0	23.6	55
Eggs	22.1	23.9	52	24.7	28.8	67	26.5	25.2	54
Fish and shellfish	4.7	6.7	43	19.9	23.9	72	18.5	32.7	105
Broth and gravy	10.9	20.5	78	20.2	59.6	160	27.3	55.5	134
Alternatives	4.7	1.2	9	7.5	2.7	15	8.8	1.3	7
Fruits and fruit juice	25.1	99.0	261	38.2	131.5	282	46.2	185.5	363
Fruit (solid)	13.4	23.2	80	24.7	43.1	124	16.9	25.9	71
Fruit (juice)	12.7	70.1	236	15.0	72.8	230	31.2	145.4	329
Canned fruit	3.0	5.5	37	5.6	15.4	83	4.2	13.2	98
Dried fruit	1.3	0.3	5	2.6	0.2	2	4.2	1.0	8
Vegetables	43.3	68.5	138	61.4	115.2	189	62.7	95.1	151
Solid vegetable	38.0	41.7	91	52.8	63.1	110	58.8	66.7	107
Vegetable sauce and soup	10.7	26.8	102	18.7	52.2	150	11.5	28.4	107
Cereals, grains and starches	87.6	186.0	191	92.9	247.0	202	97.7	216.5	166
Bread	49.8	37.7	61	68.9	67.8	80	80.0	65.1	61
Bannock	24.3	31.1	83	14.6	15.2	49	2.7	3.1	25
Crackers and other	21.5	10.0	31	24.3	13.1	47	28.5	11.3	26
Pasta	10.5	25.2	92	19.5	25.0	79	11.5	26.8	115
Rice	20.7	35.3	93	30.0	38.2	85	25.0	30.0	75
Cereals	12.9	11.9	49	21.7	44.0	119	17.7	17.4	59
Potatoes	31.4	34.6	82	37.1	43.2	81	56.5	62.7	89
Sweets and snacks	93.1	653.7	821	92.1	616.4	746	94.6	465.9	644

Market food groups / Sub groups[2]	Nunavut (n 1568)			Inuvialuit Settlement Region (n 267)			Nunatsiavut (n 260)		
	% of recalls	Mean	SD	% of recalls	Mean	SD	% of recalls	Mean	SD
Sweetened beverages	64.2	577.8	795	57.7	533.0	724	44.2	369.8	601
Sugar	69.8	36.4	61	65.5	17.7	27	71.2	21.7	35
Sweet toppings and spreads	10.3	2.1	14	15.7	4.5	20	24.6	5.2	13
Chocolate and candy	14.9	10.5	40	16.9	17.3	66	20.4	13.1	49
Pastries	15.1	10.9	37	18.4	22.4	85	24.6	18.2	47
Sweet dairy products	3.4	3.6	28	6.7	10.3	49	7.3	9.8	44
Potato chips	19.3	12.4	38	13.9	11.3	38	27.7	28.1	72
Mixed dishes and other	51.0	134.7	221	55.1	153.2	245	50.4	105.4	201
Mixtures (grain)	32.4	91.0	187	37.8	109.9	217	26.9	58.2	146
Mixtures (meat)	14.1	38.5	123	10.1	23.5	92	11.9	40.4	147
Sauces and condiments	16.0	4.9	21	21.0	10.0	33	21.5	6.9	22
Low-calorie items	92.9	1377.4	1282	94.4	1491.6	1118	96.5	1267.9	1168
Coffee and tea	87.1	1100.7	1121	87.3	976.1	903	85.4	706.8	684
Diet / low calorie beverages	6.0	33.8	162	3.7	29.7	198	20.0	117.4	285
Salt and seasoning	11.1	0.3	1	19.5	0.4	2	13.1	0.3	2

[1] Population mean (consumers and non-consumers), by region; [2] The detailed categorization scheme for market foods is presented in the supplemental material

6.3.2 Top Dietary Sources of Energy and Nutrients

The top ten food sources of dietary energy, and nutrients, including the contribution (%) of each food to total intake, are presented by region, in Tables 6.3-6.5.

Contribution of country food to diet

The contribution of country food to total diet energy (TDE) for individuals, ranged between 0 % TDE (43.5% of all respondents), to over 50% TDE (10% of all respondents), with less than 1% of respondents consuming 90% or more of TDE from country food (data not presented). The contribution of country food to total diet energy for the population, differed by region, and was stratified by sex and age (Table 6.1). In general, the contribution of country food to TDE, was lowest in Nunatsiavut, particularly among adults younger (<40 years) adults (2.7%), and highest in Nunavut, particularly among older (>= 40 years) adults (25.6%).

At the regional level, country foods represented a modest contribution to total diet (16.4 – 19.6 TDE %), but were a major source of many nutrients across all regions (Figure 6.2-6.3). Country foods contributed significantly to protein (23-52%), with caribou ranking among the top two sources of protein in all regions (Table 6.3). Country foods were a principle source of many micronutrients (Figure 6.3), namely iron (28.1 – 54.2%), niacin (24 – 52%), and vitamins D (73% in both Nunavut and the ISR), B6 (18 – 55%), and B12 (50 – 82%).

The majority of total fat (>75%) and saturated fat (> 80%) was provided by market foods (Figure 6.2), however, country foods were a major source of cholesterol (19.6 – 47.3%) (Figure 6.2). Country foods collectively contributed less than 20 - 25% of total MUFA in Nunavut, and the ISR, respectively (Figure 6.2), with beluga ranking as the principle source of MUFA in both regions (7-8% of total intake; data not presented). Country foods contributed 18.5% polyunsaturated fatty acids (PUFA) in Nunavut, and 13.6% in the ISR (Figure 6.2), and was derived principally from caribou and local fish. Country food did not contribute significantly to carbohydrates (<0.5%), total sugar (<0.5%), dietary fiber (<5%), sodium (<6%), or calcium (<5%) (Figure 6.2-6.3). Country food likewise, did not contribute significantly to vitamin C in both the ISR (10%), and Nunatsiavut (<2%). In Nunavut, however, country foods (namely, beluga muktuk, arctic char and local berries) collectively contributed 17% of total vitamin C intake (Figure 6.3).

Contribution of market food to diet

Market foods contributed the majority of total diet energy (80.4 – 93.7%, by region). Sweetened beverages (excluding 100% fruit juices) were the primary contributor to energy in both Nunavut (11.8%) and the ISR (9.6%), and ranked third in Nunatsiavut (7.7%), after bread and potato chips (Table 6.3). Collectively, sweetened beverages, added sugar, and bread (the three most popular market foods, after coffee and tea), contributed approximately 20% of total energy (Table 6.3) while contributing minimally to most micronutrients. A notable exception was the contribution of these foods to calcium (13.2 – 21.4%), vitamins E (17 – 35%) and C (as much as 50%) (Table 6.4-6.5). Sweetened beverages were the number one source of calcium (14 – 17%) in both Nunavut and the ISR, whereas milk (fluid) was the major contributor to calcium in Nunatsiavut (21.4%). Sweetened beverages (in particular, powdered Vitamin-C fortified drinks) were likewise the principle source of vitamin C in both Nunavut and the ISR, accounting for over forty percent of the population's total intake (Table 6.4). In Nunatsiavut, vitamin C was derived principally from 100% fruit juices (44.5%), which were consumed by 30% of the respondents on day the prior (Table 6.3b).

Figure 6.2 Contribution (%) of country food to daily energy, macronutrients and dietary fiber amongst Inuit adults (n=2095), by region

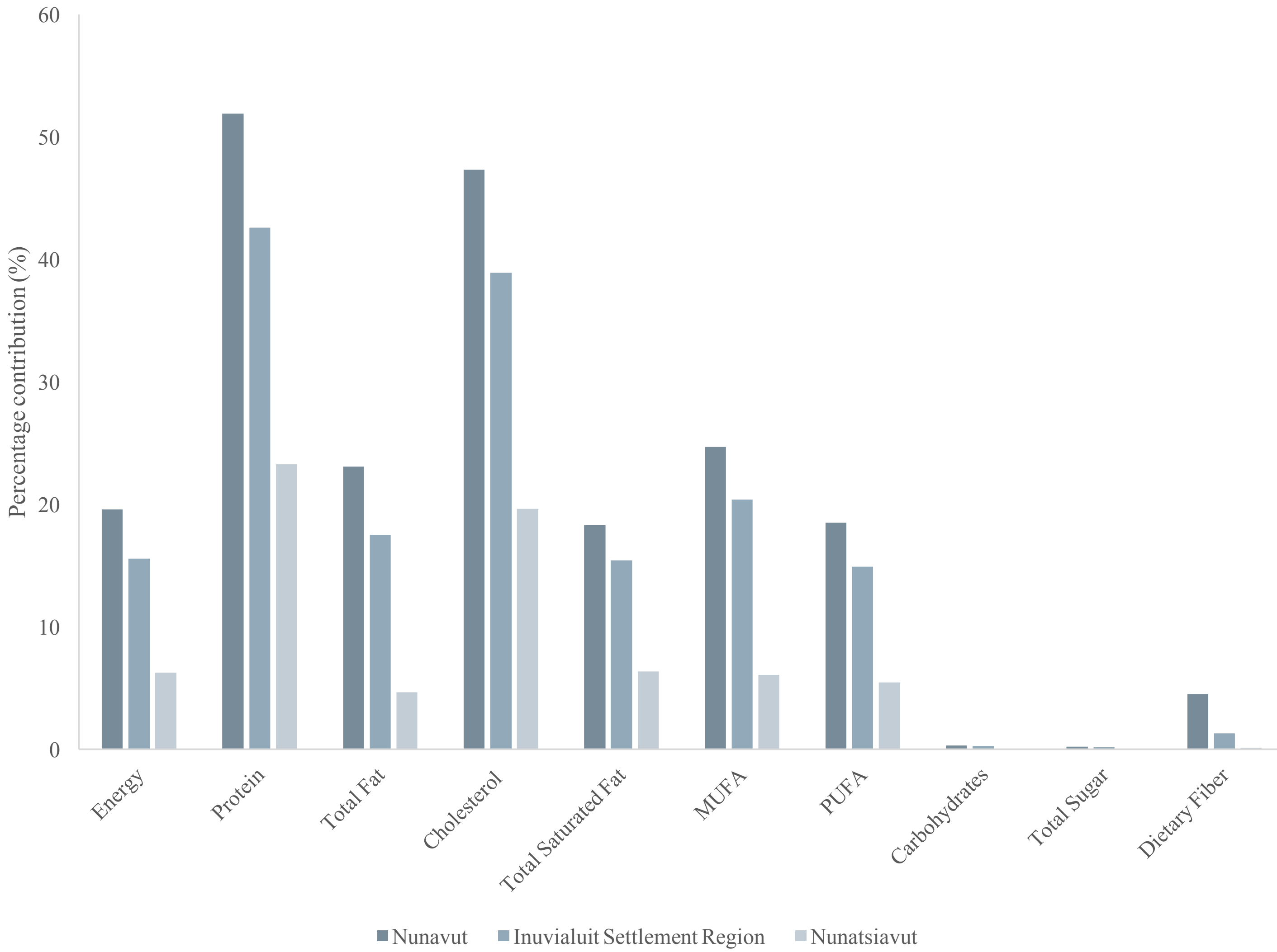

Figure 6.3 Contribution (%) of country food to micronutrient intake amongst Inuit adults (n=2095), by region.

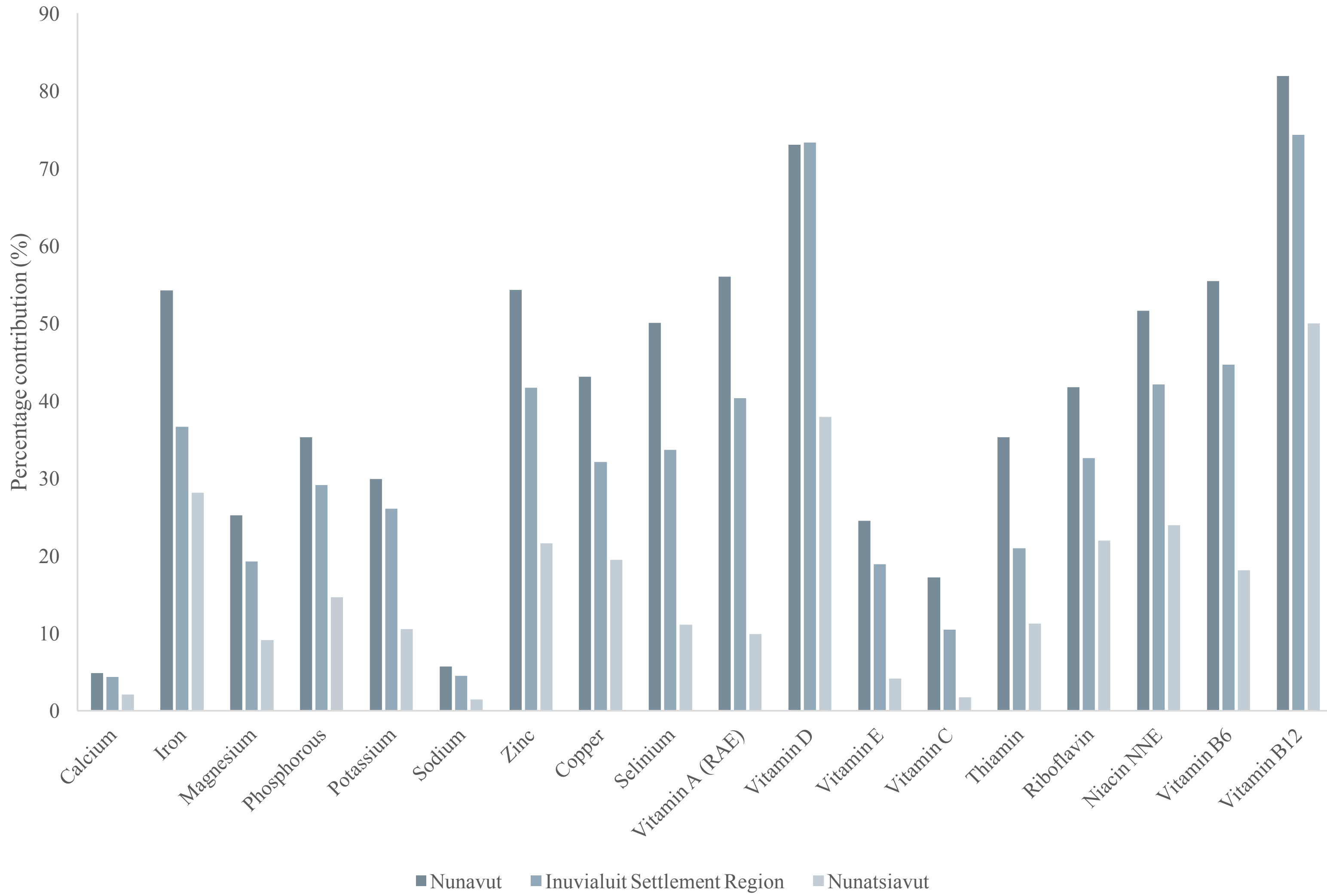

Table 6.4 Percentage of macronutrients and dietary fiber from the top 10 dietary sources among Inuit adults; Inuit Health Survey, 2007–2008 (n 2095)

Energy		Protein		Carbohydrates		Fat		Saturated fat		PUFA		Dietary fiber	
Nunavut (n 1568)													
Total (kcal)	2078	Total (g)	109	Total (g)	240	Total (g)	76	Total (g)	24	Total (g)	13	Total (g)	9
Sweetened beverages	11.3	Caribou*	27.2	Sweetened beverages	25.2	Caribou*	8.3	Caribou*	11.6	Potato chips	10.3	Bread	13.7
Caribou*	8.8	Fish*	9.7	Sugar	15.2	Poultry	6.6	Coffee whitener and milk powder	7.1	Poultry	9.7	Vegetables (solid)	11.2
Sugar	6.8	Poultry	7.9	Bread	7.8	Beluga whale*	6.3	Mixtures (grain)	6.9	Caribou*	7.6	Mixtures (grain)	9.9
Mixtures (grain)	6.1	Beluga whale*	6.5	Pasta and Rice	7.2	Mixtures (grain)	6.3	Table fat	6.5	Mixtures (grain)	6.2	Potatoes	7.7
Bread	5.1	Beef	6.2	Mixtures (grain)	6.5	Potato chips	5.4	Beef	6.3	Crackers and other	5.5	Pasta and Rice	6.6
Poultry	4.3	Mixtures (grain)	4.8	Bannock	4.5	Beef	5.0	Lard and shortening	5.4	Bread	5.2	Cereals	6.6
Pasta and Rice	4.1	Seal and walrus*	4.6	Chocolate and candy	3.2	Processed meat	4.6	Poultry	5.1	Fish*	4.5	Mixtures (meat)	5.8
Bannock	3.8	Pork	4.3	Potatoes	3.2	Lard and shortening	4.5	Pork	4.7	Eggs	4.1	Fruit (solid)	5.7
Beluga whale*	3.7	Bread	3.2	Fruit (juice)	3.1	Pork	4.3	Bannock	4.6	Vegetable oil	3.9	Potato chips	4.9
Fish*	3.3	Mixtures (meat)	2.8	Cereals	2.8	Bannock	4.2	Processed meat	4.3	Bannock	3.7	Bannock	4.8
Inuvialuit Settlement Region (n 267)													
Total (kcal)	2321	Total (g)	118	Total (g)	260	Total (g)	90	Total (g)	28	Total (g)	18	Total (g)	12
Sweetened beverages	9.3	Caribou*	18.7	Sweetened beverages	21.4	Poultry	6.6	Table fat	8.5	Poultry	8.3	Bread	19.6
Bread	8.4	Fish*	14.9	Bread	12.9	Mixtures (grain)	6.5	Caribou*	7.7	Bread	7.7	Cereals	10.2
Mixtures (grain)	6.7	Poultry	9.5	Mixtures (grain)	7.7	Table fat	6.4	Mixtures (grain)	7.1	Fish*	6.6	Vegetable (solid)	10.0
Caribou*	5.6	Beef	6.7	Pasta and Rice	7.1	Fish*	5.5	Chocolate and candy	5.7	Potato chips	6.6	Mixtures (grain)	9.0
Fish*	5.3	Pork	5.1	Sugar	6.8	Beluga whale*	5.1	Beef	5.7	Mixtures (grain)	6.3	Fruit (solid)	6.9
Poultry	4.8	Bread	5.0	Chocolate and candy	4.8	Pastries	4.8	Pastries	5.7	Crackers and other	5.1	Potatoes	6.8
Pasta and Rice	4.0	Mixtures (grain)	4.6	Pastries	4.3	Beef	4.6	Cheese	5.2	Table fat	4.8	Pasta and Rice	5.4
Pastries	3.7	Beluga whale*	4.5	Cereals	4.3	Pork	4.3	Pork	5.0	Salad dressing & mayonnaise	4.8	Crackers and other	5.0
Chocolate and candy	3.4	Fish and shellfish	4.4	Potatoes	3.6	Caribou*	4.3	Poultry	4.9	Pastries	4.7	Pastries	3.2
Beef	3.2	Birds*	3.0	Crackers and other	3.2	Potato chips	4.1	Eggs	3.7	Other mixed dishes	4.4	Potato chips	3.1
Nunatsiavut (n 260)													
Total (kcal)	1980	Total (g)	94	Total (g)	238	Total (g)	74	Total (g)	23	Total (g)	15	Total (g)	12
Bread	9.3	Poultry	13.6	Sweetened beverages	15.7	Potato chips	12.5	Table fat	8.8	Potato chips	19.4	Bread	17.7
Potato chips	7.4	Caribou*	13.0	Bread	13.9	Poultry	8.2	Processed meat	7.5	Poultry	9.7	Vegetables (solid)	12.5
Sweetened beverages	7.3	Beef	8.8	Sugar	9.1	Table fat	7.5	Beef	7.3	Bread	8.2	Potatoes	9.4
Poultry	5.8	Fish and shellfish	8.0	Pasta and Rice	6.8	Processed meat	7.1	Milk	7.2	Table fat	6.6	Mixtures (meat)	8.6
Mixtures (grain)	4.4	Pork	7.0	Fruit (juice)	6.5	Beef	5.9	Poultry	7.0	Crackers and other	5.8	Potato chips	8.4
Sugar	4.2	Bread	6.4	Potato chips	6.4	Pork	5.7	Pork	6.5	Pastries	4.8	Cereals	7.6
Pasta and Rice	4.1	Fish*	5.7	Potatoes	5.6	Mixtures (grain)	4.8	Cheese	5.3	Mixtures (grain)	4.5	Pasta and Rice	5.5
Beef	3.9	Milk	3.9	Pastries	4.4	Pastries	4.4	Mixtures (grain)	5.3	Fish and shellfish	4.2	Mixtures (grain)	5.5
Pastries	3.7	Processed meat	3.8	Mixtures (grain)	4.3	Eggs	4.1	Potato chips	5.2	Pork	3.9	Fruit (solid)	4.7

* Country food items are denoted by apteryx

Table 6.5 Percentage of vitamin intake from the top 10 dietary sources among Inuit adult; Inuit Health Survey, 2007–2008 (n 2095)

Vitamin A		Vitamin C		Vitamin D		Vitamin E[1]		Thiamin		Riboflavin		Vitamin B12	
Nunavut (n 1568)													
Total (µg RAE)	664	Total (mg)	125	Total (mg)	8	Total (mg)	7	Total (mg)	2	Total (mg)	3	Total (mg)	14
Beluga whale*	31.2	Sweetened beverages	44.5	Fish*	60.7	Potato chips	13.9	Caribou*	13.1	Caribou*	32.1	Caribou*	44.0
Vegetables (solid)	13.4	Fruit (juice)	18.9	Beluga whale*	6.9	Mixtures (grain)	9.8	Narwhal*	10.9	Coffee and tea	20.1	Fish*	22.7
Narwhal*	10.0	Beluga whale*	6.8	Eggs	5.4	Eggs	9.3	Cereals	8.5	Fish*	5.2	Beluga whale*	6.2
Caribou*	7.8	Berries*	4.5	Milk	4.5	Beluga whale*	8.6	Bread	7.9	Mixtures (grain)	4.7	Seal and walrus*	5.4
Eggs	7.8	Fruit (solid)	3.9	Mixtures (grain)	3.0	Caribou*	6.3	Mixtures (grain)	7.7	Bread	4.6	Beef	3.8
Table fat	4.0	Vegetables (solid)	3.7	Narwhal*	2.5	Narwhal*	4.4	Fish*	7.6	Eggs	4.0	Fish and shellfish	2.7
Fish*	3.4	Potato chips	3.5	Pork	2.4	Vegetable oil	4.4	Bannock	5.7	Bannock	2.5	Eggs	2.7
Milk	3.2	Narwhal*	2.5	Bread	1.9	Crackers and other	4.0	Pasta and Rice	5.3	Poultry	2.3	Narwhal*	2.4
Mixtures (grain)	3.2	Potatoes	2.4	Cereals	1.7	Fish*	3.5	Pork	4.8	Milk	2.3	Mixtures (grain)	1.7
Mixtures (meat)	2.8	Caribou*	1.8	Caribou*	1.5	Poultry	3.5	Coffee and tea	4.1	Seal and walrus*	2.2	Mixtures (meat)	1.5
Inuvialuit Settlement Region (n 267)													
Total (µg RAE)	680	Total (mg)	143	Total (mg)	13	Total (g)	9	Total (mg)	2	Total (mg)	3	Total (mg)	13
Beluga whale*	24.7	Sweetened beverages	46.2	Fish*	65.9	Mixtures (grain)	10.5	Bread	13.4	Caribou*	21.0	Caribou*	33.8
Vegetables (solid)	14.3	Fruit (juice)	18.4	Fish and shellfish	7.1	Potato chips	10.3	Cereals	10.9	Coffee and tea	20.7	Fish*	28.3
Eggs	9.0	Vegetables (solid)	6.9	Beluga whale*	4.9	Eggs	7.9	Fish*	10.0	Fish*	8.1	Fish and shellfish	7.2
Other land mammals*	8.0	Fruit (solid)	6.6	Eggs	4.0	Beluga whale*	6.5	Mixtures (grain)	9.7	Bread	7.1	Other land mammals*	5.9
Table fat	7.9	Beluga whale*	4.4	Milk	3.6	Fish*	6.1	Caribou*	8.6	Mixtures (grain)	5.4	Beluga whale*	4.8
Fish*	5.0	Potatoes	2.8	Mixtures (grain)	2.8	Bread	5.7	Pork	6.3	Eggs	4.6	Beef	4.6
Milk	4.1	Potato chips	2.5	Bread	1.9	Crackers and other	4.5	Pasta and Rice	5.6	Milk	2.9	Eggs	3.3
Mixtures (grain)	3.7	Fish*	2.2	Birds*	1.7	Vegetable oil	4.4	Coffee and tea	4.5	Poultry	2.8	Milk	1.5
Cheese	2.9	Berries*	2.0	Pork	1.2	Fish and shellfish	4.2	Bannock	2.9	Pork	2.5	Pork	1.4
Bread	2.1	Milk	1.3	Processed meat	1.0	Pastries	4.0	Processed meat	2.8	Beef	2.4	Poultry	1.4
Nunatsiavut (n 260)													
Total (µg RAE)	491	Total (mg)	118	Total (mg)	6	Total (g)	8	Total (mg)	2	Total (mg)	2	Total (mg)	9
Vegetables (solid)	27.3	Fruit (juice)	44.5	Fish*	34.6	Potato chips	29.8	Bread	17.7	Caribou*	15.4	Caribou*	26.6
Milk	11.4	Sweetened beverages	17.2	Fish and shellfish	16.8	Eggs	8.6	Cereals	9.0	Bread	10.8	Fish*	18.7
Eggs	11.0	Vegetables (solid)	8.8	Milk	16.3	Mixtures (grain)	6.3	Pork	8.9	Coffee and tea	10.6	Fish and shellfish	16.2
Table fat	10.8	Potato chips	7.8	Eggs	7.0	Fish and shellfish	5.2	Pasta and Rice	6.1	Milk	8.9	Beef	10.5
Other land mammals*	4.5	Milk	6.6	Bread	3.6	Bread	4.8	Caribou*	5.8	Eggs	5.5	Eggs	4.4
Beef	4.4	Potatoes	5.0	Pork	3.2	Vegetable oil	4.5	Mixtures (grain)	5.6	Poultry	5.1	Milk	3.7
Cheese	3.7	Fruit (solid)	3.9	Birds*	3.1	Crackers and other	3.9	Processed meat	5.4	Beef	4.2	Poultry	3.6
Fish*	3.3	Caribou*	0.9	Processed meat	3.0	Pastries	3.7	Fish*	4.5	Mixtures (grain)	4.0	Processed meat	2.9
Mixtures (grain)	2.6	Mixtures (meat)	0.9	Cheese	2.0	Vegetables (solid)	3.5	Potato chips	4.1	Fish*	3.8	Other land mammals*	2.4
Mixtures (meat)	2.3	Vegetables (sauce and soup)	0.9	Mixtures (grain)	1.5	Table fat	3.4	Fish and shellfish	3.93	Pork	3.6	Pork	2.2

*Country food items are denoted by apteryx

[1]Vitamin E as α-Tocopherol

Table 6.6 Percentage of mineral intake from the top 10 dietary sources among Inuit adults; Inuit Health Survey, 2007–2008 (n 2095)

Calcium		Iron		Magnesium		Zinc		Copper		Selenium		Sodium	
Nunavut (n 1568)													
Total (mg)	493	Total (mg)	21	Total (mg)	233	Total (mg)	16	Total (mg)	1	Total (mg)	269	Total (mg)	2386
Sweetened beverages	17.1	Caribou*	26.6	Coffee and tea	14.1	Caribou*	31.3	Caribou*	29.2	Beluga whale*	26.0	Mixtures (grain)	14.9
Bannock	11.8	Seal and walrus*	20.1	Caribou*	13.1	Beluga whale*	11.5	Mixtures (grain)	6.7	Mixtures (grain)	23.5	Bread	8.3
Mixtures (grain)	11.6	Bread	6.0	Mixtures (grain)	6.3	Beef	9.3	Bread	4.7	Narwhal*	14.9	Mixtures (meat)	7.4
Milk	9.0	Mixtures (grain)	5.2	Bread	6.1	Narwhal*	4.7	Potatoes	3.8	Bread	4.0	Processed meat	6.8
Bread	7.3	Cereals	4.7	Fish*	5.8	Mixtures (grain)	3.9	Fish*	3.8	Caribou*	3.7	Bannock	5.1
Cheese	6.6	Bannock	3.5	Potatoes	3.7	Fish and shellfish	3.5	Sweetened beverages	3.4	Pasta and Rice	3.3	Sauces and condiments	4.8
Mixtures (meat)	3.4	Beef	3.3	Poultry	3.6	Seal and walrus*	3.5	Mixtures (meat)	3.4	Poultry	3.2	Salt	4.3
Coffee and tea	2.8	Beluga whale*	3.2	Pasta and Rice	3.4	Poultry	3.3	Fish and shellfish	3.3	Eggs	3.0	Poultry	4.1
Eggs	2.6	Mixtures (meat)	3.1	Potato chips	3.3	Pork	3.3	Pasta and Rice	3.1	Fish*	3.0	Vegetables (sauce and soup)	3.8
Fish*	2.1	Sweetened beverages	2.3	Vegetables (solid)	3.1	Mixtures (meat)	2.9	Berries*	2.9	Pork	2.7	Crackers and other	3.5
Inuvialuit Settlement Region (n 267)													
Total (mg)	600	Total (mg)	18	Total (mg)	282	Total (g)	16	Total (mg)	1	Total (mg)	253	Total (mg)	3128
Sweetened beverages	14.4	Caribou*	22.0	Coffee and tea	10.3	Caribou*	24.4	Caribou*	19.3	Mixtures (grain)	29.7	Mixtures (grain)	14.3
Mixtures (grain)	10.5	Bread	11.5	Bread	9.3	Beef	11.7	Bread	7.2	Beluga whale*	21.7	Bread	10.8
Bread	10.2	Cereals	7.5	Fish*	7.9	Beluga whale*	9.2	Mixtures (grain)	6.6	Bread	7.1	Broths and gravy	7.2
Milk	9.8	Mixtures (grain)	6.8	Caribou*	7.7	Fish and shellfish	5.3	Fish and shellfish	5.4	Fish*	5.9	Processed meat	6.4
Cheese	8.6	Birds*	5.5	Mixtures (grain)	5.8	Bread	4.4	Fish*	4.9	Poultry	4.6	Vegetables (sauce and soup)	5.9
Bannock	4.8	Beef	4.7	Cereals	4.8	Pork	4.3	Birds*	4.5	Pork	3.8	Poultry	4.1
Fish*	2.9	Fish*	3.3	Poultry	4.0	Poultry	3.9	Potatoes	4.5	Pasta and Rice	3.7	Mixtures (meat)	3.8
Water	2.8	Beluga whale*	3.1	Potatoes	3.7	Mixtures (grain)	3.9	Sweetened beverages	4.3	Eggs	3.6	Sauces and condiments	3.5
Eggs	2.7	Pasta and Rice	2.8	Pasta and Rice	3.1	Fish*	3.3	Cereals	3.0	Fish and shellfish	2.9	Crackers and other	3.2
Coffee and tea	2.4	Poultry	2.8	Vegetables (solid)	3.1	Birds*	2.5	Pasta and Rice	3.0	Caribou*	2.7	Pork	3.0
Nunatsiavut (n 260)													
Total (mg)	532	Total (mg)	15	Total (mg)	250	Total (g)	12	Total (mg)	1	Total (mg)	117	Total (mg)	2782
Milk	25.3	Caribou*	14.3	Bread	9.6	Caribou*	17.7	Caribou*	12.1	Bread	15.7	Bread	12.4
Bread	11.0	Bread	14.2	Coffee and tea	8.2	Beef	16.4	Potatoes	8.9	Poultry	10.9	Processed meat	9.7
Cheese	7.3	Seal and walrus*	6.6	Potato chips	7.1	Poultry	8.9	Bread	7.6	Fish and shellfish	10.4	Broths and gravy	8.6
Mixtures (grain)	6.8	Cereals	6.1	Potatoes	5.9	Pork	6.3	Potato chips	6.2	Pork	8.6	Mixtures (grain)	8.5
Sweetened beverages	6.1	Birds*	5.8	Milk	5.0	Bread	4.9	Beef	6.1	Pasta and Rice	7.8	Mixtures (meat)	6.1
Vegetables (solid)	3.2	Beef	5.5	Fruit (juice)	4.9	Mixtures (meat)	4.5	Fish and shellfish	5.1	Eggs	7.1	Potato chips	5.6
Fish and shellfish	2.9	Mixtures (grain)	4.6	Caribou*	4.8	Milk	3.8	Birds*	4.5	Mixtures (grain)	5.9	Beef	3.9
Mixtures (meat)	2.8	Poultry	4.3	Fish and shellfish	4.8	Processed meat	3.7	Mixtures (meat)	4.4	Beef	5.8	Vegetables (sauce and soup)	3.9
Fruit (juice)	2.7	Mixtures (meat)	4.2	Poultry	4.7	Mixtures (grain)	3.6	Mixtures (grain)	4.1	Fish*	4.7	Fish and shellfish	3.7
Eggs	2.6	Pasta and Rice	3.0	Mixtures (grain)	3.8	Fish and shellfish	3.1	Poultry	3.9	Processed meat	4.2	Pork	3.5

*Country food items are denoted by apteryx

6.4 Discussion

Market foods, though largely unavailable to Inuit during the first half of the 20th century now constitute over 80% of the total diet (on the basis of energy). As recently as 1987, country foods provided nearly half (43.5% of total diet energy) of the total diet of Inuit men (based on September data from the Qikiqtaaluk region) (Kuhnlein 1995). By contrast, the highest contribution of country food reported in this study, was just over a quarter (27.6%) of total diet energy, based on older Inuit men in Nunavut. The attenuation of country food consumption has come at the expense of diet quality and nutrient adequacy, and bears important implications for the risk of obesity and chronic disease(Kuhnlein et al. 2004). Sweets (including sweetened beverages, sugar added to coffee/tea, pastries, and others desserts) and potato chips, were reported by over ninety percent of participants in the present study, while less than a quarter of participants reported consumption of solid fruit. Collectively, sweets and potato chips represented approximately one quarter of total diet energy (23 – 27%), nearly half of total carbohydrates (42 – 49.8), and the vast majority of total sugar (65 – 79%), while contributing less than of 5-10% of most vitamins and minerals. Despite this change, our results continue to show that country foods, despite their modest contribution to total diet energy, contribute substantively to protein, and many micronutrients, including iron, and vitamins D, B6, B12 and niacin (Kuhnlein & Chan 2000; Kuhnlein & Receveur 1996; Aarluk Consulting Incorporated 2006; Sharma 2010; Hopping et al. 2010; Duhaime et al. 2002). These findings echo long-held local knowledge that country foods contribute importantly to nutritional wellbeing in Inuit communities (Lambden et al. 2007).

Previous research has identified dietary fiber, calcium, folate, and vitamins A, D, and E (and to a lesser extent, vitamin C) as nutrients of issue (i.e. consumed inadequately and/or low intakes) in the contemporary diet of Inuit in Canada (Sharma 2010; Sharma et al. 2010; Erber et al. 2010; Johnson-Down & Egeland 2010; Hopping et al. 2010; Sharma et al. 2013; Kuhnlein et al. 2004; Egeland et al. 2011). Nutrients of issue, namely, dietary fiber and calcium, tend to be those for which country food is not generally considered a major contributor (< 5% of total intake). However, calcium and fiber are understudied in several country foods such as skins/muktuk (fiber) and broths (calcium). Sweetened beverages were the principle source of both calcium (up to 17%) and vitamin C (up to 46%) among Inuit in Nunavut and the ISR. Alternate sources of calcium and vitamin C should be identified, as sweetened beverages were the main source of total sugar across all regions

(31 - 44%), and consumption of high-sugar beverages in this population has been associated with an at-risk BMI (Zienczuk et al. 2012). Furthermore, nutrient intakes from fortified foods may be overestimated if the fortificant is prone to uneven dispersion in the food (e.g. settling of calcium to the bottom of carton in calcium-fortified-beverages (Heaney & Rafferty 2006)). Roughly half of the total calcium intake in the diet of Canadian adults is derived from milk and cheese (Johnson-Down et al. 2006). By contrast, these foods contributed less than twenty percent of total calcium intake in the diet of Inuit adults in Nunavut and the ISR. Country foods are an extremely rich source of calcium. Whereas one cup (250ml) of 2% milk contributes 309 mg of calcium, a 100 g portion of baked whitefish, raw sculpin, raw fireweed leaves, and raw arctic char skin contribute 544, 429, 429, and 268 mg of calcium, respectively (Health Canada 2015). Likewise, there are many vitamin-C rich country foods, including local berries, fish eggs, muktuk, caribou liver and ringed seal liver (Fediuk et al. 2002).

Dietary recommendations based on the promotion of country foods, must however, judiciously evaluate the risks associated with the presence of environmental contaminants (e.g. mercury and persistent organic pollutants) in these foods (Laird et al. 2013). Furthermore, the diets of Indigenous Peoples, including the species/parts consumed, and the modes of preparation (e.g. raw, cooked, fermented, dried) represent an articulation of culture, and identity, that embodies the multigenerational knowledge and experience of humans with local environments (Kuhnlein et al. 2004; Kuhnlein & Receveur 2007). For Inuit, diet selection, health and cultural identity are imbedded in various facets of the food system, including the relationship between animals and humans; the relationship between the body and the soul; and life and health (Borré 1991). While traditional Arctic food systems are comprised of a rich micronutrient base, provided by a diversity of plant species, and animal parts (Kuhnlein et al. 2004), use of country food organs in this study, consistent with previous literature (Kuhnlein et al. 2004), was very infrequent (less than 2% of participants). The decreased use of micronutrient-rich animal parts, coupled with the broader pattern of substituting country foods with micronutrient-poor market foods, poses considerable risks to adequate nutrition in Inuit communities(Kuhnlein et al. 2004)

While dietary variations exist both between, and within, Inuit communities and regions, these results offer a broad perspective on Inuit dietary trends across the Canadian north. Results from this study are very similar to those reported in dietary assessments involving a more restricted community (or multiple-community focus) (Sharma et al. 2013; Hopping et al. 2010; Blanchet & Rochette 2008). For example, our results are very similar to those previously reported by Sharma and colleagues (2010; 2013) for adults in Nunavut, whereby non-nutrient-dense foods contributed 30% of energy, 73% of sugars and 22% of fat, while country foods contributed 56% of protein and 49% of iron (Sharma et al. 2013; Sharma et al. 2010). While local knowledge is requisite to the development of health promotion programs in the North (Bjerregaard 2010), programs and policies aimed at mitigating food insecurity and promoting healthy diets, may operate at broader scales (e.g. Nutrition North Canada retailer food subsidy). Likewise, external food system drivers, such as climate change, may be manifested and modelled by scientists at broader scales (Wesche & Chan 2010). Targeted food security interventions are often implemented at local levels. They are often ad hoc and based on limited available data. Regional-level data is essential for informing the development of broader policies, which are effectuated and administered at this scale.

Although the intent of the present study was not to compare region-level differences in diets, we did observe large variations in the consumption of country food (namely marine mammals), and a few market food items – namely, fluid milk vs. powdered milk and coffee whitener, as well as fruit juice vs. crystal sweetened beverages – between the eastern and western Arctic.

Limitations

The many limitations inherent to the assessment of diet by 24-hour recall must be acknowledged (Shim et al. 2014). Validity of the 24-hour recall is contingent upon the respondents' ability to recall all foods consumed, and accurately estimate portion sizes (Shim et al. 2014). Use of the Automated Multiple Pass Method in the present study is likely to have mitigated response bias, and has been validated in other populations as an accurate measure of energy and nutrients at the group level (Blanton et al. 2006). The exclusion of alcohol and nutrient supplements in the present study may have resulted in an underestimation of total energy and nutrient intakes. Nevertheless, less than 10% of participants of the IHS reported using vitamins and dietary supplements (IHS, unpublished results). This study was based on a single 24-hour recall for each participant. As the 24-hour recall was collected during a single season results of country food consumption reflect species harvest, and availability, during the study period (late summer – fall) and may differ through the year. The importance of recognizing the variability in seasonal food use in Indigenous Peoples' food systems has been previously highlighted (Kuhnlein 1995).

6.5 Conclusion

This study reports on the largest sample and most vast geographic scope of Inuit diet to date. Given their rich nutrient profiles and cultural favorability, country foods should be prioritized within strategies to promote nutrient adequacy among Inuit. Such strategies, however, must take into account the human health risks of contaminant exposure, and respect the ecological limits of harvest sustainability – as determined by both traditional/local knowledge, and, the strongest available science. Furthermore, promoting Inuit health and food security through the consumption of country foods necessitates broader ecological frameworks to support the environment and sensitive habitats of country food species. However, this study also highlights the importance of market foods in the contemporary Inuit food system. Ultimately, policies and programs aimed at fostering dietary adequacy, and food security among Inuit, should be predicated upon community-identified priorities and should affirm Indigenous food sovereignty and self determination.

6.6 Acknowledgements

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6.7 Supplemental Material

Table 6.7S Country food groups aggregated from 93 unique food items/preparations reported in the 24h recall of Inuit adults (n 2095)

Major groups (number of unique items)	Item included
Country food, by part	
Country food – meat (27)	duck; goose; ptarmigan; squab (pigeon);caribou meat (raw, cooked, dried); moose; muskox; polar bear; ringed seal meat (boiled, raw); bearded seal meat (boiled and raw); beluga meat (dried, raw); narwhal meat;
Country food – fat (23)	caribou fat; ringed seal blubber (aged, boiled, raw); bearded seal oil; walrus blubber (aged, boiled, raw); beluga oil; beluga blubber (boiled and raw); beluga muktuk (boiled, raw); narwhal blubber (boiled and raw); narwhal muktuk (boiled and raw)
Country food – organs (15)	caribou bone marrow; caribou heart; caribou liver; caribou stomach; caribou tongue; bear liver; ringed seal blood; ringed seal heart; ringed seal liver; bearded seal intestine (boiled and raw);
Country food, by species	
Birds (14)	duck; goose; ptarmigan; squab (pigeon)
Fish and seafood, country food only (16)	arctic char; cisco; sculpin; whitefish; sea cucumber
Caribou (12)	caribou meat (raw, cooked, dried); caribou fat; caribou bone marrow; caribou heart; caribou liver; caribou stomach; caribou tongue
Other land mammals (8)	bear; moose; muskox; polar bear
Seal and walrus (28)	ringed seal blubber (aged, boiled, raw); ringed seal meat (boiled, raw); ringed seal blood; ringed seal flippers; ringed seal heart; ringed seal liver; bearded seal oil; bearded seal meat (boiled and raw); bearded seal intestine (boiled and raw); walrus blubber (aged, boiled, raw); walrus skin; harp seal
Beluga whale (8)	beluga oil; beluga blubber (boiled and raw); beluga muktuk (boiled, raw); beluga meat (dried, raw)
Narwhal (5)	Narwhal blubber (boiled and raw); narwhal meat; narwhal muktuk (boiled and raw)
Berries (2)	Black crowberry; cloudberry

Table 6.8S Market food groups (n=9) and sub groups (n=41) and items, aggregated from 1591 unique food codes[1] (unique items and preparations) reported in the 24h recall of Inuit adults (n 2095)

Major group (number of unique items)	Sub groups (number of unique items)[2]	Description and item groups[3]
Dairy products (74)		
	milk (11)	fluid milk (all fat contents); evaporated milk (all fat contents)
	coffee whitener and milk powder (5)	milk powder (skim); non-dairy coffee whitener
	cream (8)	
	cheese (27)	natural cheese; processed cheese (slices and spread)
	yoghurt (11)	
Added fat (43)		
	table fats (18)	butter; margarine
	vegetable oil (4)	
	lard and shortening (5)	
	salad dressing and mayonnaise (16)	
Market meat and alternatives (315)		
	poultry (72)	broiler chicken (various parts); turkey; dove; domestic duck
	pork (39)	pork loin; cured pork (bacon, ham)
	beef (51)	ground beef; beef roast; beef steak
	processed meat (35)	canned luncheon meat; sliced cold cuts; frankfurters and sausages
	eggs (9)	all preparations
	fish and shellfish (59)	canned fish; fish fillets; other seafood
	broth and gravy (19)	
	alternatives (28)	nut butter; nuts and seeds; legumes and beans
Fruit (86)		
	fruit (solid) (35)	apple; citrus fruit; banana; other fruit
	fruit (juice) (24)	apple juice; citrus juice; other fruit juice
	canned fruit (20)	
	dried fruit (7)	
Vegetables (167)		
	Solid vegetables (125)	corn; onion; carrots; tomato; lettuce and leafy greens; mushrooms; sweet pepper; celery; broccoli and cauliflower; cucumber; other
	Vegetable sauce and soup (42)	
Cereals, grains, and starches (281)		
	bread (73)	white bread; wheat and grain breads; other bread products (e.g. bagels); quick breads; bread crumbs and other dry bread
	bannock (23)	various recipes/preparations
	crackers and other (48)	crackers; pilot biscuits; other snacks from grain products
	pasta and rice (27)	pasta; rice
	cereals (68)	ready to eat cereals; hot cereals
	potatoes (38)	potatoes (prepared); mashed potatoes, fried potatoes and hash browns;
Sweets and snacks (285)		
	sweetened beverages (48)	sweetened carbonated beverages; powdered fruit drinks; other sweetened beverages
	sugar (3)	

Major group (number of unique items)	Sub groups (number of unique items)[2]	Description and item groups[3]
	sweet toppings and spreads (27)	sweet toppings; jams and preserves
	chocolate and candy (61)	candies (with chocolate); candies (without chocolate)
	pastries (113)	includes cakes, pies, pastries, cookies and granola bars
	sweet dairy products (23)	
	potato chips (10)	
Mixed dishes and other (186)		
	mixtures (grain) (70)	pizza; pasta dishes; macaroni and cheese; soups (mostly noodles)
	mixtures (meat) (73)	sandwich-type (hamburgers, hot dogs); meat sauce; meat soup and stew
	sauces and condiments (37)	ketchup; other condiments
Low-calorie items (49)	low-calorie beverages (26)	water; coffee; tea; diet carbonated beverages;
	low-calorie items (23)	salt and seasoning; spices; low-calorie sweeteners

[1]Alcoholic beverages were excluded from all analyses

[2] Distinct item-level groups are designated by semicolon

[3] Sum of sub group items may not equal total food group items, with the difference attributed to other / ungrouped items

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7 CALORIES ARE CHEAP, NUTRIENTS ARE EXPENSIVE – THE CHALLENGE OF HEALTHY LIVING IN ARCTIC COMMUNITIES

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T.K conceived of the of the research question, designed the study, oversaw the data collection, prepared and analyzed the data, and drafted the manuscript. M.F. provided guidance on the field work and data collection, and provided input on the drafted manuscript. J.M. contributed to the study design, supervised the data collection, and provided input on the drafted manuscript. S.D.W. and L.H.M oversaw all phases of the research, and revised the drafted manuscript.

ABSTRACT

Indigenous Peoples of rural and remote regions of Canada, the United States, and Australia pay the highest food prices in each country. High food prices, low per capita income, and limited access to nutritious perishable foods foster increased reliance on poor quality non-perishable foods. Inuit of northern Canada experience the highest documented prevalence of food insecurity among all Indigenous Peoples in a developed country. The objective of this study is to document the price of food in remote communities in one Arctic region and investigate the economic dimensions of diet quality and nutrition for Inuit. A participatory food costing study was undertaken seasonally in six communities of the western Arctic during a 14-month period (late 2014 to early 2016). Community research assistants systematically collected food prices for a list of 106 market foods. Food prices in the region were markedly higher than the national average. The average cost of the Revised Northern Food Basket (to feed a family of four for one week) was CAD $410, over two times the equivalent cost of feeding a family of four (CAD $192) in Ottawa, the nation's capital. These results provide evidence of price differentials between energy-dense nutrient-poor foods, and costlier nutrient-rich foods in a northern remote setting of Arctic Canada. Evidenced-based policy is required to overcome the unique challenges of food retailing in remote northern environments.

7.1 Introduction

The Nutrition Transition Among Indigenous Peoples

Worldwide, Indigenous Peoples systematically experience disparities in health status relative to national averages (Valeggia & Snodgrass 2015). Health inequities among Indigenous Peoples are associated with various factors and generally embody the pervasive and enduring consequences of colonization, including poverty and poor living conditions (Gracey & King 2009; Adelson 2005). Moreover, these inequities are often associated with the adverse diet and lifestyle consequences of the nutrition transition – the erosion of subsistence-based lifestyles, and the increased representation of foods sourced from industrial and commercial processes in the diet (Albala et al. 2006; Port Lourenco et al. 2008; Kuhnlein et al. 2004; Hughes & Lawrence 2005).

Indigenous Peoples in developed countries, such as Canada, Australia, and the United States often reside in remote and/or rural regions where food prices are high, per capita incomes are low, and availability of nutritious perishable foods is limited. These factors collectively challenge food security and promote higher reliance on a limited diversity of non-perishable, and highly-processed, foods (Kuhnlein & Receveur 1996; Ferguson et al. 2016; Hughes & Lawrence 2005). Indigenous Peoples of Australia, the United States, and Canada pay the highest food prices in each respective country (First Nations Development Institute 2016; Ferguson et al. 2015; Duhaime & Caron 2012). The price of food in community stores of remote Northern Territory (Australia) was on average 60% higher than in capital cities (Ferguson et al. 2015). Similarly, food prices in the Inuit region of Nunavik (northern Quebec, Canada) were on average 81% higher than equivalent food items in Quebec city, the provincial capital (Duhaime & Caron 2012). High food prices may represent a barrier to the adoption of more healthful diets, particularly among low income consumers, and may be partly responsible for the higher prevalence of obesity and nutritional deficiencies documented among people of lower socioeconomic status (Drewnowski et al. 2004; Darmon & Drewnowski 2015; Darmon et al. 2002; Drewnowski & Darmon 2005a).

The Economics of Food Choice and Obesity

It is hypothesized that poverty and obesity are linked through habitual consumption of a low-cost, high energy density diet (Drewnowski 2003). Low-cost foods of high energy density (e.g. foods high in sugar and fat), but low essential nutrient content, are often heavily relied upon by low income and food insecure consumers who resort to low-cost diets to satisfy energy requirements within budgetary constraints (Drewnowski & Specter 2004; Agarwal et al. 2015). Energy dense foods like cereal, grains, pulses, potato chips, and chocolate bars, are typically dry, resist degradation during shipping, have stable shelf lives, and provide considerable dietary energy at low cost (Agarwal et al. 2015; Drewnowski & Darmon 2005b). Therefore, these foods are likely to be favored in remote retailing environments, given the challenging logistics and high cost of shipping food to remote community stores. Conversely, naturally-hydrated / energy-dilute foods (e.g. fruits and vegetables) are generally more susceptible to degradation during shipment, have shorter shelf lives, and are generally more costly (Darmon et al. 2007). The analysis of food price in relation to energy and nutrient density represents an established approach for research into the socioeconomic determinants of diet quality (Darmon et al. 2003; Drewnowski et al. 2015; Drewnowski & Darmon 2005b). However, information on the role of energy density, and energy cost, in the diet of Indigenous Peoples in remote settings is limited (Brimblecombe & O'Dea 2009).

Inuit Food Security in Arctic Canada

Inuit of the Canadian Arctic experience the highest documented prevalence of food insecurity among all Indigenous Peoples in a developed country (Egeland 2011). Over sixty percent (62.6%) of Inuit households in Canada were food insecure in 2007-2008 (Rosol et al. 2011; Egeland 2011; Huet et al. 2012). By contrast, less than eight percent (7.7%) of Canadian households experienced food insecurity during this same period (Health Canada 2012). Food insecurity among Inuit has been associated with disturbed eating patterns, reduced diet quality, and increased susceptibility to chronic and infectious disease (Egeland et al. 2011; Jamieson et al. 2012). Compounding the matter, Inuit face a dual burden of food insecurity and unhealthy body weight, with over 60% of Inuit men and 66% of Inuit women classified as overweight or obese (Zienczuk et al. 2012).

Food security is multifaceted and predicated upon dimensions of availability, access, utilization, quality/safety, and stability (FAO 1996). Among Indigenous Peoples, food security is contingent, furthermore, upon the harvest, consumption, and sharing of locally harvested, culturally-preferred, country foods (Power 2008; Lambden et al. 2007). While conventional metrics of food security (which emphasize economic access to market foods) seldom embody the nuances of the traditional diet of Indigenous Peoples, they provide meaningful insights, into the economic challenges experienced by individuals and households in acquiring a healthful diet. The three principal reasons for food insecurity documented in the 2007-8 Inuit Health Survey (unemployment, low income, and high food costs) (Egeland 2010), collectively represent economic barriers to diet acquisition, whether through the direct purchase of food in stores, or through the acquisition of equipment and supplies for harvesting. Between 40% and 70% of Arctic Indigenous women interviewed in three large cross sectional surveys (1993 to 2000) indicated that they could not afford to purchase sufficient food to meet their family's needs (Lambden et al. 2006).

7.1.1 Food Cost and Food Subsidies in the North

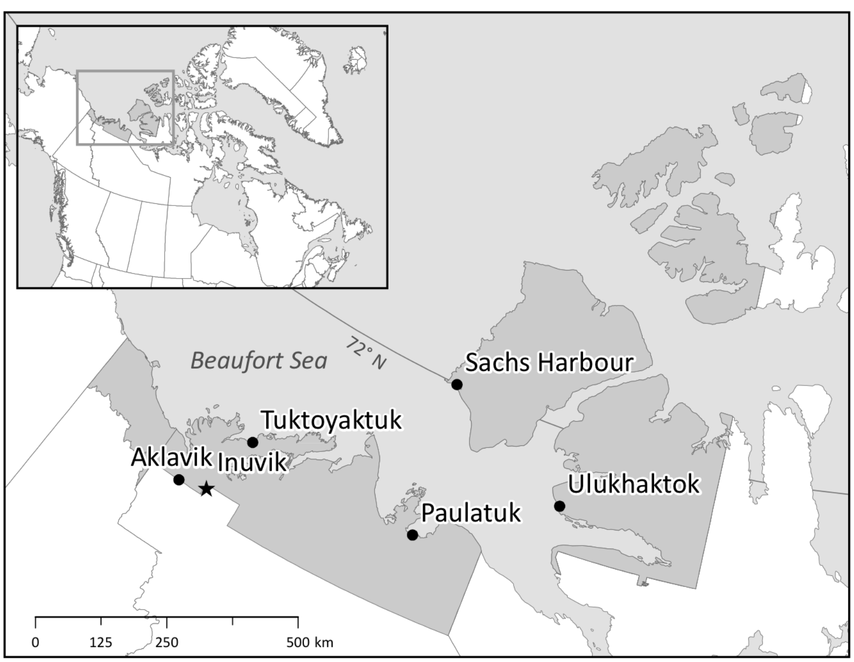
The high cost of food in northern Canada is well documented and, together with poor food quality, is perceived by Inuit as the main barrier to purchasing nutritious market foods (Mead et al. 2010). Inuit spent an estimated CAD $19.70 per person per day on food (CAD $7,217 annually) (2014), roughly three times the amount spent by the average Canadian (CAD $6.44 / day) on food purchased in-store (based on the annual average household expenditure of CAD $5,880, 2.5 persons per household) (Statistics Canada 2016a)). In Canada, northern food subsidy programs have been administered by the federal government since the 1960s (e.g. the federal Food Mail Program, 1999-2011) to promote the availability of and access to nutritious foods in northern remote communities that lack road access. The Nutrition North Canada (NNC, 2011-present) federal subsidy program is currently available in eligible communities to offset the high cost of transporting food to remote northern communities (Government of Canada n.d.). Nevertheless, food prices in remote communities remain "extremely high" (Enrg Research Group 2016) and the program has been critiqued for its administration and reporting structure, as well as its effectiveness in meaningfully promoting access to nutritious foods

(Galloway 2014; Office of the Auditor General of Canada 2014; de Schutter 2012).
The relationship between food price and nutritional value bears important implications for food security and public health policy (Monsivais et al. 2010; Aaron et al. 2013; Jones & Monsivais 2016), however, the economic dimensions of diet and nutrition among Inuit, like other Indigenous Peoples in rural and remote communities, has received limited attention to date. The objective of this study is to report food cost in communities of the Inuvialuit Settlement Region in western Canadian Arctic and to examine the relation between food cost, energy density, and nutrient density. The goal is to provide information for food policy makers to make evidence-based decision

7.2 Study Location and Setting

This study was conducted in the Inuvialuit Settlement Region (ISR) (total population of 5,800), a Land Claim Settlement area located in the western Canadian Arctic, and homeland of the Inuvialuit People (Figure 7.1).

Figure 7.1 Location of the six communities of the Inuvialuit Settlement Region, Northwest Territories Canada. The Nutrition North Canada food subsidy program is available in the five remote communities (excluding Inuvik), lacking year round road access.



The region is comprised of six communities, ranging in population from 132 to 3265 people (Table 7.1). Inuvik, the largest community, serves as the administrative center for the western Canadian Arctic and is road-accessible from Whitehorse (Yukon). Five communities (Aklavik, Paulatuk, Tuktoyaktuk, Sachs Harbour, Ulukhaktok) lack year-round road-access and are serviced by air transport. Residents of the region are primarily Inuvialuit (Indigenous Arctic People), particularly in the smaller communities, where 80 – 96% of the population is Indigenous (Table 7.1). The Inuit Health Survey (2008) documented that nearly half of households in the region experienced food insecurity, with 13% reporting severe food insecurity (Egeland 2010). The average family income in the region ranged from CAD $58,958 in Ulukhaktok to CAD $112,044 in Inuvik. The majority of individuals in the region reported consuming half or more of their meat as country food, with the exception of Inuvik (22.5%) (Table 7.1).

Each community of the ISR has one or two grocery stores that are either private corporations or co-operatives (Enrg Research Group 2016). Options for out-of-home consumption are limited, or unavailable, depending on the community (Table 7.1). Stores in the five remote communities obtain food year-round through air shipment, and seasonally by ice road (Aklavik and Tuktoyaktuk, in winter) and barge (once per year, during ice melt). Inuvik is serviced year-round via the Dempster Highway, except during brief freezing and thawing periods. The Nutrition North Canada retail subsidy program is available in all communities of the ISR, excluding Inuvik.

Table 7.1 Demographic, socioeconomic, and food retailing information* for the six communities of the Inuvialuit Settlement Region, Northwest Territories

Community characteristics	Aklavik	Inuvik	Paulatuk	Sachs Harbour	Tuktoyaktuk	Ulukhaktok
Location (latitude)	68.23	68.33	69.33	72.03	69.45	70.78
Demographic and socioeconomic information+						
Total population (2015)	668	3,265	321	132	965	415
% Indigenous	94	69	93	80	89	96
% High school diploma or more (2014)	48.2	67.9	37.5	61.1	43.4	42.0
% Unemployment (2014)	28.6	9.0	31.4	10.1	32.3	12.0
% Lone-parent families (2011)	29.0	25.7	18.8	28.6	26.8	36.4
% Households owned (2014)	32.2	35.0	20.4	33.2	30.2	21.2
Personal and family income (2013)+						
Average family income (CAD $)	66, 625	112, 044	67, 000	-	68, 500	58, 958
% Families < CAD $30,000	31.3	20.9	37.5	-	27.3	33.3
Average personal income (CAD $)	31, 573	55, 229	31, 605	-	32, 078	29, 357
% Tax filers < CAD $15,000	41.5	25.0	42.1	-	36.2	46.4
Retail Food Environment						
Nutrition North Canada subsidy	yes	no	yes	yes	yes	yes
Number of food retail stores	2	2	1	1	2	2
Other food venues[1]	one	several	one	none	one	two
Cost of the Revised Northern Food Basket[2]	420.61	ND	436.04	ND	407.86	446.95
Food Price Index[3] (YK = 100) (2012)+	174.0	149.0	198.0	189.0	168.0	195.0
Living Cost Differential[5]4 (Edmonton = 100) (2013)+	162.5	147.5	177.5	177.5	162.5	177.5
Country food+						
% Hunted & fished[5] (2014)+	59.8	44.9	71.7	68.7	66.0	80.4
% Households consuming country food (half or more)[6] (2014)+	71.6	22.5	74.5	61.2	61.1	56.4

*Data source: +NWT Statistics Bureau Community Profiles (2015).

1 Availability of canteens/restaurants or convenience stores in the community

2 Cost of the revised Northern Food basket as reported by NNC in March 2015(Government of Canada & of 2016). Food prices were
reported by retailers. The RNFB is not monitored in Inuvik, as it is not included within the Nutrition North subsidy program. Information on the cost of the RNFB for the community of Sachs Harbour was not available from NNC.

3 Food Price Index is the cost of a fixed basket of goods and services purchased by consumers. The index is used as an indicator of changes in consumer prices experienced by Canadians. Values are expressed relative to Yellowknife, NT (=100)

4 Living Cost Differential = the relationship between the prices for a specific range of goods and services in the communities of the ISR, relative to the price of the same range of products in a comparison city (i.e. Edmonton). The price level in Edmonton is expressed as 100, as such, a value of 150, signifies that prices are 50 % relative to Edmonton

5 Refers to the percent of Peoples 15 years of age or older that hunted or fished during the year

6 Refers to the percent of households reporting that half or more of the meat or fish consumed is from harvesting

7.3 Research Methods

This project was developed in consultation with the ISR Food Security Working Group (ISR FSWG). This group (active between 2014-2015) was initiated following a strategic planning process to promote food security and food safety in the region (Fillion et al. 2014). ISR FSWG members recommended that the following research priorities and methodological considerations be included in the design of the food costing study: (i) that food items included in the study reflect the food that Inuvialuit actually consume; (ii) that quality and freshness (e.g. spoiled or past date products) be documented, in addition to cost; (iii) that the importance of country food (i.e. local subsistence foods) to the Inuvialuit diet be recognized

– including the possibility of comparing the cost of purchasing market foods and harvesting country food; and (iv) that the study build on previous food and nutrition research conducted in the region (e.g. the Inuit Health Survey). The Aurora Research Institute (Inuvik, NT) granted research licenses (No. 15446; No. 15676) for both this research and the broader food security project.

7.3.1 Participatory Food Costing Study

A participatory food costing study was undertaken seasonally in communities of the ISR during a 14-month period, between late 2014 and early 2016. Study methodology was developed by adapting an existing participatory food costing model developed for Nova Scotia, Canada (Williams et al. 2012; Atlantic Health Promotion Research Centre et al. 2007). The participatory methodology was favoured given the potential to enhance research skills of community members and, over the long term, foster capacity for communities to initiate and implement their own food security research (Government of Canada et al. 2014). A research assistant was employed in each community, selected on the basis of previous experience with community health and nutrition programs, to collect in-store food prices. A member of the research team, together with the IRC regional dietitian (Registered Dietitian), provided community-level training for each research assistant in 2014.

Following the research scope defined by the ISR FSWG, the list of food and beverages included in the costing study was derived from multiple sources: (i) the Revised Northern Food Basket (RNFB) (Minister of Public Works and Government Services Canada 2007), (ii) dietary recalls from the Inuit Health Survey (Saudny et al. 2012), (iii) feedback from community research assistants, and (iv) input from the IRC regional dietitian. The RNFB is a tool used to monitor trends in the cost of healthy eating in isolated northern communities that are eligible for NNC subsidies (Minister of Public Works and Government Services Canada 2007). The RNFB is an example of a nutritious diet (i.e. meets most nutrient requirements and food serving recommendations for Canadians) for a family of four for one week, and includes 67 food items available in remote northern communities. The RNFB, however, does not include prepared/convenience foods or foods of little nutritional value. Furthermore, the basket is not intended to be representative of actual food consumption habits or expenditure in the concerned population (Minister of Public Works and

Government Services Canada 2007). Here, the initial list of foods from the RNFB was supplemented with foods and beverages reported by the 24h recall of the Inuit Health Survey (IHS) in the ISR (Saudny et al. 2012). As described comprehensively elsewhere in Chapter 6, unique market food items (food and beverages, including various preparations) in each recall were aggregated into food groups (n = 9) and subgroups (41) according to nutritional and culinary similarity. For each of the unique subgroups, a single representative item was selected for the food costing study. Low calorie items (i.e. coffee and tea, low-calorie sweeteners) and alcoholic beverages were excluded from the study. A final list of the 106 market foods is shown in the supplemental material.

Food costing worksheets were developed to facilitate in-store data collection. For each item, preferred and alternate purchase volumes were listed to reflect typical product sizes and to avoid the pricing of bulk product volumes. In the absence of northern consumer data, preferred purchase volumes were selected based on existing Indigenous dietary studies in Canada (First Nations Food Nutrition and Environment Survey; FNFNES) and adapted (where necessary) to reflect product availability in stores of the western Arctic. When a product was not available in the preferred purchase volume, the item was priced in the first available alternate purchase volume as listed on the costing worksheets. The brand names, sales, and coupon rebates were not considered in this study. The lowest regular priced item corresponding to the preferred purchase volume was recorded for each item. The price and volume/weight for each item was recorded on the worksheet. In addition to food cost, research assistants documented the quality of food based on date, damage, or deterioration, and, furthermore, recorded prices for commercially-available country foods (e.g. arctic char) and hunting equipment (e.g. gasoline, heating fuel, snowmobile oil). Items not available during the in-store costing were marked as unavailable. Reporting on the cost of the harvest items was beyond the scope of this chapter.

Merging Food Price and Nutrient Composition Data

To synchronize price data with Canadian nutrient composition data (Health Canada 2015), prices per unit weight (CAD $/100 g) were calculated for all items costed. To this end, food prices recorded on a volumetric basis (e.g. 750ml can) were converted to prices per weight (100g) using standard density tables (Health Canada 2015; Charrondiere et al. 2014). Food prices recorded on an "item" basis (e.g. price per melon) were assigned "medium" reference weights (Health Canada 2015). Food prices “as purchased” were converted to prices per “edible” weight by correcting for inedible portions and refuse (Health Canada 2015). For items that would not typically be consumed in purchased form (e.g. dry pasta, raw potatoes, dry sugar crystal drinks), food prices were converted to prices per weight “as consumed” by adjusting for preparation (hydration and cooking). Preparation yields were derived from the USDA Food Yield Handbook (Matthews et al. 1975). Finally, food prices per edible weight were matched with equivalent items the Canadian Nutrient File (Health Canada 2015). Missing nutrient values in the CNF were imputed following the methodology elaborated by Schakel and colleagues (1997) with nutrient values from the USDA Food and Nutrient Database for Dietary Studies (FNDDS) (Montville et al. 2013).

Energy Density, Energy Cost and Nutrient Density

Energy density (i.e. energy (kcal) per weight (100g) of edible portion) and energy cost (i.e. the cost of food per unit of energy (CAD $ / 100 kcal)) was calculated for each item. A composite nutrient value for each item was computed based on the previously validated Nutrient Rich Food Index (NRF) (Drewnowski 2010; Fulgoni et al. 2009). The NRF 9.3 is an aggregated metric based on nine “qualifying nutrients” to encourage (protein, dietary fiber, calcium, iron, magnesium, potassium, Vitamin A, C, and E) and three “disqualifying nutrients” to limit (saturated fat, total sugar, and sodium) in the diet (Supplemental Material – Table 7.2). The NRF 9.3 was selected as it prioritized several nutrients previously identified as shortfall nutrients in the contemporary Inuit diet (namely: dietary fiber, calcium, folate, and vitamins A, C, D, and E) (Kuhnlein et al. 2004; Egeland et al. 2011; Sharma 2010; Sharma et al. 2010; Erber, Hopping, et al. 2010). The nutrient profile for each food represented the ratio between the amount of a nutrient contributed by a 100 kcal portion of the food relative to the Dietary Reference Intake (DRI) value (Health Canada 2010). DRIs were based on the Recommended Canadian Dietary Allowance (RD) and Adequate Intake (AI) (Health Canada 2010) and weighted according to the age and sex distribution of the adult population in the ISR to generate a single adult population DRI for a 2000kcal diet. Calculations for each nutrient were truncated at 100% of the DRI (Drewnowski 2005). The score for disqualifying nutrients was based on maximum recommended values for saturated fat (20g), total sugar (125g), and sodium (2300 mg) based on a 2000kcal diet (Maillot et al. 2007). Scores for both qualifying and disqualifying nutrients were each calculated for 100 kcal of food. The final nutrient profile score was computed by subtracting the disqualifying nutrient sub score from the positive nutrient sub score.

7.3.2 Analyses

Management of data and statistical analyses were performed with SAS statistical software (version 9.4; SAS Institute, Cary, NC). Mean (standard deviation, SD) regional food prices were computed based on community-average values (averaged during the entire study to). The cost of the RNFB (family of four, for one week) was estimated using the average regional cost and weight/volume, of 67 food items comprising the basket (Supplemental Material – Table 7.3), as detailed elsewhere (Minister of Public Works and Government Services Canada 2007). Similarly, the average daily cost of satisfying serving recommendations stipulated by Canada's Food Guide - First Nations, Inuit and Métis (Government of Canada & Inuit Health Branch 2007) was estimated for adult females and males in the region (based on regionally-averaged data). The relation between energy cost (CAD $ /100kcal), energy density (kcal/100g), and nutrient density (NRF 9.3 score) was examined using scatter plots. Regression analyses were used to examine the relationship between nutrient content (nutrient per 100g) and price (CAD $ / 100g). Nutrient values were adjusted for energy following the Willet multivariate model (Willett et al. 1997). Nutrient-by-nutrient analyses were conducted on those foods where the amount of the nutrient was >0. A level of $\alpha = 0.05$ was used to determine statistical significance.

7.4 Results and Discussion

7.4.1 Cost of Food in the Arctic

Mean (SD) regional food prices in the ISR are contrasted with national average food prices collected by Statistics Canada during the study period (October 2014 -16) (Statistics Canada 2016b) in Table 7.2. Food prices in the ISR were markedly higher than national average retail prices for both perishable and non-perishable products. For instance, the price of fresh produce was between 41% (apples) and 121% (celery) higher in the ISR compared to the national average. The average price of the most frequently reported market foods, based on the 24-hour recall of the IHS (i.e. milk, butter, bread, pasta, potatoes, and cola), were 78% higher in the ISR relative to the national average. The highest price differential documented in the study was for carbonated beverages (cola), which were 140.3% higher in the ISR than the average across Canada (Table 7.2).

Based on the average regional food prices collected during this study, the cost of the RNFB in the ISR was CAD $ 410 per week (Figure 7.2), corresponding to an average annual cost of approximately CAD $ 21,379 for a family of four. By contrast, the average weekly cost to feed the same sized family in the nation's capital (Ottawa, Ontario) was approximately CAD $ 192, or CAD $9, 993 per year in 2015 (Ottawa Public Health 2015). Moreover, it is noteworthy that familial income in remote ISR communities is often considerably lower than elsewhere in the country (median total family income in Canada was CAD $ 78,870 (Statistics Canada 2016c)). In contrast, the total income of more than one third of families (38%) in the hamlet of Paulatuk was less than CAD $ 30,000 (Table 7.1). Moreover, the average household in the ISR spent CAD $ 17,652 annually on shelter (CAD $ 1,471 per month), including rent or mortgage, electricity, heating fuel, gas, water and sewage, and garbage) (Egeland 2010).

Table 7.2 Comparison of food price in the Inuvialuit Settlement Region[1] western Canadian Arctic and average national prices[2]

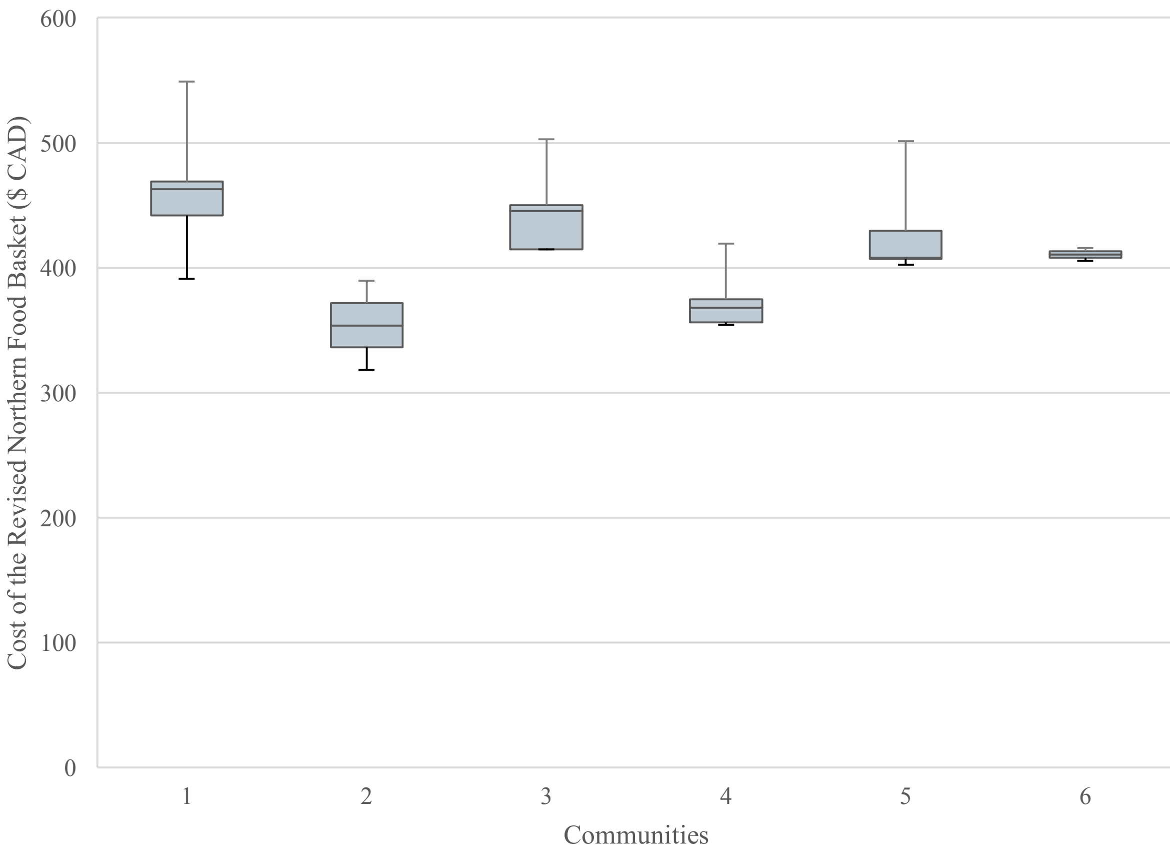
Item Description[1,3]	Price in the ISR[1] (CAD $ / kg)		Mean Price in Canada[2] (CAD $ / kg)	Difference between ISR and national prices	
	Mean	SD	Mean	% Higher in ISR	Percentage difference
Dairy					
Milk, partly skimmed*	3.2	0.9	2.25	40.9	34.0
Cheese, processed slices	19.7	6.1	11.61	69.9	51.8
Evaporated milk (canned), 2%	8.5	1.2	4.48	88.8	61.5
Added fat					
Butter*	14.5	2.0	10.20	42.0	34.7
Vegetable oil (not olive)	10.6	2.9	4.40	141.8	83.0
Meat and alternatives					
Eggs	6.7	0.8	5.08	32.7	28.1
Chicken legs (i.e. drumsticks)	10.7	3.2	7.61	40.1	33.4
Chicken breast	17.1	2.4	7.61	124.7	76.8
Pork chops	23.8	12.0	12.87	84.6	59.4
Ground beef	15.4	4.7	12.44	23.7	21.2
Beef round roast, inside (top)	28.4	8.1	15.90	78.4	56.3
Beef steak, inside round	39.7	14.1	18.30	117.1	73.9
Wieners (beef and pork)	16.5	3.9	9.56	72.8	53.4
Bacon	25.8	6.3	13.53	90.7	62.4
Pink salmon, canned	20.3	6.5	21.02	-7.2	-3.3
Peanut butter	13.7	1.5	7.05	94.7	64.3
Baked beans, canned	8.3	2.9	3.20	158.9	88.6
Bread and grains					
Bread*	6.5	1.4	4.28	51.3	40.8
Cracker	14.4	3.0	6.47	123.2	76.2
Flour	4.5	0.8	1.92	134.6	80.4
Pasta – macaroni*	8.3	2.2	2.98	178.5	94.3
Cereal, corn flakes	14.5	4.3	7.21	101.7	67.4
Fruits and vegetables					
Apples	6.1	1.2	4.01	52.1	41.4
Oranges	5.6	1.7	3.35	67.0	50.2
Bananas	5.0	1.3	1.65	202.0	100.5
Carrots	5.1	1.7	1.73	192.5	98.1
Celery	8.7	4.0	2.15	302.9	120.5
Mushroom	17.0	6.5	8.55	98.5	66.0
Potatoes*	4.5	1.8	1.27	256.0	112.3
Onions	4.3	1.4	1.84	134.8	80.5
Canned whole tomatoes	7.2	3.2	1.95	266.9	114.3
Juice and sweetened beverages					
Apple juice, canned or bottled, added vitamin C	5.0	1.5	1.45	243.2	109.7
Orange juice, chilled, added vitamin C	5.3	1.6	3.77	39.9	33.2
Cola, carbonated beverage*	5.4	2.0	0.94	469.7	140.3
Other					
Soup, chicken noodle (Canned)	17.2	10.7	3.50	390.7	132.3
Frozen French fries	7.1	3.0	2.67	164.8	90.4
Tomato, ketchup	10.4	3.5	3.34	210.4	102.5
Sugar, white, granulated	5.5	2.3	1.38	296.5	119.4

[1] Mean regional food prices in the Inuvialuit Settlement Region based on community-averaged prices during the study period (2014-16) – only items for which national comparative data was available is presented in the table

[2] Mean national retail food prices – average national values for October 2014-16 (Statistics Canada 2016b)

[3] Items with apteryx denote a top ten food item by respondents of the 2007-8 Inuit Health Survey (% consumers recalls in the 24-hour dietary recall)

Figure 7.2 Cost of the Revised Northern Food Basket[1] in communities[2] of the Inuvialuit Settlement Region, western Canadian Arctic during the study period (n = 4 time points)[3]



[1] The RNFB is a tool used by the federal government to monitor the cost of a healthy food basket in northern Canada, for a family of four (2 adults, 2 children) for 1 week. The list and weight/volume of the 67 items that comprise the RNFB is included in the supplemental material.

[2] Community names have been anonymized to maintain retailer confidentiality

[3] Due to logistical constraints, food prices in community six, were only collected during 2 seasons only

Despite differing food costing methodologies (participatory food costing approach versus data documented by registered retailers), the values we have reported for the RNFB (Figure 7.2) are similar to those reported by Nutrition North Canada (Table 7.1) during the same study period. It is important to highlight that these values represent the cost of an idealized food basket, and do not reflect actual expenditure in the concerned population. The average cost for the RNFB in this study was higher than average household food expenditure estimated by ISR participants in the 2008 Inuit Health Survey (CAD $ 303 per week; CAD $1,317 per month) (Egeland 2010). To our knowledge, data regarding household food expenditure in the western Canadian Arctic has not been monitored through point of sale data or till receipts (Brimblecombe et al. 2012).

7.4.2 Cost of Attaining Health Canada's Food Guidelines

The average daily cost of adhering to national food serving recommendations in Health Canada's Food Guide - First Nations, Inuit and Métis for adult females and males in the ISR was CAD $12.41 and CAD $15.24, respectively, based on average food group prices for items included in this study (CAD $ 4 530 and CAD $ 5 563, annually) (Table 7.3). Approximately 40% of individuals residing in the five remote ISR communities (i.e. excluding Inuvik) earned an annual income inferior to CAD $ 15 000 (Table 7.1). Among these individuals, the cost of meeting food guidelines represents at least 30% of annual income. Economic barriers to meeting federally promoted dietary recommendations raises significant concern regarding the equitable access to health for Inuit. The majority of the total cost of adhering to the food guideline was attributed to satisfying requirements for fruit and vegetables, as well as meat and alternatives, highlighting the pivotal role occupied by country food in the affordability of healthful diets in the region. The mean ± SD price per serving of meat and alternatives (1.69 ± 0.84 CAD $ /serving) was higher than the mean price of all other food groups (Table 7.3). The mean price for a serving of fruit (1.12 ± 0.54 CAD $) was higher than for vegetables (0.68 ± 0.34). Prices for grains (CAD $ 0.34 ± 0.16) were significantly lower than for meat, fruit and vegetables.

Table 7.3 Eating Well with Canada's Food Guide Servings for Adults

Food Group	Food Guide Number of servings per day[1]		Price per serving (CAD $)	Estimated average cost to meet guideline[2] (CAD $ /person/day)		Estimated daily expenditure [3] (CAD $ /person/day)	
	Women	Men	Mean ± SD	Women	Men	Women	Men
Fruit and vegetables	7-8	8-10	0.78 ± 0.45	4.71	5.65	2.03 ± 3.14	1.65 ± 2.52
Fruit	-	-	1.12 ± 0.54			1.27 ± 2.62	0.68 ± 2.01
Vegetable	-	-	0.68 ± 0.34			0.76 ± 1.41	0.97 ± 1.56
Grain products	6-7	7-8	0.34 ± 0.16	1.59	1.84	1.52 ± 1.60	1.51 ± 1.50
Milk and alternatives	2-3	2-3	1.21 ± 0.63	2.81	2.81	0.61 ± 1.07	0.46 ± 0.87
Meat and alternatives	2	3	1.69 ± 0.84	3.29	4.94	3.96 ± 4.29	5.68 ± 5.45
Meat	-	-	1.86 ± 0.77			3.71 ± 4.28	5.34 ± 5.25
Added fat	-	-				0.17 ± 0.24	0.22 ± 0.32
Mixed dishes	-	-				1.39 ± 2.65	0.94 ± 2.04
Sweets and snacks	-	-				3.07 ± 3.89	3.67 ± 4.57
Total	-	-		12.41	15.24	13.44 ± 8.04	15.01 ± 8.14

[1] Eating Well with Canada's Food Guide – Servings. No Serving amounts specified for fats.
[2] Estimated total cost to meet guideline recommendations by food group, and total. Values based on average price per serving as documented in the ISR participatory food costing
[3] Estimated average (population =consumers + non-consumers) expenditure by food group based on dietary responses of the 2008 Inuit Health Survey, and food prices documented in the present food costing study

7.4.3 Food Cost and Energy Density

The scatter plot of the relation between energy density of foods (kcal/100 g) and energy cost (CAD $ /100 kcal) shows that energy-dense foods tend to be associated with lower cost (Figure 7.3). Added fats, sugar, and grains and starches were associated with higher energy density and lower energy costs. Conversely, fruits and vegetables, which also have a low energy density, were associated with higher energy costs relative to other foods. We observed a price differential, at times several orders of magnitude higher (10 to 1000 times), for energy-dilute foods relative to energy-dense foods (Figure 7.3), consistent with the international weight of evidence relating energy density to food cost (Darmon & Maillot 2010). Energy dense foods generally have a lower energy cost (i.e. more energy per unit cost) and have a stable shelf life, while foods with lower energy density, like fruits and vegetables, are perishable (Agarwal et al. 2015). Given the logistical challenges of transporting food long distances to remote northern communities, the energy-dense foods with stable shelf lives are often favoured in northern retailing environments. As food energy density plays an important role in the regulation of energy intake, diet quality, and weight status (Ledikwe et al. 2006; Cuco et al. 2001), the economic conditions favouring the ubiquity and economic accessibility of energy dense foods in northern retailing environments should be addressed

Figure 7.3 Energy cost (CAD $ /100kcal) in relation to energy density (kcal/100g). The size of the bubble reflects the % of respondents in the ISR who reported consuming the item in the previous 24 hours (2008, Inuit Health Survey). Note logarithmic scale.

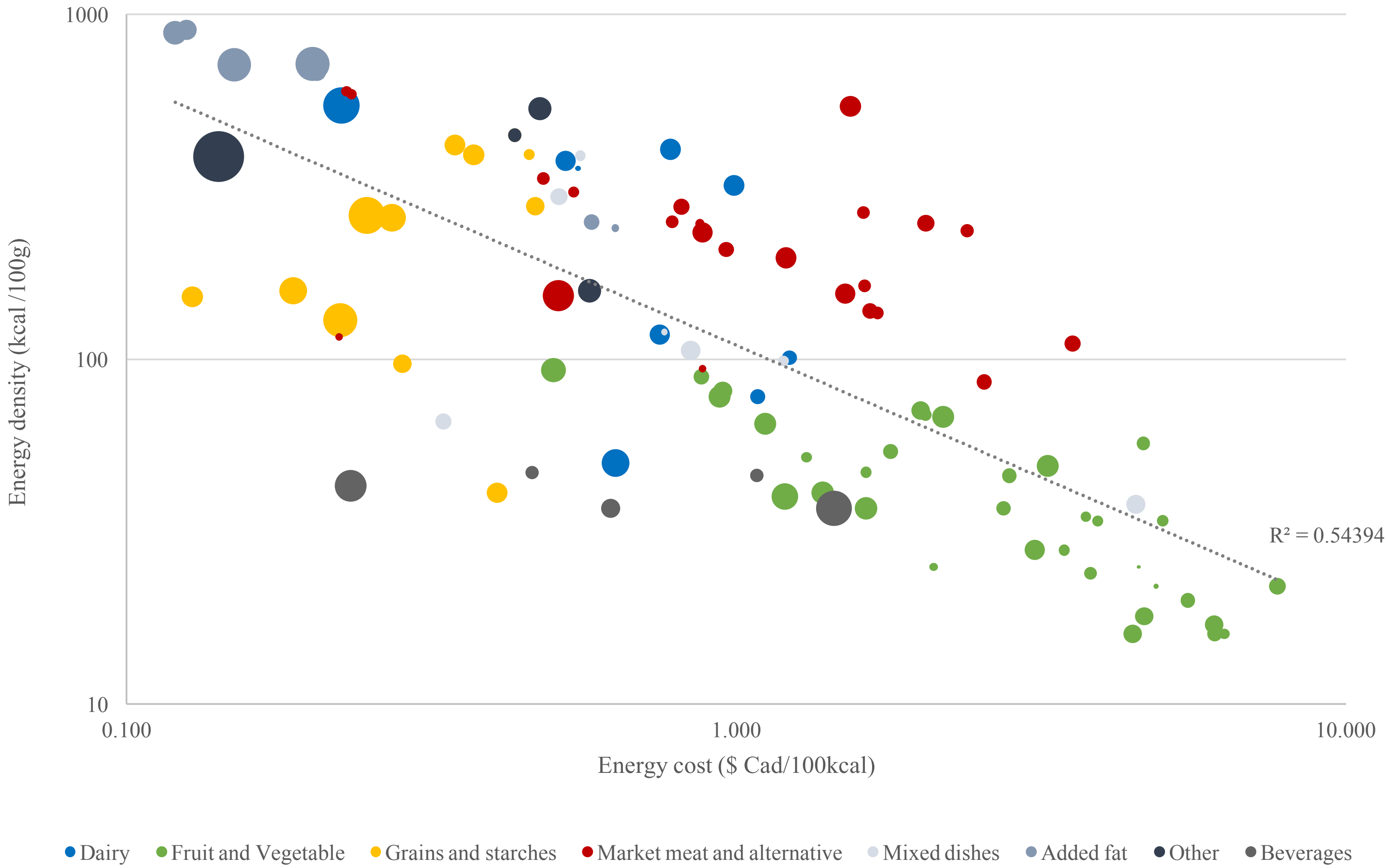
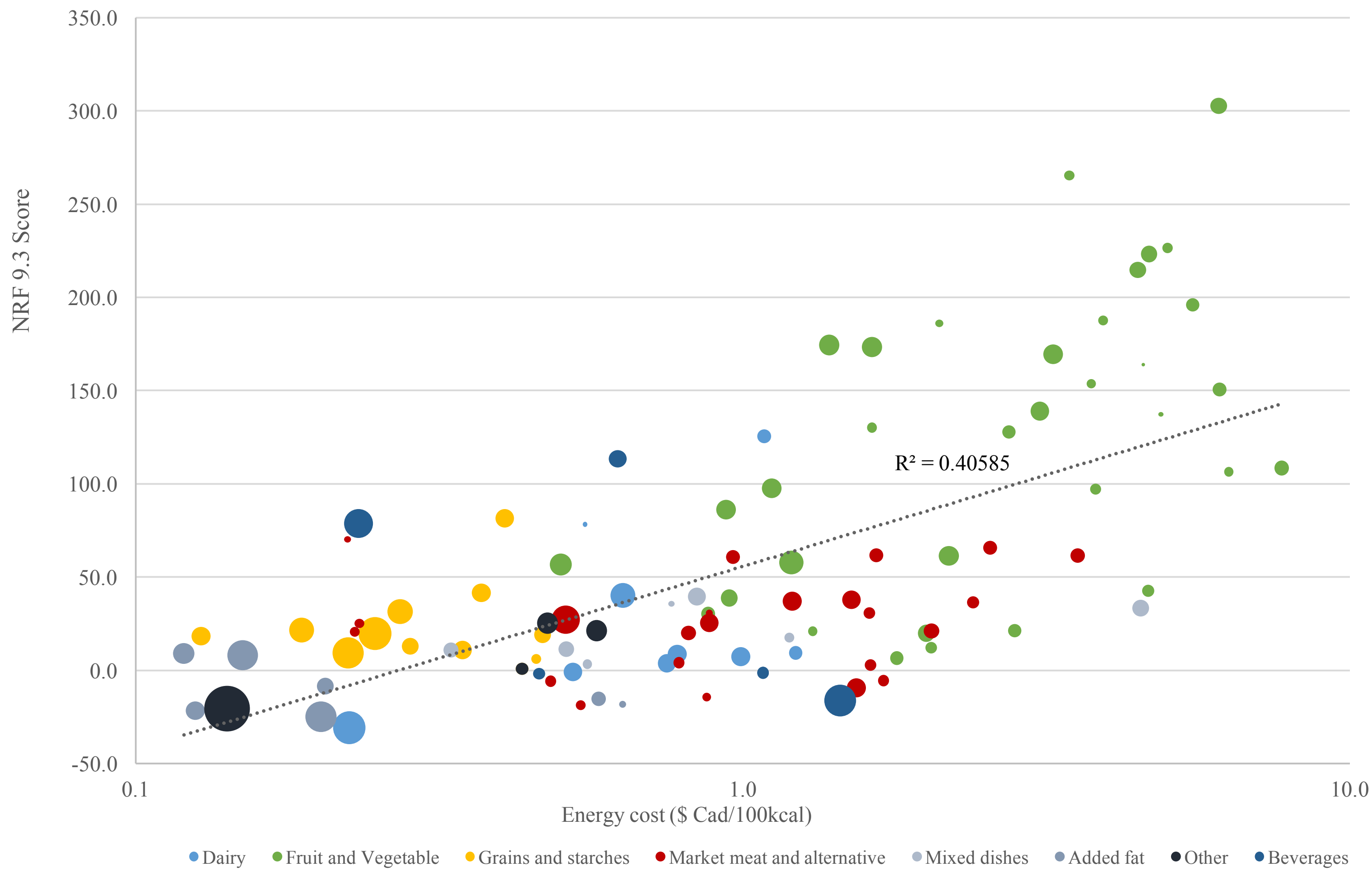


Figure 7.4 Nutrient density in relation on energy cost (CAD $ / 100kcal). Nutrient Density was based on the NRF9.3 Index (the sum of the DV for protein, dietary fiber, vitamin A, vitamin C, vitamin E, calcium, magnesium, iron, and potassium minus the DV of saturated fat, added sugars, and sodium). Daily values were computed for the adult population in the ISR based on Health Canada Daily Recommended Intake Tables (DRI). Note logarithmic scale on x-axis



7.4.4 Food Cost and Nutrients

Consistent with existent literature (Agarwal et al. 2015), nutrient density of foods priced in the ISR was positively correlated with food cost (CAD $/100kcal), such that foods of higher nutritional quality (i.e. higher Nutrient Rich 9.3 index score) were often several orders of magnitude more expensive than nutrient-poor foods. Figure 7.4 shows the positive relationship between the nutrient density of foods based on the NRF 9.3 index (Fulgoni et al. 2009) and their energy cost (CAD $ /100 kcal). Fruit and vegetables (including fresh, frozen, and canned), although associated with a higher cost, were also more nutrient dense than all other food groups (NRF 9.3 score > 50 for most items). Grains and starches were associated with lower energy costs, but were also considerably less nutrient dense (< 50 for most items). Added fat and other (sugar) were associated with negative nutrient density scores, or close to zero, suggesting the food items provision minimal nutrient benefits while contributing to disqualifying nutrients (i.e. saturated fat, sugar and sodium). The Nutrient Rich Food Index (NRF) used in the present study is a validated indicator when calculating nutrients per calorie and nutrients per unit cost (Drewnowski 2009). Nutrient profiles were based on 100 kcal, as this best reflected the ratio of nutrients to calories; however, the use of a 100 kcal base tends to favour very low-energy density foods (e.g. salad greens and cabbage) (Drewnowski 2009). Total carbohydrates and folate were each negatively associated ($p < 0.01$) with food costs (CAD $ /100g), after adjustment for energy in multivariate regression analysis (Table 7.4). Conversely, protein was highly positively associated with food cost ($P < 0.0001$). Likewise, potassium, zinc, selenium, phosphorous, niacin, and sodium were all positively associated with food cost per 100g, after adjustment for energy (Table 7.3). The effect of fortified foods, which provision high nutrient content at low cost (e.g. iron in breakfast cereals), may have confounded the relationship between micronutrient content and food cost. Although fortified foods occupy an important public health role in promoting economic access to several micronutrients, nutrient bioavailability must be considered (Rafferty et al. 2007). The price differential between high energy density non-perishable foods (e.g. as added sugar and potato chips), and energy-dilute perishable foods (e.g. fresh fruits and vegetables), may represent a mediating factor in the dietary transition from country foods towards processed, low nutrient dense foods in the contemporary Inuit diet. Although vegetables and fruits are a relatively costly source of dietary energy, they represent very good value when it comes to vitamins, minerals, and other key nutrients (Darmon et al. 2005). Although trans fats and added sugar are of significant public health interest, limited data for these nutrients in Canadian food composition tables precluded the possibility of including them within the analysis.

Table 7.4 Regression between food price (CAD $ per 100g) as a dependent variable, and nutrient content and calories as independent variables

		Regression Results		
Nutrient[1]	n	Standardized β	t	P value[2]
Total fat	98	-0.19322	-0.88	0.3787
Total carbohydrate	92	-0.28077	-2.79	**0.0064**
Total sugar	85	-0.10426	-1.03	0.3065
Protein	100	0.70472	9.05	**<0.0001**
Calcium	103	0.08398	0.88	0.3807
Iron	99	-0.05800	-0.58	0.5622
Potassium	103	0.20522	2.18	**0.0314**
Magnesium	101	-0.05418	-0.53	0.5998
Vitamin C	62	0.01605	0.13	0.8975
Vitamin E	86	-0.20532	-1.62	0.1089
Vitamin A (RAE)	68	-0.20461	-1.79	0.0779
Zinc	95	0.52781	6.08	**<0.0001**
Selenium	100	0.46951	5.41	**<0.0001**
Copper	60	-0.26263	-1.93	0.0584
B12	76	0.30407	2.96	**0.0041**
Phosphorous	102	0.41049	4.20	**<0.0001**
Niacin	98	0.60811	6.52	**<0.0001**
Folate	95	-0.30603	-3.22	**0.0018**
Sodium	101	0.39433	3.82	**0.0002**

[1]Nutrient values were adjusted for energy according to the Willet (1997) residual (energy-adjusted) model

[2] Statistical significance demonstrated by bold font.

7.5 Promoting Food Security and Nutrition in Northern Canada

Policy strategies to support healthful diets and prevent obesity generally include increasing the availability of and access to healthier food and beverage choices and/or restricting the availability/access of less healthy foods and beverages (Calancie et al. 2015). The evidence base to inform nutrition-related policy in rural and remote settings is currently largely constructed from experiences in urban and suburban settings (Calancie et al. 2015). Various interventions to increase availability of healthful foods, and promote consumption at the point of purchase, have been employed in Indigenous communities (Gittelsohn et al. 2013; Kolahdooz et al. 2014). While these programs have been associated with improved health behavior (Gittelsohn et al. 2013), they have generally been implemented as pilot-studies, and long-term program continuity remains a significant challenge.

7.5.1 Lowering Food Cost in Northern Communities

Tens of millions of dollars are expended annually by the federal government to subsidize Northern food retailers (CAD $ 68.2 million in the 2016 federal budget (Government of Canada 2016). However, it remains unclear how effective such programs are at promoting healthful diets (Canadian Council of Academies 2014). The federal Food Mail Program (1999-2011), predecessor to NNC, provided a subsidized rate on the shipment of food to remote northern communities. While the program was successful in lowering the cost of nutritious perishable foods (between 15 - 20% of their non-subsidized prices) (Stanton 2011), the contribution of convenience and low nutrient dense foods in the diet of northern Indigenous Peoples has nonetheless continued to increase over time (Canadian Council of Academies 2014).

Simulation models can be used as complementary tools to establish the evidence base for policies on food subsidies (Shemilt et al. 2015). To our knowledge, however, there has been no published empirical or modelling research to evaluate the cost-effectiveness, or the dietary / health impacts of fiscal strategies in northern Canada. Modelling results in Australian Aboriginal communities indicate that fiscal strategies to support healthful diets represent good 'value-for-money'; however, the health benefits of modelled food subsidies are modest (<250 DALYs saved) (Magnus et al. 2016). Information on price elasticity (i.e. the responsiveness of consumer demand for good in relation to changes in prices and consumer income) is critical for understanding the extent to which changes in food price affect food consumption (Cornelsen et al. 2015). To our knowledge however, price elasticity information specific to Indigenous Peoples residing in remote communities in Canada, the USA or Australia is not available.

Factors considered to drive high food prices in remote stores include small community size, high operating costs (e.g. high transport, electricity and other costs), and store management practices (Ferguson et al. 2016). Electricity costs, which can be five to ten times higher in northern communities relative to the south, are a significant contributor to the total costs of operation, and innovative strategies, such as alternate energy, are required to offset the higher operational cost for retail outlets in northern and remote settings (Enrg Research Group 2016).

Decisions regarding food inventories in remote communities of the Canadian Arctic are predicated upon sales history/ consumer demand, and various logistical considerations such as resistance to degradation during transport (Mead et al. 2010). In the Northern Territory (Australia), most (70%) stores are Indigenous owned, and roughly half have a nutrition policy (Brimblecombe & Ferguson 2015). While there are co-operatives in the Canadian Arctic, it is unclear how health and nutrient policies are translated into these retail environments.

7.5.2 Addressing Poverty and Low Socioeconomic Status

Northern Governments are increasingly developing actions to reduce poverty. Inuit adults with higher socio-economic status, including higher levels of formal education, and individuals living in households with employed residents, were more likely to consume fruits and vegetables (Pakseresht et al. 2014; Erber, Beck, et al. 2010; Hopping et al. 2010). Socioeconomic indicators, however, do not appear to be related to higher reliance on non-nutrient dense foods, and factors such as availability or taste preference, may bear greater influence on food expenditure patterns for these items (Erber, Beck, et al. 2010; Pakseresht et al. 2014).

The role of traditional and country food

More fundamentally, there is concern that programs which emphasize support for imported foods promote a transition away from traditional diets (Myers et al. 2004). Country foods remain strongly culturally preferred by Inuit (Lambden et al. 2007), and over 80% of respondents of the Inuit Health Survey expressed a preference for eating more country food than they currently have access to (Egeland 2010). At the international scale, wild foods contribute importantly to household nutrition and warrant greater formal inclusion into regional, national, and international food security policy and programs (Hickey et al. 2016). Economic factors, including the high cost of harvest (including gasoline and equipment) and time off from the wage-economy, can be represent important barriers to country food access (Lambden et al. 2006). Nevertheless, the role of market foods within contemporary Inuit diets cannot be ignored. The vast majority (74 %) of respondents in the Inuit Health Survey reported a preference for a mixed diet of both country and market food, while approximately one-quarter of respondents expressed preference for country foods exclusively (Egeland 2010).

7.5.3 Study Limitations and Strengths

Several important study limitations must be acknowledged. We have reported on a comprehensive list of market food items available in northern remote communities; however, the list of food items costed is not exhaustive. This study considers the cost of foods purchased in community stores, and does not consider "out shopping" purchases (i.e. food purchases from outside local physical stores via internet order) or foods purchased from other communities (Enrg Research Group 2016). While brand names and product volumes are important factors contributing to food prices, the lack of consumer purchase/preference data specific to this population, and the limited diversity of product formats in small stores of northern/remote communities, precluded inclusion of this factor within the present study. As we have consistently priced the lowest cost item in the defined product volume, our results represent a lower estimate on food costs. Inclusion of "time cost" for raw/brute products relative to prepared or convenience products was beyond the scope of the present study, but may lead to differing conclusions about relative prices of foods (Yang et al. 2015). Finally, although there has been considerable debate in the literature regarding the relevance of assessing food price on an energetic basis (Jones & Monsivais 2016), Beheshti and colleagues (2016) recently demonstrated that price per calorie is the dominant price metric used by low-income consumers in making food decisions. Nevertheless, there are several important strengths to the participatory-methodology used in this study (Williams et al. 2012). Elsewhere, participatory food costing experiences have yielded prolonged engagement of community members in research and action to build capacity surrounding food security (Johnson et al. 2015). Local engagement, and hiring community researchers, are important factors affecting the success of northern research(Brunet et al. 2016). However, securing adequate funding to support research during all project phases (from inception to dissemination) of a multi-year project is challenged by conventional funding structures.

7.6 Conclusion

Despite the availability of a food subsidy program in remote northern communities of Canada, appropriate policy to attenuate the price differential between nutritious foods and "cheap calories" may help support food security and nutrition in isolated northern communities. As economic decisions are generally predicated upon on relative, rather than absolute, prices, the significant price differential between nutrient-rich energy-dilute foods and energy-dense nutrient-poor foods may favour the dietary transition towards unhealthful foods. Although higher food prices in rural and remote Indigenous communities reflect inherent challenges to food retailing in northern contexts (e.g. higher operating costs, and complex logistics), this system, has likely fostered greater reliance on low-cost, non-perishable, energy dense foods of poor nutrient quality. The nutrition transition experienced by Indigenous Peoples can be approached as a human rights issue (Damman et al. 2008) and food system inequities experienced by Indigenous Peoples include systematically higher food prices (First Nations Development Institute 2016; Duhaime & Caron 2012), higher rates of food insecurity (Egeland 2011), and increasing prevalence of obesity and other diet related chronic illnesses (Zienczuk & Egeland 2012). Greater attention should focus on the omnipresent influences of capitalism as a critical element in the nutrition transition of Indigenous Peoples. Ongoing monitoring of community-level food price and diet information, as well as community-identified food security, are necessary to inform action aimed at mitigating food insecurity and promote healthful diets in remote Indigenous communities.

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7.8 Supplemental Material

Table 7.5S Nutrients included in nutrient profile score

Nutrients[1]	Daily value[2] / Maximum value[3] for adults
Qualifying nutrients	
Protein (g)	51.0
Dietary fiber (g)	29.7
Calcium (mg)	1041.7
Iron (mg)	11.4
Magnesium (mg)	367.2
Potassium (mg)	4698.9
Vitamin A (μg RAE)	801.4
Vitamin C (mg)	82.3
Vitamin E (mg)	15.0
Nutrients to limit	
Saturated fat (g)	20
Total sugar (g)	125
Sodium (mg)	2300

[1] Nutrients included in were based on the NRF9.3 (Fulgoni et al. 2009)

[2] Daily values were based on the Recommended Canadian Dietary Allowance (RD) and Adequate Intake (AI)(Health Canada 2010), and were weighted according to the age and sex distribution of the adult population in the ISR (Statistics Canada 2011 Census), to generate a single adult population DRI

[3] Maximum recommended intake values were based on a 2000kcal diet (Maillot et al. 2007)

Table 7.6S Items and weight/volume included in the Revised Northern Food Basket

Food Groups	Items	Amount	Unit
Dairy	Milk (fluid), partly skimmed, 2% M.F.	4760	ml
	Cheese, processed slices (cheddar)	385	g
	Cheese, mozzarella block (not slices)	485	g
	Yogurt, fruit bottom, 1% to 2% M.F.	1670	g
	Evaporated milk (canned), 2%	1580	ml
	Skim milk powder	90	g
Added fat	Margarine (tub), composite, non-hydrogenated	715	g
	Butter, salted	65	g
	Canola oil (or canola oil blend), not olive oil	185	g
	Lard (Pork)	105	g
Meat and alternatives	Large eggs	8	eggs
	Chicken legs (i.e. drumsticks)	2680	g
	Pork loin, center-cut chops, bone-in	1210	g
	Beef steak, inside round	470	g
	Sliced ham, pre-packaged, regular (not low fat)	135	g
	Sliced Bologna, pre-packaged, regular (not lower fat)	60	g
	Wieners (beef and pork)	100	g
	Luncheon Meat (canned), pork	50	g
	Corned Beef (Canned)	40	g
	Canned ham	200	g
	Frozen fish sticks, breaded	135	g
	Pink Salmon, canned	270	g
	Canned sardines in soya oil	270	g
	Peanut butter, smooth type, fat, sugar and salt added	90	g
Bread and cereals	Bread, enriched white, sliced	660	g
	Bread, 100% whole wheat	660	g
	Pilot biscuits	275	g
	White flour, wheat enriched, all purpose	1920	g
	Pasta (dry), spaghetti or macaroni, enriched	385	g
	White rice (dry), long-grain, parboiled	330	g
	Macaroni and cheese dinner	550	g
	Rolled oats, quick cooking (not instant)	275	g
	Cereal, corn flakes	440	g
Fruits and vegetables	Apples	4380	g
	Oranges	1230	g
	Bananas	3580	g
	Grapes (red or green)	500	g
	Carrots	2000	g
	Cabbage	520	g
	Rutabaga (turnip), raw	350	g
	Fresh potatoes, white	3000	g
	Onions	695	g
	Frozen mixed vegetables	1740	g
	Frozen carrots	260	g
	Frozen Broccoli	695	g
	Frozen corn	260	g
	Frozen French fries	480	g
	Instant potato flakes	220	g
	Canned mixed vegetables	545	ml
	Canned green peas (considered canned mixed as peas and carrots)	1215	ml
	Canned carrots	325	ml
	Canned kernel corn	1090	ml
	Canned whole tomatoes	215	ml
	Canned tomato sauce	300	ml
	Canned fruit cocktail in juice	855	ml
	Canned pineapple in juice - changed to canned mandarin	285	ml
	Canned peaches in juice	285	ml

Fruit juice	Apple juice, frozen concentrate	33	ml
	Orange juice, frozen concentrate, unsweetened	282	ml
	Apple juice, canned or bottled, added vitamin C	880	ml
	Orange juice, chilled, added vitamin C	375	ml
Other	Canned beans with pork	290	ml
	Canned beef stew	180	g
	Canned spaghetti sauce with meat	155	ml
	Sugar, white, granulated	600	g

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8 IS IT POSSIBLE TO MEET NATIONAL NUTRIENT RECOMMENDATIONS WITH A MIXED DIET OF TRADITIONAL AND MARKET FOODS IN ARCTIC CANADA?

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TK conceived of the research question, prepared the data, developed and coded the models, interpreted the results and drafted the manuscript. SDW and LHMC provided intellectual support through all phases of the project, and provided feedback on the drafted manuscript.

ABSTRACT

Context: The high price and limited availability of nutritious market food in remote Arctic communities pose major challenges for food security and diet quality. Numerous studies have documented inadequacies of dietary fibre, calcium, and vitamin E among Inuit adults in Canada. Micronutrient-rich traditional foods (i.e. country foods) remain fundamental to Inuit diet and culture, but their consumption has diminished in the last several decades. The objectives of this study are to: (i) assess the feasibility of meeting national nutrient recommendations based on a combination of market foods and country foods consumed by Inuit adults; (ii) identify limiting nutrients in the northern food supply; (iii) identify what changes in dietary patterns, and patterns of market food expenditure are necessary to meet nutrient recommendations.

Methods: Optimization modelling was used to formulate theoretical diets that satisfied nutrient intake values recommended by Health Canada, while minimizing dietary modifications from the average diets of Inuit adults. Dietary data were derived from the 2007-8 Inuit Health Survey. Results from the Inuvialuit Settlement Region (ISR), exclusively, were used for these analyses (n = 267). Constraints limiting portion sizes for food subgroups (<95th percentile of consumption in the population diet of men and women, respectively) were used in the models to avoid generating unrealistic diets. Food cost data were obtained from a participatory food costing survey conducted across the six communities of the ISR.

Results: The mean reported diet for both men and women lacked sufficient calcium, dietary fibre, vitamin E, and vitamin A. It was impossible to generate a modelled diet that satisfied all nutrient requirements, within the 95th percentile of food subgroup consumption, as reported in the dietary surveys. Requirements for calcium, dietary fibre, vitamin E, and sodium (tolerable upper intake level) were the most difficult requirements to fulfill. Only by relaxing portion size constraint was it feasible to meet these requirements. However, significant increases in consumption of country food (namely fish and berries), and several market food groups (namely dairy products, fruit and vegetables, and grains and starches), coupled with significant reductions (>10% change in contribution to total diet energy) in consumption of sweetened beverages and snacks, as well mixed dishes, and meat (market food) were necessary. All model scenarios resulted in sodium intake values equal to the tolerable upper intake, suggesting that high sodium intake from market foods is an important dietary issue for Inuit. The estimated cost of market food in the population diets of Inuit men and women was approximately CAD $13-14. Although the achievement of nutrient recommendations in modelled diets did not markedly change diet costs (~ CAD$ 2), significant modification in food group expenditures were required. Increasing consumption of country food alone was not sufficient to meet requirements for key limiting nutrients. Traditional knowledge and food composition analyses are required to identify rich sources of dietary fibre, calcium, and vitamin E in traditional Inuit diets. Optimization modelling is a useful tool to translate nutrient requirements into population-specific food-based recommendations in the Arctic.

8.1 Introduction

Micronutrient malnutrition affects over 2 billion people globally (Kennedy et al. 2003). Moreover, nearly 30% of the global population, over 2.1 billion people, are either overweight or obese (Ng et al. 2014). Food systems that provision adequate dietary energy but lack essential micronutrients represent a distinct concern for population health, including disposition to obesity and the development, and severity, of chronic disease (Via 2012; Eckhardt 2006). The increasing ubiquity of low-cost, energy-dense, nutrient-poor foods is a key driver in the rise of obesity worldwide (Swinburn et al. 2011). While agricultural intensification has mitigated the global burden of hunger (Godfray et al. 2010), it has also dramatically narrowed the world's food base (over 90% of the world's food energy provided by fifteen crop plants (FAO 1995)), fostered the simplification of human diets (i.e. reduced dietary diversity), and undermined Indigenous and traditional food systems (Frison et al. 2005; Matson et al. 1997; Johns & Eyzaguirre 2007; Toledo & Burlingame 2006). In the Arctic, Indigenous Peoples have developed traditional food systems in some of the most extreme environments with some of the lowest biodiversity and species richness on the planet (ACI Assessment 2004; Walker et al. 2001; Meltofte 2013).

Indigenous Peoples' food systems include a wealth of exceptionally micronutrient-rich foods (Kuhnlein et al. 2004; Kuhnlein 2003). Inuit have been sustained by harvesting, trapping, fishing, and gathering local species (i.e. "country foods") for thousands of years (Nuttall et al. 2005). However, policies and programs initiated by the federal government during the mid-twentieth century systematically undermined the sovereignty of Inuit communities (Bonesteel & Anderson 2008) and fundamentally transformed local Arctic food systems. Consequently, the consumption of country food (CF) has diminished markedly in recent decades, and, despite complex logistics and high operating costs, food is now regularly shipped long distances to remote northern community stores (Lambden et al. 2006).

Although country foods generally contribute modestly (less than one-third) to total energy in the contemporary Inuit diet, they remain a significant proportion of total animal-source foods, and, furthermore, remain critical in provisioning essential micronutrients (Kuhnlein et al. 2004). CFs are generally the principle source of protein, iron, and several micronutrients (e.g. niacin, riboflavin, thiamin) (Kuhnlein & Receveur 2007; Kuhnlein et al. 1996). Higher essential nutrient intakes are observed on days when CF are included in the diet, and consumption of a single portion of CF is sufficient to significantly increase intake of protein, vitamin D, vitamin E, riboflavin, vitamin B6, iron, zinc, copper, magnesium, manganese, phosphorus, and potassium (Kuhnlein et al. 2004; Kuhnlein & Receveur 2007). Over three quarters (74% to 80%, according to region) of Inuit adults who participated in the 2007-8 Inuit Health Survey preferred to eat a mix of market and country food (Egeland 2010a; Egeland 2010b; Egeland 2010c). However, nutrient-poor foods are increasingly selected as alternatives to country foods, while fruit and vegetables remain scarcely consumed (Kuhnlein et al. 1996). Market food prices in remote community stores are very high, and despite a federal subsidy program (Government of Canada n.d.) remain economically inaccessible for many households (Lambden et al. 2006; Duhaime & Caron 2012). Food security and dietary adequacy thus remains elusive for Inuit communities. Studies conducted over the last two decades identify a range of nutrient adequacy issues for Inuit adults in Arctic Canada (Table 1). Inadequacies for dietary fibre, calcium, vitamins A, C, D and E, folate, and n–6 fatty acids are pervasive (Erber et al. 2010; Kuhnlein et al. 2007; Kuhnlein 2003; Hopping et al. 2010; Sharma et al. 2013). The prevalence of inadequate daily intakes tends to be highest for calcium, vitamins A and D, and to a lesser extent zinc and vitamin C (Table 1). Moreover, maximum recommended sodium intakes are commonly exceeded (Blanchet & Rochette 2008).

Nutrient inadequacies for dietary fibre and micronutrients reflect low intake of dairy products, solid fruits and vegetables, and whole-grain products, while high sodium intake is related to high reliance on packaged and processed packaged foods. Several studies (Erber et al. 2010; Schaefer et al. 2011) have highlighted the need to substitute non-nutrient-dense foods with nutrient-rich country foods and nutritious market foods (e.g. whole grains, fruits and vegetables) to overcome nutrient deficiencies. It is not yet known whether it is theoretically feasible to obtain a nutritionally adequate diet (i.e. meeting the recommended nutrient intake levels) based on a combination of foods currently available or consumed by Inuit in Arctic Canada.

8.1.1 Objectives

Dietary advice is designed to counsel the public in meeting nutrient requirements in a manner that is culturally acceptable, and economically attainable. Optimization modelling is a powerful technique to inform the development of dietary recommendations and public health policy (Buttriss et al. 2014).

Optimization models mathematically assess the feasibility of meeting a defined objective (e.g. nutrient requirements) based on defined constraints (e.g. maximum food budget and food portions). The method has been variously employed to assess the nutrient quality of the food supply, including among rural populations (Darmon, Ferguson & Briend 2002b) and in Indigenous communities of Australia (Brimblecombe et al. 2013). There is no previous research using optimization modelling to assess the feasibility of meeting nutrient recommendations based on a combination of traditional Indigenous foods and store-bought foods.

The objectives of this study are to use optimization modelling to: (i) assess whether a nutritionally adequate diet (defined based on national Dietary Reference Intake (DRI) values (Health Canada 2010)) is achievable with locally available foods (including both market food, and country food) for Inuit adults in a remote region of Arctic Canada; (ii) identify limiting nutrients (i.e. nutrients that are difficult to consume in adequate quantities) in the food supply; and, (iii) identify what changes in dietary patterns, and patterns of market food expenditure are necessary to meet nutrient recommendations.

Table 8.1 Summary of nutrient issues for Inuit adults in Canada, as identified in the literature

Location Communities or Region	Participants	Nutrients[1] (% of participants below the dietary reference intakes) Calcium	Dietary Fibre	Folate	Magnesium	Vitamin A	Vitamin B6	Vitamin C	Vitamin D	Vitamin E	Zinc	Sodium	Reference
Adults													
Various, Nunavik	Men and women	93	98	42	80	76	46	57	17		34	61	(Blanchet & Rochette 2008)
Women													
Various, NU	Women 19 – 50 y	53	92	35	26	24	19	19	69	98	8	-	(Sharma et al. 2013)
Various, ISR	Women 19 – 50 y	90	100	68	-	90	61	42	84	100	32	-	(Erber et al. 2010)
Various, ISR	Women > 50 y	95	89	79	-	84	74	47	100	100	21	-	(Erber et al. 2010)
Qikiqtarjuaq, NU	Women > 40 y	-	-	22	84	44	-	94	-	100	-	-	(Berti & Soueida 2008)
Various (18 communities)	Women > 40 y	-	-	44	6	55	11	24	-	100	-	-	(Berti & Soueida 2008)
Kitikmeot, NU	Women ≤ 50 y	76	100	78	-	60	11	27	91	100	36	-	(Hopping et al. 2010)
Kitikmeot, NU	Women > 50 y	96	100	78	-	78	30	52	91	100	17	-	(Hopping et al. 2010)
Various (18 communities)	Women ≤ 40 y	99	100	56	86	7	11	24	24	100	3	-	(Kuhnlein et al. 2007)
Various (18 communities)	Women > 40 y	100	100	64	78	47	8	47	0	94	2	-	
Men													
Various, NU	Men 19 – 50 y	39	100	22	33	39	3	14	47	97	8	-	(Sharma et al. 2013)
Kitikmeot, NU	Men	86	100	43	-	86	-	71	-	100	71	-	(Hopping et al. 2010)
Various, ISR	Men ≥ 19 y	71	100	86	-	93	64	43	43	100	57	-	(Erber et al. 2010)
Various (18 communities)	Men ≤ 40 y	98	100	30	95	44	0	44	41	99	9	-	(Kuhnlein et al. 2007)
Various (18 communities)	Men >40 y	100	100	39	86	22	0	56	9	88	4	-	(Kuhnlein et al. 2007)

Acronyms: ISR = Inuvialuit Settlement Region; NU= Nunavut
[1] Values not reported in the study are designated by a dash (-)

8.2 Methodology

8.2.1 Study Setting

Inuvialuit Settlement Region

The Inuvialuit Settlement Region (ISR), located in the western Canadian Arctic, is the homeland of the Inuvialuit People (Figure 1). The ISR (total population of 5,800) is comprised of six communities which range in population from 132 to 3,265 people (NWT Bureau of Statistics 2015). The largest community, Inuvik, serves as the administrative centre for the western Canadian Arctic and is serviced by an all-season road. The five remote communities (Aklavik, Paulatuk, Tuktoyaktuk, Sachs Harbour, Ulukhaktok) lack year-round road access and are accessible by air transport (and for some communities by ice road from Inuvik, seasonally). Average family incomes in the region range from CAD $58,958 to CAD $112,044 (Inuvik). A high proportion of residents from the region (45% to 80%, according to community) participate in subsistence activities (NWT Bureau of Statistics 2015), and most households (56 to 75% of households, varying by community) in the five remote communities obtain half or more of their animal-source food from CF (NWT Bureau of Statistics 2015). The Inuit Health Survey (2008) documented that nearly half of households in the region experienced food insecurity (i.e. the state of lacking reliable access to a sufficient supply of affordable, nutritious food), with 13% reporting severe food insecurity (Egeland 2010a). Each community of the ISR has one or two grocery stores that are either private corporations or co-operatives (Enrg Research Group 2016). Stores in the five remote communities obtain food year-round through air shipment, and seasonally by ice road and barge (once per year, during ice melt). The Nutrition North Canada (NNC) retail subsidy program is available in all communities of the ISR, excluding Inuvik.

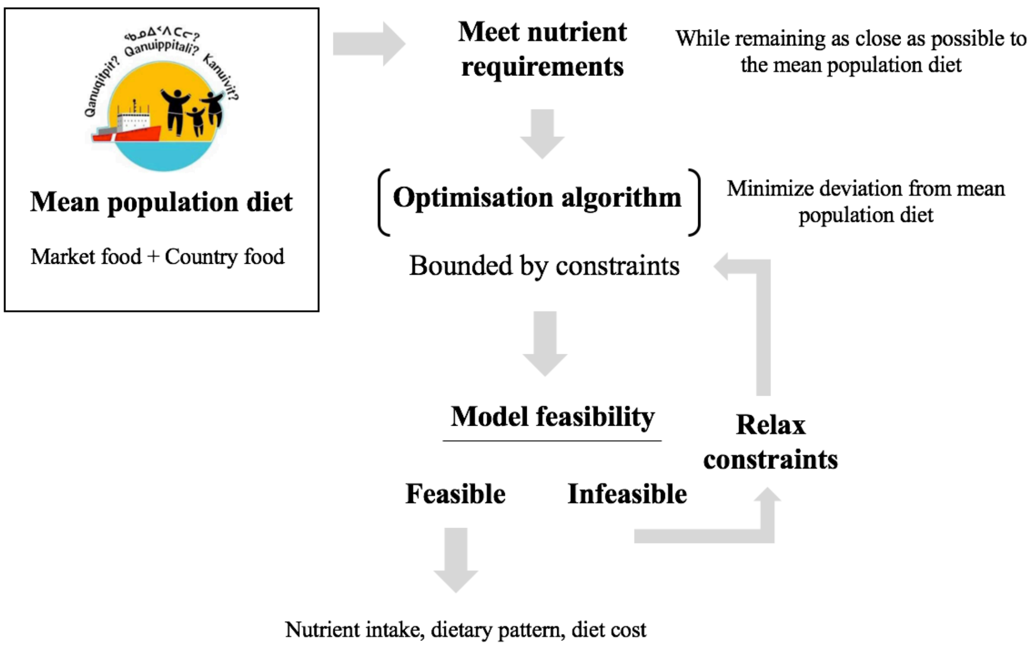
Figure 8.1 Location of the six communities of the Inuvialuit Settlement Region, Northwest Territories, Canada.

The Nutrition North Canada food subsidy program is available in the five remote communities (i.e. excluding Inuvik), which lack year-round road access.

8.2.2 Model Data

Optimization modelling was used to formulate food intake patterns that satisfied dietary reference intake (DRI) values defined by Health Canada (Health Canada 2010) based on food selection documented in Inuit communities. Three core sets of data were used to design the models: (i) dietary data for Inuit adults (i.e. foods consumed, and portion size distributions for food groups and subgroups); (ii) food composition data (energy and nutrient content); and (iii) regional food cost data.

Figure 8.2 Conceptual overview of the modelling process



i. Dietary Data

Dietary data for Inuit adults were derived from the 2007-8 International Polar Year (IPY) Inuit Health Survey (IHS). The IHS was a cross-sectional health survey of Inuit adults residing in three regions of northern Canada: the Inuvialuit Settlement Region (ISR), Nunavut, and Nunatsiavut. Complete methodology for the IHS, including the participatory design of the survey, has been described in Saudny et al. (2012). The IHS collected comprehensive baseline data about diet, health, and living conditions in Inuit communities across the north. All non-pregnant Inuit adults aged 18 years and older were eligible to participate in the survey. Of the 2,796 households that were randomly selected to participate, 1,901 households agreed to take part in the survey (68%), representing a total of 2,595 unique participants, among whom 61.5% were female. The present analyses were restricted to the 267 adults (86 men and 181 women) from the ISR who provided complete dietary recalls. Informed consent was obtained from all participants. Ethics approval was granted by the McGill University Faculty of Medicine Institutional Review Board and the University of Ottawa Health Sciences and Science Research Ethics Board. A Scientific Research License for the project was obtained from the Aurora Research Institute.

Dietary Assessments

Diet composition and nutrient intakes were estimated using data collected by the 24-hour recall of the IHS. Dietary assessments were conducted in-person by trained interviewers, in English and Inuit languages, as described elsewhere (Egeland et al. 2011; Jamieson et al. 2012). Diet was assessed using a single 24-hour recall based on an adapted form of the USDA multi-pass approach (Blanton et al. 2006). Three-dimensional graduated food model kits (Direction de Santé Québec, Institut de la Statistique du Québec 2013) were available to aid participants in estimating portion sizes. Survey logistical constraints precluded the collection of a repeat dietary recall on a nonconsecutive day. A single 24-hour recall is deemed adequate for estimating of the mean of the usual intake distribution in the population without specific statistical adjustment (Willett 2013). Dietary data were entered using CANDAT Software (Godin London) and matched with food items in the Canadian Nutrient File (CNF) (Health Canada 2015). When no equivalent item existed in the CNF, an additional dietary file was created at McGill University.

Aggregation of dietary data

As described more completely in Chapter 6, similar food items in each recall were collapsed as a daily sum for the item (g/person/day). Alcoholic and low-energy yielding beverages (e.g. diet soda, water and coffee/tea), and spices/seasonings (e.g. added salt), were excluded from all analyses. Foods were dichotomized as either country foods or market foods and systematically aggregated into discrete food groups and subgroups. Country foods were classified into five broad categories (birds, fish, land mammals, marine mammals, and berries/plants), and were further categorized by species (e.g. caribou) and by part (e.g. meat, fats, and organs). Market foods were collapsed into seven major food groups ((i) dairy, (ii) added fat, (iii) meat & alternatives, (iv) fruits & fruit juice, (v) vegetables & vegetable preparations, (vi) sweets & snacks, and (vii) mixed dishes & other), and forty-one subgroups (Chapter 6). The mean (population mean, including both consumers and non-consumers) daily portion size (g/day) for each of the 60 subgroups was calculated and used as baseline input for the models (hereafter referred to simply as the "mean/population diet" or the "referent diet"). Consumption distributions were calculated to the define upper bounds on model portion sizes ($< 95^{th}$ percentile) for each of the 60 subgroups and food groups. Values of the population diet were calculated separately for men and women to account for differences in consumption patterns.

ii. Food Composition Data

Diet energy and nutrient intakes for the population were calculated using national reference food composition data from the Canada Nutrient File (CNF), which includes information for both market foods and country foods (Health Canada 2015). Food composition data for foods not included in the CNF were available from an additional McGill School of Dietetics and Human Nutrition in-house food file, as described elsewhere (Egeland et al. 2011). All nutrients were verified for completeness and missing values were imputed following the procedures described by Shakel et al. (1997). The United States Department of Agriculture (USDA) Food and Nutrient Database for Dietary Surveys (FNDDS) 5.0 was used to supplement missing nutrient values for market foods (J. Ahuja et al. 2012; Montville et al. 2013). Missing nutrient values for country foods (not in the FNDDS) were imputed and/or manually calculated based on similar food items, considering the species, body part, and preparation method.

Composite Nutrient Profiles

Composite nutrient profile (energy and nutrients per 100g) were calculated for each food subgroup and included in the models (Marcoe et al. 2006). Nutrient profiles were calculated based on the population-weighted average nutrient content (percentage consumption of its food subgroup composition, as reported in the IHS) for each food item included in the composite subgroup. For example, the nutrient content of the "bread" subgroup represented the mean of white, whole grain, and other bread products, weighted by the average reported consumption of each food items in the population. Composite nutrient profiles were calculated separately for men and women.

iii. Food Cost Data

Diet cost was estimated by linking dietary data from the IHS to a region-specific food price database, as described elsewhere in Chapter 7. Merging supermarket food prices with dietary assessment data can provide estimates of individual diet cost that are closely associated with the actual food consumed (Monsivais et al. 2013). "Diet cost" (Agarwal et al. 2015) is defined here as the daily cost of food for an individual, and is analogous to the "monetary value" of diet (Rehm et al. 2011). We distinguish between this definition and the concept of "food expenditure," which reflects results from expenditure diaries or till receipts (Timmins et al. 2013). Furthermore, the diet cost is here intended to reflect only the cost of market foods (i.e. the cost of country food procurement was not included within our estimates of diet cost).

8.2.3 Model Formulation

A series of optimization models were formulated to investigate the minimum population-level dietary changes necessary to achieve nutrient recommendations for Inuit adults in the ISR. Figure 2 presents a conceptual overview of the modelling process. Models were run separately for men and women, as dietary patterns and nutritional recommendations differ between sexes. Models were designed to meet nutrient recommendations (i.e. constraints) while remaining as close as possible to the mean population diet (reported in the dietary recalls of the IHS). This stipulation is based on the assumption that diets conforming as close as possible to observed population diets are more likely to be adopted by the population, and that individuals facing constraints in food access (e.g. budgetary constraints) are most likely to choose diets that remain as close as possible to the mean population diet (Darmon, Ferguson & Briend 2002a).

8.2.4 Objective function

Optimization models are characterized by an objective function subject to a set of defined constrains (Dantzig 1998). The optimization process identifies a set of decision variables (e.g. food portions) that yield an optimal value (i.e. maximum or minimum) of the objective function while respecting the imposed constraints (e.g. nutrient constraints). The objective function defines the criteria by which the optimal solution is selected by the solving algorithm from all feasible solutions. The Diet Problem (Dantzig 1990) is a classic application of optimization modelling, wherein each optimization process results in the design of a theoretical diet.

Following previous work by Darmon et al. (2002a), the objective function was defined as the "total departure from mean food intake" (TDMI). The TDMI is defined as the sum of the absolute value differences between the portion size of each food item selected by linear programming 'X^{opt}', and the mean portion sizes 'X^{obs}' in the referent diets (Darmon, Ferguson & Briend 2002a). Differences across food subgroups were standardized. This function translates the objective of remaining as close as possible to the observed population diet by minimizing the deviation in food intake between the mean population diet and the diets selected by modelling.

$$\text{Minimize } f = \sum_{i=1}^{60} \text{ABS}\left(\frac{X_i^{opt} - X_i^{obs}}{X_i^{obs}}\right)$$

Where X ^{opt} and X ^{obs} are the portion sizes of each food subgroup 'i', as reported in population dietary studies and as selected by optimization modeling, respectively.

As the absolute value (ABS) argument yields a nonlinear function, the TDMI function was transformed linearly as:

$$\text{If } X_i^{opt} < X_i^{obs} \text{ then } N_i = \left(\frac{X_i^{obs} - X_i^{opt}}{X_i^{obs}}\right) \text{ and } P_i = 0$$

$$\text{If } X_i^{opt} > X_i^{obs} \text{ then } N_i = 0 \text{ and } P_i = \left(\frac{X_i^{obs} - X_i^{opt}}{X_i^{obs}}\right)$$

$$\text{If } X_i^{opt} = X_i^{obs} \text{ then } N_i = 0 \text{ and } P_i = 0$$

$$\text{Subject to } P_i - N_i = \left(\frac{X_i^{obs} - X_i^{opt}}{X_i^{obs}}\right)$$

Where X ^{opt} and X ^{obs} are the portion sizes of each food subgroup 'i', and P_i and N_i represent the positive and negative deviational variables, respectively.

The sum of the deviational variables was thus chosen as the linear, objective function for all models. All models were run on the basis of grams per day.

8.2.5 Model Constraints

All models were designed to be isoenergetic (i.e. total diet energy was kept constant) to ensure that model solutions satisfied nutrient requirements within the range of acceptable energy intake. Isoenergetic diets were generated by restricting total diet energy to the mean energy intake for men and women.

Nutrient intake constraints

Nutrient constraints were introduced to ensure the nutritional quality of modeled diets. Nutrient constraints were based on Health Canada Dietary Reference Intakes (DRI) for healthy people (Health Canada 2010). A lower bound on the total intake of each nutrient was set to the recommended dietary allowance (RDA). The RDA is the average daily dietary intake level that is sufficient to meet the nutrient requirement of nearly all (97-98%) healthy individuals in a particular life-stage and gender group (Health Canada 2010). When an RDA was not defined, the acceptable intake (AI) was used. When established, the tolerable upper intake level (UL) was included as an upper bound on intake. Health Canada does not define an UL on saturated fat or dietary cholesterol, but recommends intake be "as low as possible while consuming a nutritionally adequate diet" (Health Canada 2010). Accordingly, maximum intakes for saturated fat, dietary cholesterol, and free sugar (i.e. granulated sugar and sugars naturally present in honey, syrups and fruit juices) were based on World Health Organization values (WHO & FAO 2003).

Of the twelve vitamins and fourteen minerals for which DRIs are defined in Canada, sufficient food composition information was available for ten vitamins (vitamin A as retinol activity equivalents (RAE), B6, B12, C, D, E, niacin as niacin activity equivalents (NNE), riboflavin, thiamin, folate) and nine minerals (calcium, copper, iron, magnesium, phosphorous, potassium, selenium, sodium, and zinc). Pantothenic acid, vitamin K, chromium, fluoride, iodine, manganese, and chloride were excluded from the models due to incomplete data. A single population-weighted requirement was calculated for each sex based on the age structure of the region based on 2011 census data (Statistics Canada 2016) (Table 2).

Maximum portion sizes

To ensure the food portions selected by models were realistic and within the range of foods consumed by the Inuit adult population, a maximum constraint on food portions was included in the models. Limits on daily portion sizes (g/day) for subgroups were set to be below the 95^{th} percentile of the IHS consumer intake distributions for each sex (supplemental material). Intake of fruits and vegetables, and certain country foods, were very low in the ISR (i.e. 95^{th} percentile =0). For these subgroups, the upper limit was based on the entire Inuit Health Survey adult population, by sex, rather than the regional-data. Furthermore, constraints limiting the energy contributed by each food group to the < 95th percentile observed in the Inuit population was included in all models.

8.2.6 Model feasibility

Optimization models result in either a feasible solution (i.e. the objective function achieves an optimal value) or an infeasible solution (i.e. meeting all of the constraints is not possible). In the latter case, the irreducible infeasible set (IIS) can be used to isolate the structural infeasibility of the model. Infeasible constraints can be subsequently removed or relaxed to be less restrictive in order to achieve a feasible model solution. Dual values represent the improvement in the objective function when the constraint is relaxed by one unit. Dual values were calculated for all feasible models to compare the relative strength of model constraints. Null dual values indicate that the constraint is not restrictive (i.e. fulfilling the constraint does not have an effect on the objective function), while non-zero dual values suggest that the constraint is restrictive (i.e. fulfilling the constraint has an effect on food selection and thus deviates from the observed diet; the greater the value, the more difficult the constraint is to satisfy). Dual values were used to identify binding constraints (Table 3).

Analyses

Management and analysis of the data was performed with SAS statistical software (version 9.4; SAS Institute, Cary, NC). The PROC OPTMODEL procedure was used to solve all models.

8.3 Results

8.3.1 Study Sample

Demographic and socioeconomic characteristics of the study population are summarized in Table 2. The mean ± SD age of participants was 47 ± 16 and 43 ± 16 years for men and women, respectively. Mean ± SD BMI was 27.8 ± 7.5 and 31.2 ± 7.2 for men and women, respectively, both of which fall within the overweight (BMI = 25.00 - 29.99 kg/m^2) and obese (BMI = 30 - 34.99) class defined by the World Health Organization. Over 60% of participants reported to be current smokers. Approximately half of men (49%) and women (45%) had not completed high school, and over half of participants (57% of men and 59% of women) reported an annual personal income inferior to CAD $40,000.

Table 8.2 Sociodemographic characteristics of the participants of the Inuvialuit Settlement Region (n 267)

	Men (n 86)		Women (n 181)	
	Mean /n	SD / %	Mean	SD
Age (years)	46.9	15.6	42.9	15.8
Weight (kg)	85.9	17.1	78.7	19.3
Height (cm)	166	6.9	159	5.8
BMI[1] (kg/m^2)	27.8	7.5	31.2	7.2
Body fat percentage (%)	25.3	9.9	38.7	8.9
Current smokers (n/%)	52	63	120	67
Education >= high school[2] (n/%)	42	49	81	45
Personal income below CAD $40,000 (n/%)	48	57	107	59

[1] According to World Health Organization, a BMI score between 25 – 30 is considered overweight. A score above 30 is considered obese.
[2] High school education, with or without any level of post secondary education defined

8.3.2 Characteristics of the Mean Population Diet

The mean population diet provided 2,717 kcal for men and 2,074 kcal for women. As shown in Table 4 - 5, for men the mean population diet lacked sufficient dietary fibre (achieving 37% of the recommended intake), calcium (58%), magnesium (69%), potassium (67%), vitamin A (83%), and vitamin E (76%). Likewise, the mean population diet for women lacked sufficient dietary fibre (50% of the recommended intake level), calcium (51%), magnesium (71%), potassium (49%), vitamin A (68%), and vitamin E (54%), in addition to vitamin D (74%) and folate (93%). Both men's and women's diets exceeded recommended maximums intake levels for free sugar and statured fat (<10% of TDE, respectively), cholesterol, and sodium.

Grains and starches, sweets and snacks, and market food meats provided most of the total diet energy for men (21%, 23%, and 19% of TDE) and women (23% 23% and 16% of TDE). Country foods collectively provided 18% of TDE for men and 13% for women (Figures 3-6). Details of the diet composition by food subgroups are presented in the supplemental material. Mean sweetened beverage consumption (g/day) was 539 ± 690 and 530 ± 741 for men and women, respectively. Mean consumption of solid fruit was very low (8 g/day for men; 60g/day for women). The highest consumed country foods were caribou (mean ± SD = 89.5 ± 179.8 g/day for men, and 48.1 ± 107 g/day for women) and arctic char (mean ± SD (g/day)= 6 ± 177.0 for men, and 36.2 ± 102.3 for women) for both sexes. Beluga (muktuk) was important in men's diets at the time of the survey (mean ± SD 45.7 ± 214.9g/day).

8.3.3 Meeting Nutrient Recommendations in Modelled Diets

For both men and women, formulating a feasible diet that satisfied all nutrient requirements while respecting constraints on maximum food portions (95th percentile of consumption) was infeasible (Table 3). Requirements for dietary fibre, calcium, potassium, vitamin D, vitamin E, and the UL for sodium were prohibitive for both sexes. To investigate the impact of nutrient constraints on model feasibility, constraints on limiting micronutrients (i.e. dietary fibre, calcium, vitamin D, vitamin E, and sodium) were relaxed one by one to allow the model more flexibility.

Relaxing the requirement for dietary fibre yielded a feasible diet for both sexes that satisfied all other nutrient requirements within acceptable food intake portions (<95th percentile); however, intake of dietary fibre in the modelled diets achieved approximately half of the adequate intake (Table 4 - 5). Similarly, relaxing the calcium constraint yielded a feasible model solution for both sexes; however, calcium intake in the modelled diets was less than half the RDA (Table 4 - 5). For men, relaxing the requirements for both vitamin D and E did not yield a feasible model solution. Relaxing the vitamin D requirement for women generated a feasible model solution for all other nutrients. Relaxing the sodium constraint yielded a feasible model solution for all other nutrients; however, sodium intake in the modelled diet reached over 200% of the UL (Table 4 – 5)

Maximum portions (95th percentile) for cisco (CF fish) and CF berries, as well as dairy products (milk, yoghurt), meat alternatives, fruit (solid, juice, canned, and dry), solid vegetables, cereal, and potatoes rendered the models infeasible for men (Table 2). Similarly, for women, constraints on maximum portions on CF berries, dairy (milk, cheese, and yoghurt), meat alternatives, fruit (solid), vegetables (solid), potatoes, and potato chips rendered the model infeasible (Table 2).

Table 8.3 Summary of model scenarios and outcomes for men and women, respectively, in the Inuvialuit Settlement Region

Model Description[1]			Model Results			
		Feasibility	Model Constraints[2]			Diet cost (CAD $ / day)
			Nutrients	Market foods	Country foods	
Men						14.28
Model 1	Meet nutrient requirements	**Infeasible**	Fibre, calcium, potassium, vitamin D, vitamin E, sodium (UL)	Milk, yoghurt, meat alternatives, fruit (solid, juice, canned, dry), vegetables(solid), cereal, potatoes	Cisco, berries	
Model TDF	Relax fibre	Feasible	Calcium, magnesium, vitamin E, sodium (UB)	Milk, vegetables (solid)		11.81
Model Ca	Relax calcium	Feasible	Fibre, potassium, vitamin D, E, sodium (UL)	Meat alternatives, fruit (solid and canned), vegetable (solid), cereal, potatoes		11.24
Model VitD	Relax vitamin D	**Infeasible**	Fibre, calcium, vitamin E, sodium (UL)	Milk, yoghurt, meat alternatives, fruit (solid, canned, dried), vegetables (solid), cereal, potatoes	Berries	-
Model VitE	Relax vitamin E	**Infeasible**	Fibre, calcium, sodium (UL)	Milk, yoghurt, meat alternatives, fruit (solid, canned, dried), vegetables (solid), cereal, potatoes	Berries	-
Model Na	Relax sodium	Feasible	Fibre, calcium potassium, vitamin E	Meat alternatives, vegetables (solid and other), cereal		12.7
Model CF	Relax max CF until feasible	**Feasible**	Fibre, calcium, potassium, sodium (UL)	Meat alternatives, fruit (solid, canned, dried), vegetables (solid), cereal, sweet dairy products	Berries	-
Model MF	Relax max MF until feasible	Feasible	Fibre, calcium, Vitamin E, sodium (UL)	Yoghurt, meat alternatives, fruit (solid, canned), vegetables (solid), cereal, potatoes		14.69
Women						
Model 1	Meet nutrient requirements	**Infeasible**	Fibre, calcium, potassium, vitamin D, vitamin E, sodium (UL)	Milk, cheese, yoghurt, meat alternatives, fruit (solid), vegetables (solid), potatoes, potato chips	Berries	
Model TDF	Relax fibre	Feasible	Calcium, iron, potassium, vitamin E, folate, sodium (UB)	Milk, cheese, eggs, vegetables (solid)		12.35
Model Ca	Relax calcium	Feasible	Fibre, potassium, vitamin E, sodium (UB)	Meat alternatives, fruits (solid), vegetables (solid), potatoes, potato chips		13.16
Model VitD	Relax vitamin D	**Infeasible**	Fibre, calcium, potassium, vitamin E, sodium (UB)	Milk, cheese, yoghurt, meat alternatives, fruit (solid), vegetables (solid), potatoes, potato chips		-
Model VitE	Relax vitamin E	Feasible	Fibre, calcium, potassium, sodium (UB)	Milk, cheese, fruit (solid), vegetable (solid), potatoes		14.12
Model Na	Relax sodium	Feasible	Fibre, calcium, potassium, vitamin E, folate, sodium (UB)	Milk, cheese, meat alternatives, fruit (solid), vegetables (solid and other), potatoes, potato chips		17.10
Model CF	Relax max CF until feasible	**Infeasible**	Fibre, calcium, potassium, vitamin E, folate, sodium (UB)	Milk, yoghurt, meat alternatives, fruit (solid), vegetables (solid), potatoes, potato chips		15.66
Model MF	Relax max MF until feasible	Feasible	Fibre, calcium, potassium, vitamin E, sodium (UB)	Milk, meat alternatives, fruit (solid), vegetables (solid), potatoes, potato chips		15.88

Acronyms: AI = adequate intake; CF = country food; MF = market food; RDA= recommended dietary allowance; UL= upper intake level;

[1] All models were isoenergetic and set equal the mean total energy intake for men (2,717 kcal) and women (2,074 kcal) in the Inuit Health Survey, Inuvialuit Settlement Region

[2] Constraints are for the infeasible (i.e. infeasible models) and binding (i.e. feasible models) constraints.

Table 8.4 Comparison between the population-weighted dietary reference intake (DRI), the mean observed population diet for Inuit men in the Inuvialuit Settlement Region, and diets generated by optimization models for Inuit men. Optimization models were formulated to meet nutrient requirements while remaining as close as possible to the observed population diet. Infeasible nutrient and portion constraints were relaxed to achieve feasible model solutions.

			Dietary Reference Intake[1]		Observed[2]	Modelled[3]				
		Unit/day	Weighted requirement[4]		Population mean intake	Relaxing nutrient constraints			Relaxing consumption constraints	
			Min	Max[5]		Model TDF	Model Ca	Model Na	Model CF	Model MF
Macronutrients	Carbohydrate	g	130		284	263	393	365	359	386
	Fat	g			110	106	74	80	86	78
	Protein	g	56		152	190	129	141	144	134
	Total sugar [6,7]	g			134	118	81	88	143	131
	Saturated fat [7]	g			34	30	16	21	23	20
	MUFA	g			43	46	33	32	37	33
	PUFA	g			22	24	22	20	20	20
	Cholesterol[7]	mg		300	591	724	287	317	526	308
	Dietary fibre (total)	g	35		13	**18**	35	35	**35**	**35**
Minerals	Calcium	mg	1016	2500	**579**	1016	**448**	1016	**1016**	**1016**
	Copper	mg	0.9	10	1.6	1.85	2.26	2.26	2.57	2.28
	Iron	mg	8	45	22	24	36	38	35	35
	Magnesium	mg	420		**290**	415	478	502	467	520
	Phosphorous	mg	713	3957	1817	2540	1846	2223	2339	2169
	Potassium	mg	4700		**3172**	5355	4700	4700	**4700**	5639
	Selenium	µg	55	400	**344**	288	255	264	286	230
	Sodium	mg	1500	2300	3416	**2300**	**2300**	**4607**	**2300**	**2300**
	Zinc	mg	11	40	21	20	20	22	21	21
Vitamins	Vitamin A (RAE)	µg	900	2995	**744**	1332	932	1216	1230	1271
	Vitamin B6	mg	1.4	100	2.8	4.4	4.1	3.8	3.9	4.2
	Vitamin B12	µg	2.4		18	37	16	17	21	16
	Vitamin C	mg	90	1995	151	204	188	116	347	280
	Vitamin D	µg	15	100	16	47	15	18	24	18
	Vitamin E [8]	mg	15	995	**11.4**	**15**	**15**	**15**	**15**	**15**
	Folate (DFE)	µg	400	995	461	515	813	754	729	684
	Niacin (NE)	mg	16		72	100	70	71	74	67
	Riboflavin	mg	1.3		3.8	5.2	3.7	4.6	4.7	4.4
	Thiamin	mg	1.2		2.3	3.3	4.6	4.6	4.5	4.4

Acronyms: AMDR = Acceptable macronutrient distribution range; NE= niacin equivalents; DFE= dietary folate equivalents; MUFA = monounsaturated fatty acids; NE = niacin equivalents; PUFA = polyunsaturated fatty acids; RAE = retinol activity equivalents

Bold type indicates limiting, binding, or inadequate nutrients in the population and modelled diets

[1] Nutrient requirements are based on Health Canada Dietary Reference Intake values. Minimum values are based on recommended dietary allowance (RDA) values. When an RDA was not defined, the adequate intake (AI) value was used.

[2] Mean population diets are based on results from the 24-h recall of the 2008 Inuit Health Survey for Inuit men (n 86) in the Inuvialuit Settlement Region

[3] Results obtained from optimization modelling, where the objective was to derive isoenergetic, diets that met nutrient requirements, while minimizing the departure from the mean population diet. As no feasible model could be achieved, model constraints limiting nutrient intake values, and maximum portion size (< 95[th] percentile of group and subgroup consumption, based on grams). Only nutrient results for feasible model solutions are presented.

[4] Population weighted requirements are based on 2011 census figures for the six communities of the ISR (Statistics Canada 2016)

[5] When available, the upper limit (UL) based on DRIs was included as an upper boundary on nutrient intake.

[6] Models were run on the basis of "free sugar" – defined as added sugar, plus sugars naturally present in honey, syrups and fruit juices (WHO & FAO 2003)

[7] Health Canada does not define an explicit UL value for saturated fat, dietary cholesterol, or free sugar. Therefore, World Health Organization recommendations were used (WHO & FAO 2003). Saturated fat, and free sugars were limited to < 10% of total diet energy.

[8] Vitamin E as α-Tocopherol.

Table 8.5 Comparison between the population-weighted dietary reference intake (DRI), the mean observed population diet for Inuit men in the Inuvialuit Settlement Region, and diets generated by optimization models for Inuit men. Optimization models were formulated to meet nutrient requirements while remaining as close as possible to the observed population diet. Infeasible nutrient and portion constraints were relaxed to achieve feasible model solutions.

		Unit/day	Dietary Reference Intake[1]		Observed[2]	Modelled[3]					
			Weighted requirement[4]		Population mean intake	Relaxing nutrient constraints [5]				Relaxing consumption constraints	
			Min	Max[5]		Model TDF	Model Ca	Model VitE	Model Na	Model CF	Model MF
Macronutrients	Carbohydrate	g	130		244	150	237	234	244	240	242
	Fat	g			79	102	82	72	86	87	87
	Protein	g	46.0		100	157	111	137	101	102	102
	Total sugar [6,7]	g			119	63	73	94	89	101	101
	Saturated fat [7]	g			25	30	18	25	26	26	26
	MUFA	g			29	42	35	27	33	33	33
	PUFA	g			16	20	22	13	18	18	18
	Cholesterol[7]	mg		300	**361**	893	406	420	361	535	535
	Dietary fibre (total)	g	24		**12**	**13**	24	24	24	24	24
Minerals	Calcium	mg	1069	2361	**548**	1069	**408**	1069	1069	1069	1069
	Copper	mg	0.9	10	1	1.4	2	1.7	2	2	1.8
	Iron	mg	15	45	17	15	19	21	18	17	17
	Magnesium	mg	318		225	322	346	383	353	351	351
	Phosphorous	mg	715	3943	1341	2186	1536	2127	1720	1698	1698
	Potassium	mg	4700		2324	4700	4700	4700	4700	4700	4700
	Selenium	µg	55	400	187	182	112	129	99	109	109
	Sodium	mg	1433	2300	**2658**	**2300**	**2300**	**2300**	**3439**	**2300**	**2300**
	Zinc	mg	8	40	13	14	11	14	13	13	13
Vitamins	Vitamin A (RAE)	µg	700	2995	479	1303	839	1089	1057	1124	1124
	Vitamin B6	mg	1.4	100	2	3.5	3	3.8	3	3	2.8
	Vitamin B12	µg	2.4		10	30	19	24	12	12	12
	Vitamin C	mg	75	1995	134	147	185	179	201	279	279
	Vitamin D	µg	15	100	**11**	42	26	34	16	16	16
	Vitamin E [8]	mg	15	995	**8**	15	15	**9**	15	15	15
	Folate (DFE)	µg	400	995	**372**	400	429	457	400	400	400
	Niacin (NE)	mg	14		50	83	66	75	51	49	49
	Riboflavin	mg	1.1		2	3.7	2	3.2	3	3	2.8
	Thiamin	mg	1.1		2	2.2	2	3.2	2	2	1.9

Acronyms: AMDR = Acceptable macronutrient distribution range; NE= niacin equivalents; DFE= dietary folate equivalents; MUFA = monounsaturated fatty acids; NE = niacin equivalents; PUFA = polyunsaturated fatty acids; RAE = retinol activity equivalents

Bold type indicates limiting, binding, or inadequate nutrients in the population and modelled diets

[1] Nutrient requirements are based on Health Canada Dietary Reference Intake values. Minimum values are based on recommended dietary allowance (RDA) values. When an RDA was not defined, the adequate intake (AI) value was used.

[2] Mean population diets are based on results from the 24-h recall of the 2008 Inuit Health Survey for Inuit men (n 86) in the Inuvialuit Settlement Region

[3] Results obtained from optimization modelling, where the objective was to derive isoenergetic, diets that met nutrient requirements, while minimizing the departure from the mean population diet. As no feasible model could be achieved, model constraints limiting nutrient intake values, and maximum portion size (< 95th percentile of group and subgroup consumption, based on grams). Only nutrient results for feasible model solutions are presented.

[4] Population weighted requirements are based on 2011 census figures for the six communities of the ISR (Statistics Canada 2016)

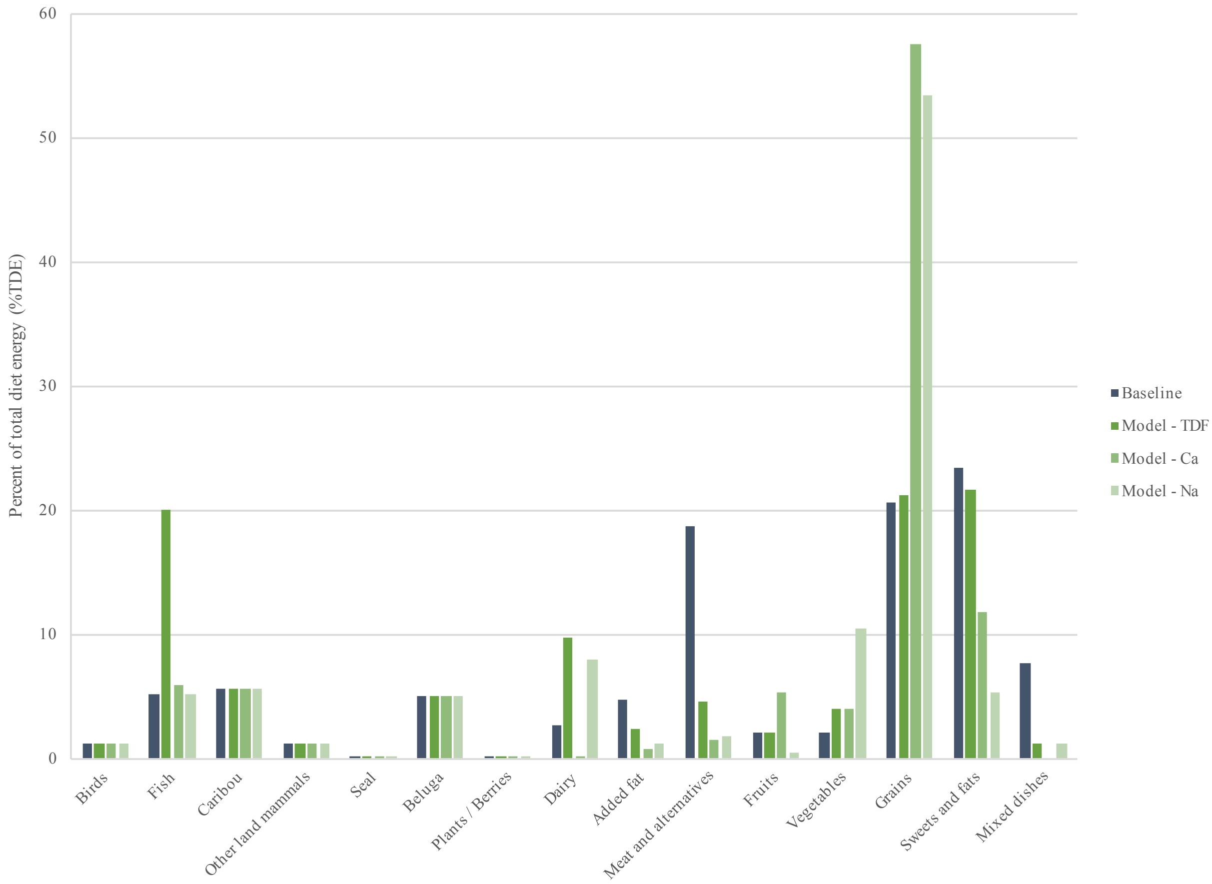
[5] When available, the upper limit (UL) based on DRIs was included as an upper boundary on nutrient intake.

[6] Models were run on the basis of "free sugar" – defined as added sugar, plus sugars naturally present in honey, syrups and fruit juices (WHO & FAO 2003)

[7] Health Canada does not define an explicit UL value for saturated fat, dietary cholesterol, or free sugar. Therefore, World Health Organization recommendations were used (WHO & FAO 2003). Saturated fat, and free sugars were limited to < 10% of total diet energy.

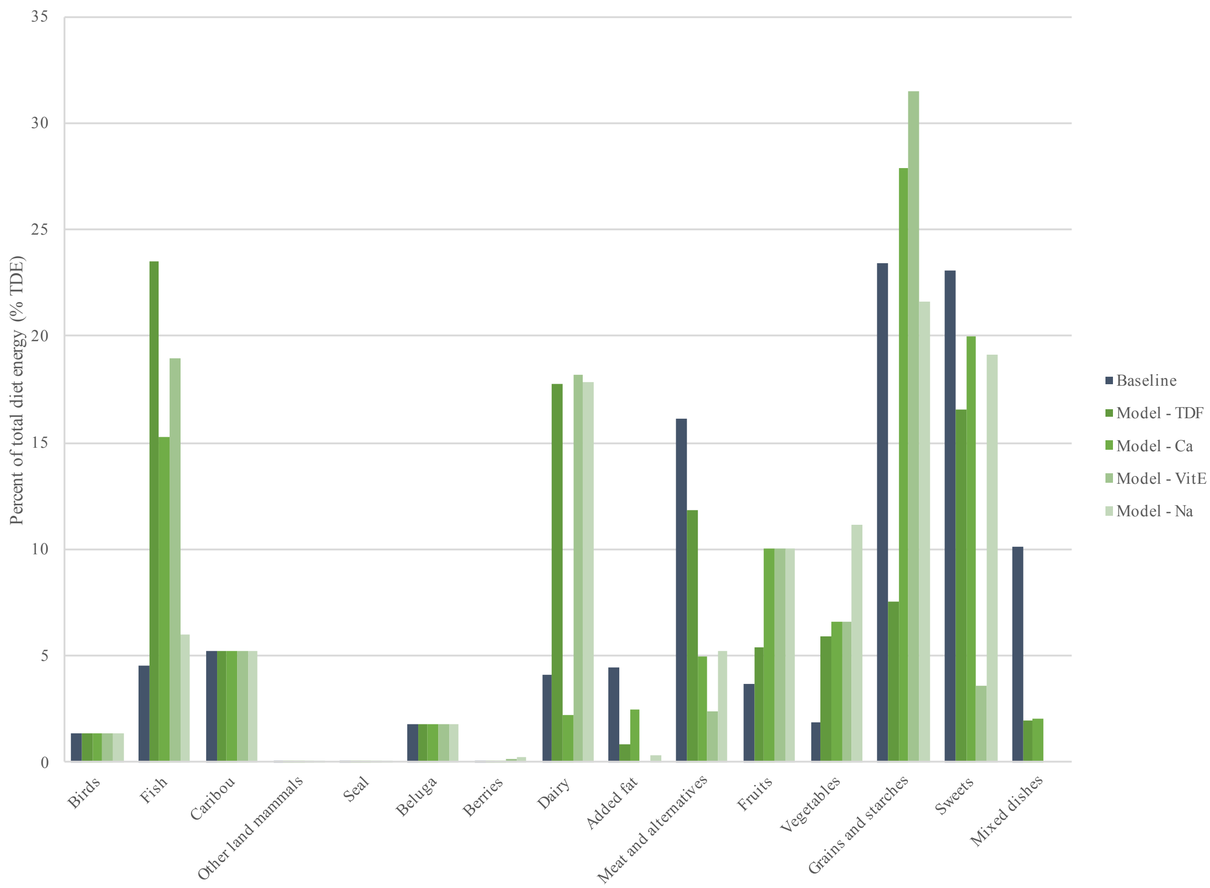
[8] Vitamin E as α-Tocopherol.

Figure 8.3 Effect of relaxing infeasible nutrient constraints for dietary fibre (Model –TDF), calcium (Model – Ca), and sodium (Model - Na) on the composition of food groups (% total diet energy) in the diet of Inuit men in the Inuvialuit Settlement Region.



[1] Relaxing constraints for vitamin D, and vitamin E did not yield a feasible model solution

Figure 8.4 Effect of relaxing binding nutrient constraints[1] for dietary fibre (Model –TDF), calcium (Model – Ca), vitamin E (Model – VitE) and sodium (Model –Na) on the composition of food groups (% total diet energy) in the diet of Inuit women in the Inuvialuit Settlement Region.



[1] Relaxing constraints for vitamin D did not yield a feasible model solution.

8.3.4 Relaxing Food Portion Constraints

A series of optimization models were formulated to evaluate the feasibility of meeting nutrient requirements by increasing intake of food items beyond the 95th percentile of the mean population diet. Given the strong cultural preferences for country foods, constraints limiting maximum country food portions (< 95th percentile) were relaxed until a feasible model was achieved (country food scenario, Model – CF). Figure 5-6 shows the contribution of food groups to %TDE in the population, and modelled, diets. By design, the modelled diet satisfied all nutrient requirements. For men, increasing intake of CF fish (and berries), dairy products, fruits, vegetables, grains and starches, while decreasing consumption of sweets and snacks, mixed dishes, MF meat, and added fat provided a means to meet nutrient recommendations (Figure 5). However, this theoretical required large increases in intake of several foods groups (e.g. a two-fold increase in intake of dairy, fruits, and vegetables) from the mean population diet. It is noteworthy that the cost (market food only) of this theoretical diet (~ CAD$ 12) was lower than the estimated cost of the baseline population diet for men (~CAD$ 14); however, this dietary pattern required drastic changes in patterns of market food expenditure (Figure 8), and relied on greater intake of CF. For women, increasing intake of country food fish and berries beyond the 95th percentile of intake provided a feasible model solution that met all nutrient requirements (Figure 6). Like for men, this also required greatly increasing consumption of dairy, fruits and vegetables (namely solid fruits and vegetables) and markedly reducing consumption of MF meat.

As intake of limiting market foods (e.g. milk, yoghurt, solid fruits and vegetables) in the population diets was very low (including at the 95th percentile), the Model – MF scenario assessed the feasibility of meeting nutrient requirements, by relaxing constraints on maximum market food subgroup portions, until a feasible diet, that satisfied all nutrient requirements, could be achieved (Figure 5-6; Model – MF). For men, patterns of increase in market foods were similar to Model – CF scenario but required greater magnitude of increases in fruits, vegetables, and dairy (Figure 5). For women, magnitudes of increase in key limiting food groups (e.g. fruits and dairy) were similar.

Figure 8.5 Effect of relaxing country food constraint by 100g (Model – CF) and relaxing market food constraint by 50g (Model – MF) on the formulation of nutritionally adequate diets (all modelled diets meet 100% of the nutrient requirements)

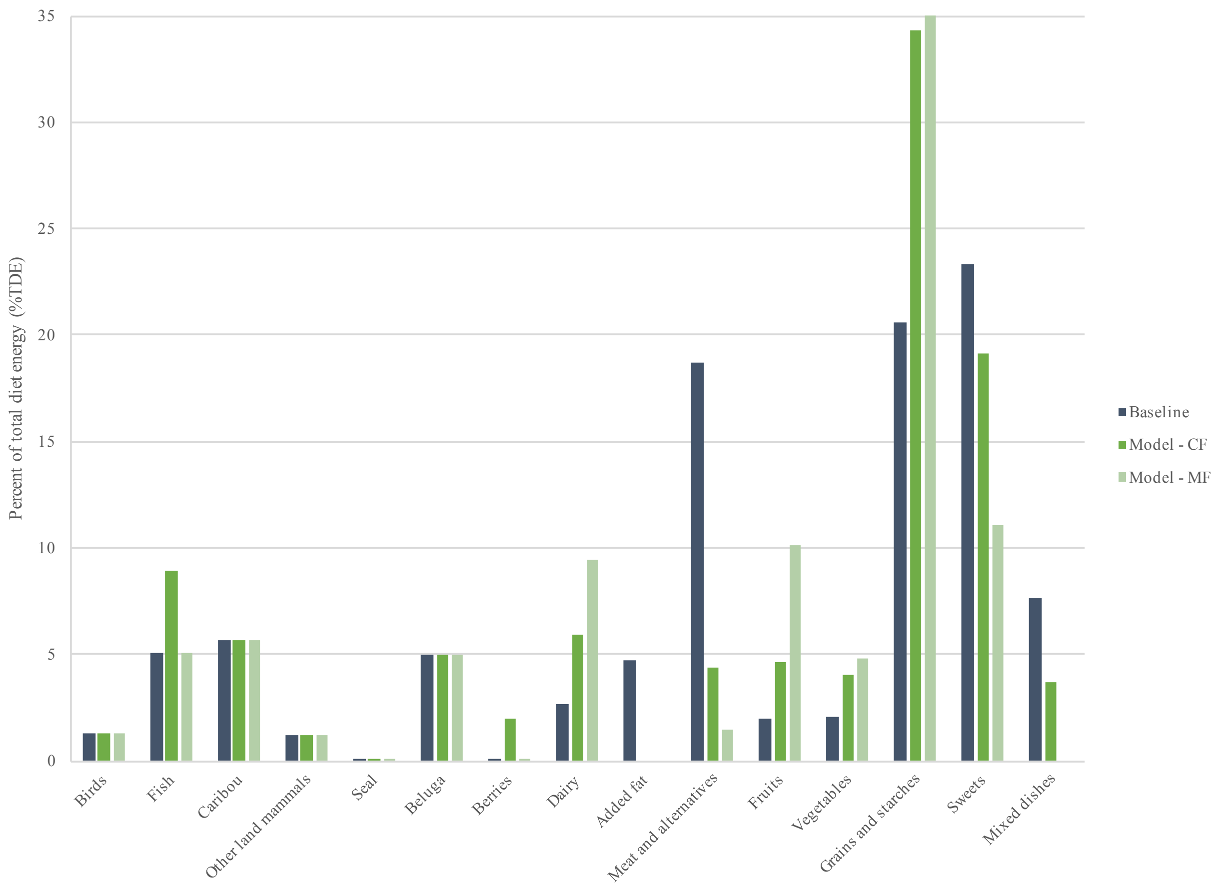


Figure 8.6 Effect of relaxing CF constraint (Model – CF) and relaxing market food constraint (Model – MF) on the formulation of nutritionally adequate diets for women in the Inuvialuit Settlement Region (all modelled diets meet 100% of the nutrient requirements)

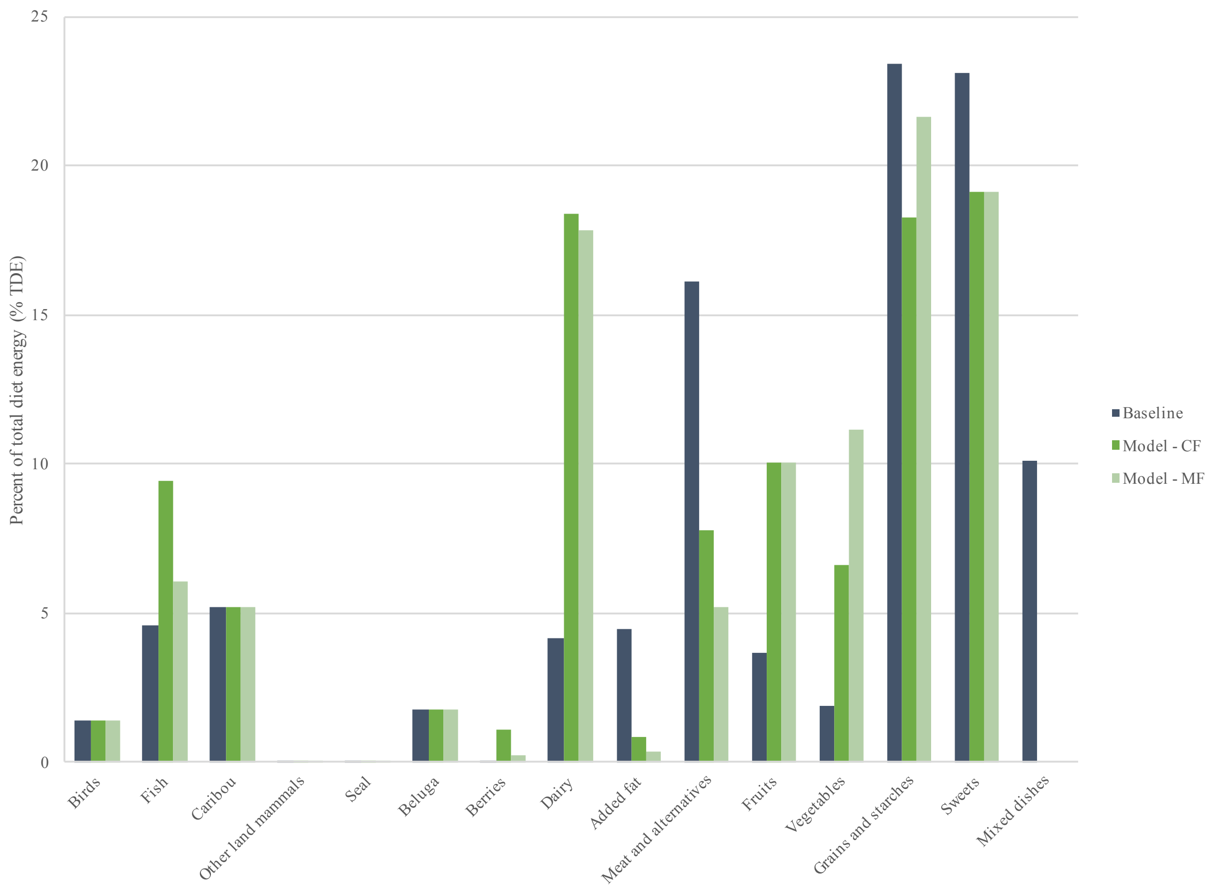
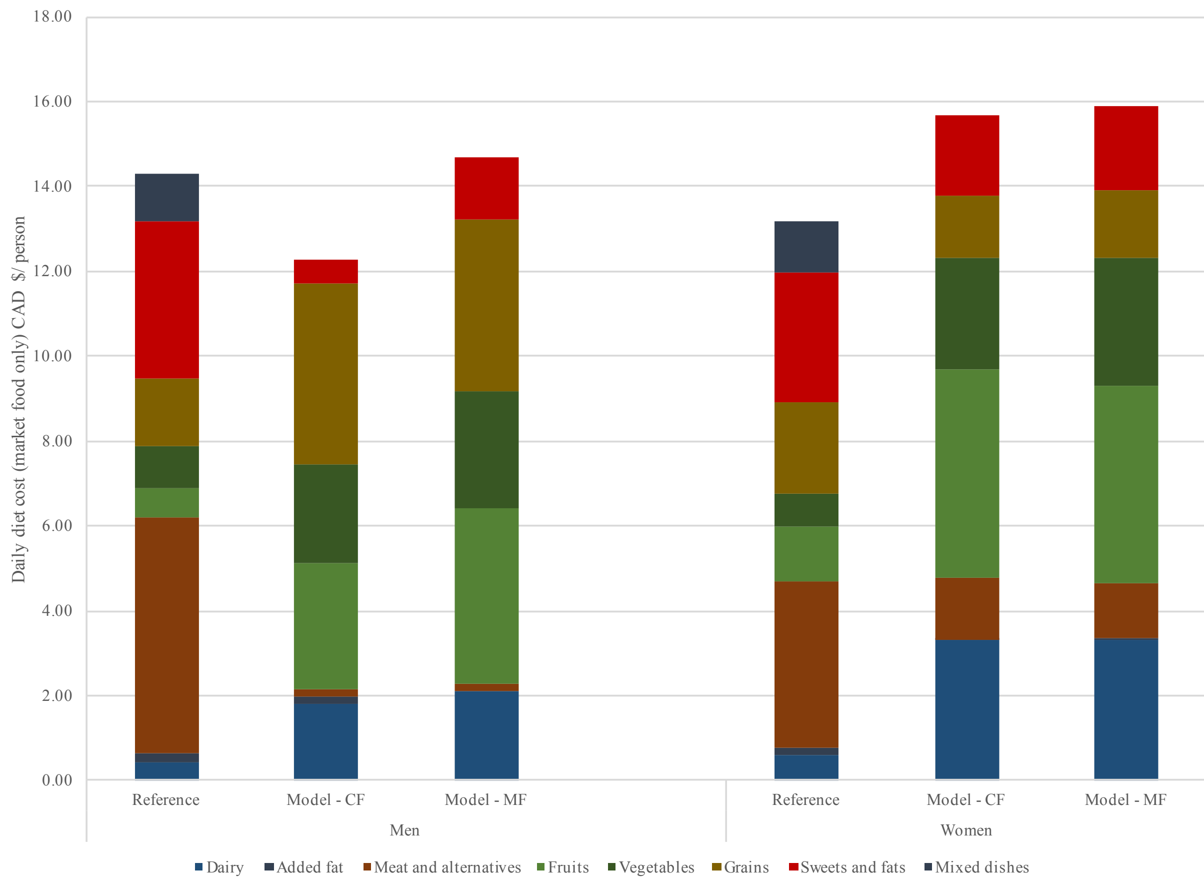


Figure 8.7 Comparison of food group costs (CAD $ / day) between the reference population diets for men and women, and diets obtained through modelling.



[1] Estimated cost of harvest was not included in the total daily diet cost

8.4 Discussion

The promotion of nutritional information is a common public health approach to promoting healthful dietary behaviour (Guthrie et al. 2015). Nutritional knowledge, however, may not be sufficient to motivate behaviour change, as competing interests for taste, convenience, and price may bear greater influence on dietary behaviour (Drewnowski & Darmon 2005; Bisogni et al. 1996). Public education initiatives to increase consumption of dairy products in the Arctic, for instance, have not been effective, and high food costs and dietary preferences/intolerances can be restrictive (Kuhnlein et al. 2007). Moreover, even with optimal dietary behaviour, the local food supply may greatly restrict (or even preclude) the possibility of achieving dietary adequacy. This is particularly relevant in remote communities where access to both nutritious market foods and country foods are challenged by environmental and economic factors.

Using optimization modelling, we have demonstrated that it is infeasible for Inuit adults to collectively achieve all nutrient targets defined by Health Canada DRIs, based on dietary patterns that resemble those documented in dietary surveys for Inuit adults. Even with optimal model behaviour, requirements for dietary fibre, calcium, and sodium could not be collectively satisfied based on observed population diets (i.e. $<95^{th}$ percentile of food subgroup consumption). This suggests that to meet a comprehensive set of nutrient requirements the population diet must exceed the 95^{th} percentile of consumption for certain items, or the diet must be diversified to include greater consumption of lesser consumed market food items and/or country food species and items (e.g. organs).

Deficiencies of dietary fibre, calcium, and vitamin E are pervasive in the diet of Inuit adults across Arctic Canada (Table 1), and are coincident with low consumption of whole grains, dairy products, and solid fruits and vegetables (Kuhnlein et al. 2007; Kuhnlein & Receveur 2007; Erber et al. 2010). Nutrient intake insufficiencies articulate the collective influence of: (i) the population diet; (ii) the nutrient composition of the local food supply (as well as the completeness of nutrient composition tables); and (iii) the standards used to define nutrient intake values. It is important to note that dietary reference values can differ significantly between countries. For instance, dietary reference values for vitamin E (as α-tocopherol) in Canada (Health Canada 2010) are 15 mg/day, over twice the 6.0 - 6.5 mg/day recommendation for Japanese adults (Okubo et al. 2015).

Sodium, dietary fibre, calcium, and vitamin E were identified by optimization modelling as limiting nutrients in Inuit food supply (i.e. nutrients that are difficult to consume at adequate levels, even with optimal dietary behaviours). It is noteworthy that all feasible model solutions reached 100% of the tolerable upper intake value for sodium, even though salt added at the table, and salt-containing seasonings, were excluded in the modelling analyses. Sodium has previously been identified as a limiting nutrient in the French (Maillot et al. 2010; Maillot et al. 2009), Japanese (Okubo et al. 2015), and American (Guenther et al. 2013) diets. Although respecting upper intakes on sodium consumption is theoretically possible, it requires significant deviations from population dietary patterns (Guenther et al. 2013). As reduced sodium intake provides many benefits for cardiovascular health (Cook et al. 2007), these results, echoing similar findings in other populations (Okubo et al. 2015; Brimblecombe et al. 2013), suggest that population-based approaches to reduce sodium content in processed and packaged food in Canada are warranted.

Consistent with our findings, vitamin E (α-tocopherol) has previously been identified as a limiting nutrient in the diet of American adults (Gao et al. 2004). The vast majority of American adults (over 90%) do not meet dietary recommendations for α-tocopherol (J. K. C. Ahuja et al. 2004), and to achieve vitamin E recommendations individuals must dramatically increase intakes of nuts and seeds, and fruit and vegetables (Gao et al. 2004). In a previous survey of Indigenous adults across northern Canada (Kuhnlein et al. 2007), older Inuit men who consumed the most country foods (including organ meats) were the only age/gender group where some participants (12%) achieved adequacy for vitamin E. However, some of these same individuals exceed UL for vitamin D (Kuhnlein et al. 2007).

Dietary reference values defined by Health Canada are for “normal, apparently healthy individuals eating a typical mixed North American diet” (Health Canada 2010). Culture/ethnic specific nutrient recommendations are not currently established in Canada and population specific dietary goals must be designed mindful of their feasibility for selected populations (Okubo et al. 2015). Nutrient intake values from dietary studies of Inuit and other Indigenous Peoples in Canada are routinely compared with national DRIs to ascertain dietary adequacy. Further research may be warranted to ascertain their relevance in populations consuming a mixed diet of traditional/country food and market food. By relaxing constraints on dietary fibre and calcium we were able to achieve feasible model solutions. Indeed, calcium and sodium are generally present in greater amounts in market food relative to country food (Kuhnlein et al. 1996).

Modelling results suggest that meeting nutritional goals requires a dramatic increase in consumption of specific food groups and subgroups. For men to achieve nutrient recommendations, large modifications in consumption of dairy, solid fruits, and solid vegetables are required. Similarly, increasing intake of TF berries, solid fruits, and vegetables and dairy products are required to achieve nutrient recommendations for women. Although nutritionally adequate diets can theoretically be achieved based on a combination of country foods and market foods available in the Arctic, dietary patterns obtained through modelling depart markedly from the observed population diet. Whether such changes are feasible at the population-level warrants further study using participatory and community-based approaches. Even with optimal combinations of available foods, however, some foods groups – in particular, solid fruits and vegetables, and dairy products – are not consumed in sufficient quantities to achieve nutrient intake targets. Without relaxing constraints on maximum food subgroup portion sizes (<95th percentile of population intake) in the models (both CF and selected MF), it was impossible to create a diet that contained adequate calcium, fibre, and vitamin E without exceeding maximum intake levels for sodium. When allowing model portions to exceed the 95th percentile of consumption, a feasible model solution that satisfied all nutrient requirements could be achieved. However, further research is required to ascertain whether this is a feasible option for Inuit communities.

Previous studies using optimization modelling have found that reaching nutritional goals may require consumers to expand their habitual food repertoire (Maillot et al. 2009). However, limited availability and high food costs in remote northern communities may restrict the degree to which consumers can diversity their dietary habits. Although country foods are micronutrient-rich, and culturally preferred, their availability and consumption observes a high degree of seasonality. Seasonality of country food harvest is based on species availability and migration patterns, as well as local/traditional knowledge and other community-specific factors (Priest & Usher 2004). Programs to support extended seasonal use of country food species, such as community freezer programs (Chan et al. 2006; Organ et al. 2014), or programs to support community capacity to safely preserve country foods (e.g. drying and canning) may help extend use of country foods in differing seasons. However, country food access in the Arctic is increasingly challenged by broader environmental factors such as climate change and species declines (Wesche & Chan 2010; Nancarrow & Chan 2010; Rosol et al. 2016). Furthermore, high concentrations of environmental contaminants in country food species (e.g. mercury and persistent organic pollutant) presents a particular challenge for food safety (Wesche & Chan 2010; Laird et al. 2013; Kuhnlein & Chan 2000). Although environmental contaminants were not included in the present models, optimization modelling to maximize nutrient intake from country foods while minimizing contaminant exposure will be explored in future research.

As suggested by Kuhnlein et al. (2007), recommendations for improving dietary adequacy must stress the value of maintaining availability and use of traditional food resources. Importantly, there is a need to integrate traditional knowledge and food composition analyses to identify rich sources of limiting nutrients (e.g. dietary sources of calcium and dietary fibre) from the traditional Inuit diet (Kuhnlein et al. 2007). There is also a strong need to promote underutilized Indigenous species for improved nutrition and health (Boedecker et al. 2014). Indigenous Peoples possess a wealth of knowledge on biodiversity; however, local and traditional knowledge is being lost at accelerating rates (Kuhnlein et al. 2009). Despite this, traditional values and preferences may help to maintain and foster the links between diet, nutrition, biodiversity, and sustainability (Johns & Sthapit 2004; Kuhnlein et al. 2009), particularly in a rapidly changing Arctic environment.

Assumptions and limitations

Optimization modelling is a powerful analytic tool but it presents several important limitations. Modelling involves abstracting the real world into simplified conceptual or mathematical representation. Accordingly, results obtained through modelling are contingent upon validity of the assumptions used in defining the model, as well as the quality and accuracy of the input data. There are a number of fundamental assumptions employed in optimization modelling which have bearing upon its application to human diets (McKnight & Finkel 2013; Locks 1980). These assumptions include (but are not limited to) the requirement that each nutrient is independent of the requirements for all other nutrients, that there are no health benefits of nutrient beyond the required minimum, and that the satisfaction of each nutrient requirement is equally important. Results presented by models are theoretical, and feasibility must be addressed in further research. While the difference between the observed and modelled food diets is considered an indicator of the cultural acceptability of the diet, additional participatory community-based research is necessary to ascertain whether these results are actually culturally acceptable, affordable, or ecologically sustainable.

8.5 Conclusions

This study provides insights into the theoretical possibility of combining locally available market foods and country foods to meet Health Canada nutrient recommendations in an Inuit region of Arctic Canada. Previous recommendations (Kuhnlein et al. 2007) to improve dietary quality in Arctic communities have included: (i) consuming more country food meats, fish, organs, and fats; (ii) encouraging selection of purchased oils high in n–6 fatty acids and vitamin E for cooking and baking; (iii) encouraging consumption of dairy products (yoghurt for those with lactose intolerance); and (iv) selecting whole vegetables and fruits regularly for vitamin C and folate. These results, obtained through modelling, echo previous recommendations; however, they also highlight the significant changes in dietary patterns involved in meeting nutrient recommendations.

8.6 Acknowledgements

The authors gratefully thank Mr. Mathieu Maillot (MS – Nutrition) for support in developing the models.

8.7 Supplemental Material

Table 8.6S Population weighted[1] nutrient requirements[2] for adults in the Inuvialuit Settlement Region.

Nutrient [3]	Unit / day	Weighted requirement Adult males		Weighted requirement Adult females	
		RDA/AI[4]	UL	RDA/AI[4]	UL
Macronutrients					
Carbohydrates	g	130	-	130	-
Total Fiber	g	35.3*	-	23.8*	-
Total Protein	g	55.9	-	46.0	-
Fat	g	-	-	-	-
linoleic acid (n-6)[3]	g	16.0	-	11.7	-
alpha linoleic acid (n-3)[3]	g	1.6	-	1.1	-
Vitamins					
Vitamin A (RAE)	µg	900	2995	700	2995
Vitamin B6	mg	1.4	100	1.4	100
Vitamin B12	µg	2.4	ND	2.4	ND
Vitamin C	mg	89.6	1995	75	1995
Vitamin D	µg	15.2	100	15	100
Vitamin E	mg	15.0	995	15	995
Vitamin K [3]	µg	119*	ND	90*	ND
Niacin (NE)[5]	mg	16	35	14	35
Riboflavin	mg	1.3	ND	1.1	ND
Thiamin	mg	1.2	ND	1.1	ND
Folate (DFE)	µg	400	995	400	995
Pantothenic acid [3]	mg	5*	ND	5.0*	ND
Elements					
Calcium	mg	1016	2356	1069	2361
Chromium [3]	µg	33.4*	-	23*	-
Copper	mg	0.9	10	0.9	10
Fluoride [3]	mg	4.0*	10	3.0	10
Iodine [3]	µg	150	1095	150	1095
Iron	mg	8.1	45	15	45
Magnesium	mg	415	350	318	350
Manganese [3]	mg	2.3*	11	1.8*	11
Phosphorous	mg	713	3957	715	3943
Selenium	µg	55	400	55	400
Zinc	mg	11	40	8.0	40
Potassium	mg	4700*	-	4700*	-
Sodium	mg	1433*	2300	1433*	2300
Chloride [3]	mg	2198*	3600	2197*	3600

[1] Weighting based on the population age-structure in the six community of the Inuvialuit Settlement Region, based on 2011 Statistics Canada census data (Statistics Canada 2016)

[2] Daily adult requirements based on Health Canada Dietary Reference Intake tables (Health Canada 2010)

[3] Requirements for linoleic acid (n-6), alpha linoleic acid (n-3), vitamin K, pantothenic acid, chromium, fluoride, iodine, and manganese, were omitted due to insufficiencies in food composition composition data

[4] Adequate intake values (AI) are denoted by an asterisk

[5] The UL for niacin applies only to synthetic forms obtained from supplements, fortified foods, or a combination of the two

Table 8.7S Intake of food subgroups in the observed diets for Inuit men in the Inuvialuit Settlement Region

Food group	Food subgroup	Population[1] intake, men (g/day)		Population[1] intake, women (g/day)	
		Mean	95th	Mean	95th
Birds	Duck [a]	2	7	1	4
	Goose - meat	11	44	10	40
	Ptarmigan [a]	1	3	0	1
Fish	Arctic char	60	437	36	291
	Cisco	12	46	3	11
	Whitefish [a]	5	19	9	36
Caribou	Caribou meat	89	500	48	287
	Caribou dry meat	3	10	5	19
	Caribou fat	1	3	2	10
	Caribou organs [a]	1	3	1	2
Other land mammals	Moose - meat	7	28	0	2
	Muskox - meat	6	25	0	2
	Bear – meat [a]	0	4	0	1
	Small land mammals [a]	13	52	0	1
Ringed seal	Ringed seal blubber [a]	0	2	0	1
	Ringed seal meat [a]	0	29	0	16
	Ringed seal organ [a]	0	3	1	3
Beluga whale	Beluga oil	7	14	3	12
	Beluga blubber [a]	0	11	0	7
	Beluga muktuk	46	236	5	22
	Beluga meat	1	3	1	3
Berries	Berries [a]	0	6	3	13
Dairy Products	Milk	38	355	43	258
	Coffee whitener (powder)	4	16	3	13
	Cream	9	61	3	15
	Cheese	4	42	11	51
	Yoghurt	3	6	8	97
Added Fats and Oils	Table Fats	9	36	6	22
	Vegetable oils	2	18	2	18
	Lards and shortening	3	19	2	13
	Mayonnaise and dressing	2	16	3	15
Proteins	Poultry	63	367	40	251
	Pork	29	164	18	108
	Beef	26	223	28	145
	Processed meat	29	144	11	75
	Eggs	40	184	23	122
	Fish and shellfish	28	168	22	153
	Meat broths and gravy	61	351	59	351
	Meat alternatives	3	11	3	5
Fruits and Fruit Juice	Total Fruits (solid) [b]	8	85	60	277
	Total Fruits (juice)	88	396	65	526
	Canned fruit	15	30	16	116
	Dried fruit	0	1	0	1
Vegetables	Total vegetable (solid)	70	274	60	259
	Total vegetable (liquid)	77	469	41	354
Grains and starches	Breads	72	256	66	196
	Bannock	21	162	13	87
	Crackers	9	53	15	75
	Rice and pasta	79	393	56	258
	Cereals	52	495	40	336
	Potatoes	54	264	38	173
Sweets and snacks	Sweetened beverages [c]	539	539	530	530
	Granulated sugar	23	92	15	59
	Toppings and preserves	5	13	4	27
	Chocolate & candy	22	132	15	54
	Pastries and granola	35	202	17	95
	Sweet dairy products	3	6	14	110
	Potato Chips [c]	15	118	10	75

Food group	Food subgroup	Population[1] intake, men (g/day)		Population[1] intake, women (g/day)	
		Mean	95th	Mean	95th
Mixed dishes and other	Mixtures (mainly grain)	118	509	106	507
	Mixtures (mainly meat)	21	102	25	170

[1] Mean population diets are based on results from the 24-h recall of the 2008 Inuit Health Survey for Inuit men (n 86), and women (n 181) in the Inuvialuit Settlement Region.

[a] Intake of country food items was zero at the 95th percentile the upper limit was set to the intake observed in other Inuit regions of the 2007-8 Inuit Health Survey

[b] as intake of solid fruits were very low (i.e. 95th percentile = 0, or < 10 grams), the upper limit was set to the intake observed in other Inuit regions of the 2007-8 Inuit Health Survey.

[c] Consumption of sweetened beverages among study participants was already high, therefore the upper limit was restricted to the mean population intake.

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9 LINKING HEALTH AND ENVIRONMENT THROUGH EDUCATION – A TRADITIONAL FOOD PROGRAM IN INUVIK, WESTERN CANADIAN ARCTIC

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ABSTRACT

We are reporting on a Traditional Food project at East Three Schools (Inuvik, Northwest Territories), in the western Canadian Arctic. The objective is to share our process and promote the development of similar activities in other Indigenous communities. The project was initiated to promote youth engagement with traditional foods in a school-based setting – including the development of knowledge (e.g. nutritional benefits) and skills (e.g. butchering, cooking, and preserving). The project was developed following a strategic planning process to promote food security in the Inuvialuit Settlement Region. The project was developed by working in close collaboration with the Inuvialuit Regional Corporation, staff at East Three (namely the Foods teacher), and community-based Indigenous organizations (e.g. Hunters committees) and is part of the research team's longer-term engagement in the development of evidenced-based strategies to promote food security in the region.

9.1 The Goal of the Project

Indigenous Peoples of the Canadian Arctic have been sustained by the harvest of local wildlife, termed "traditional food" (TF) for millennia. Rapid sociocultural change in the last several decades, however, has fostered greater reliance on store-brought foods (particularly those of poor nutritional quality) (Egeland et al. 2011; Zienczuk & Egeland 2012; Kuhnlein et al. 2004; Kuhnlein & Receveur 1996; Erber et al. 2010; Hopping et al. 2010), and undermined subsistence-based lifestyles – including the transmission of traditional knowledge, and skills to youth (Pearce et al. 2011; Collings et al. 2016). The Traditional Food project was initiated at East Three Schools in Inuvik, Northwest Territories (NT) to support youth in acquiring traditional knowledge and skills, in a school-based setting. The goal of the project was to expand the scope of activities in existing secondary-school Foods classes, towards greater inclusion of local values and priorities, by convening youth, harvesters, and elders, around TF and medicine.

9.2 Importance to Community

9.2.1 Setting

Inuvik (pop. ~3500) is a planned Arctic community in the Inuvialuit Settlement Region (ISR), situated at the confluence of the traditional territories of the Inuvialuit (Inuit) and Gwich'in (Dene First Nations) Peoples (Figure 9.1). During the mid twentieth century, Indigenous Peoples of the western Arctic settled from land camp to permanent communities, and by the 1970s, most Indigenous children were enrolled in residential day schools (Salokangas & Parlee 2009; Truth and Reconciliation Commission 2016). Today, a single elementary school and high school (East Three Secondary Schools) in Inuvik service over 700 students from the community, including secondary students from remote neighboring hamlets. Indigenous students in Canada experience significant disparities in educational attainment relative to national averages, and discontinuities between formal approaches to education, and traditional Indigenous knowledge, together with systemic inequities, including the legacy of the residential school system (Truth and Reconciliation Commission 2016), collectively challenges the academic success of Indigenous students (Gordon et al. 2014; Salokangas & Parlee 2009).

Figure 9.1 Location of Inuvik, and the five Inuit communities that comprise the Inuvialuit Settlement Region in the Northwest Territories, western Canadian Arctic.

9.2.2 Development of the Project

The TF Project was developed as an action-oriented activity emergent from the research team's long-term engagement in food safety and food security research in the region. The 2007-8 Inuit Health Survey documented that nearly half (46%) of Inuit households in the ISR experienced food insecurity, a rate significantly exceeding the Canadian average (6.1%)(Egeland 2010). A strategic planning process was thus initiated, to convene researchers, and representatives from Inuit community organizations, and local, and territorial, governments, in identifying programs and activities to support food security (i.e. reliable access to a sufficient quantity of affordable, nutritious food, and culturally-acceptable food) in the region(Fillion et al. 2014). The Traditional Food program holistically responded (both explicitly and implicitly) to several community-identified priorities(Fillion et al. 2014): learning how to cook traditional foods, and identify local vegetation; recognizing traditional skills in school curriculum; and, promoting experiential learning opportunities for students.

9.2.3 Implementation and Activities

The TF project was developed to increase opportunities for students to become engaged in the full cycle of TF procurement — from harvest, to preparation, consumption, and sharing. The project was developed in partnership with the Inuvialuit Regional Corporation and staff at East Three Secondary, and was implemented by working closely with local harvesters, elders, and, community-based organizations (e.g. Hunters and Trappers Committee). Two Indigenous youth from the community were hired to assist in the development and delivery of the project. Students from grades 7 to 12 (approximately 12 to 18 years), participated in a suite of traditional food activities, both in the classroom and on the land (Figure 9.2).

Students participated in regular outdoor activities to identify and gather traditional medicinal plants (e.g. Labrador tea, spruce gum). In the spring, students learnt to harvest birch tree sap (a traditional Indigenous activity in the territory) and prepare syrup. In the fall, students accompanied by community elders, participated in a day of berry picking (e.g. cranberries, crowberries) at the local Territorial park. During the day, students heard stories from elders of life on the land before permanent settlements, and the importance of berries to traditional culture in the region. Students shared a portion of their berries for use in future school programs. In a follow-up classroom-based activity, students reconvened with one of the elders to prepare recipes with the berries (e.g. medicinal berry juice and berry bannock), and learn about their nutritional and medicinal value. Recipes prepared with the berries were shared with younger students during snack-breaks.

Middle school and high school students enrolled in the Foods classes learnt traditional (and contemporary) methods of butchering, preparing, and preserving (e.g. smoking, and drying) various TF species, including Arctic char and caribou, from community elders. Traditional foods were either donated by community-based organizations for program use, or obtained directly from local harvesters. Once prepared, foods from the program provided nutritious snacks and meals to students, and were also shared with elder programs in the community.

A series of food-based activities were also developed in partnership with the Intergenerational Program (a therapeutic recreation program(Lee & Peterson 1984)) at the Long Term Care (LTC, Beaufort-Delta Health and Social Services) unit to convene generations, and build on the inherent strength of elders to share their traditional knowledge with youth (e.g. traditional food and crafts). During the scholastic year, middle school students from East Three participated in weekly visits to the LTC unit to cook traditional food with the guidance of elders.

Figure 9.2 Summary of program themes and activities

Traditional plants and medicine (on the land and in the classroom)

- Identifying local vegetation, and learning about the nutritional and medicinal values of local plants
- Gathering local berries (e.g. cranberries, crowberries)
- Learning to collect birch sap and make birch syrup
- Learning to prepare and and preserve local berries
- Learning about the nutritional importance of local berries

Traditonal Food Preperation (in the classroom)

- Expanding scope of existant Foods classes
  - Traditional food butchering
  - Traditional food preperation / recipes
  - Traditional food preservation

Traditional food sharing (in the commmunity)

- Preparing stews and soups with traditional food to share with elders
- Preserving (e.g. freezing and sealing) animal parts highly valued by elders (e.g. fish heads, caribou bones) and donating them to the community's elder luncheon program

Intergenerational (in the community)

- Convening elders and youth on a weekly basis to prepare traditional food at the Long Term Care unit
- Planter boxes were built by students and were donated to Long Term Care

9.3 Outcomes and Summary

The TF project ran between the spring of 2015 – 2016, while the traditional food activities of the at Long Term Care remain ongoing. The TF project provisioned an abundant supply of TF for use in school programming and activities (e.g. community feasts) and provided an opportunity for elders, harvesters, and Indigenous community organizations to support youth in developing traditional knowledge, and skills, in a school-based setting. Within this setting, Indigenous language learning (Inuvialuktun and Gwich'in languages) became an organic extension to program activities. The program supported hands-on traditional ways of teaching, both in the classroom, and on the land,

and provided a means of valorizing the traditional knowledge and skills held by students. While teachers are strongly encouraged to integrate place-based education and traditional Indigenous ways of knowing (Salokangas & Parlee 2009) in the territory, limited formal mechanisms may currently exist to support this process. The TF project highlights the merits of place-based, experiential, education, for Indigenous youth, and the need for appropriate policy to sustain these activities over the long term. Furthermore, the project highlights the strength of multisectoral collaborations between researchers, the education sector, and community-based organizations, in Indigenous communities.

9.4 Acknowledgements

The authors wish to express their gratitude to the students and staff at East Three Secondary and Elementary Schools, the Inuvik Hunters and Trappers Committee, the Inuvik Community Corporation, the Inuvialuit Regional Corporation, the Nihtat Gwich'in Renewable Resource Council, and Beaufort Delta Health and Long Term Care. Funding support for the project was provided by the Students for Canada's North program of the University of Ottawa and the Canada Research Chair Program.

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10 CONCLUSION

TiffAnnie Kenny

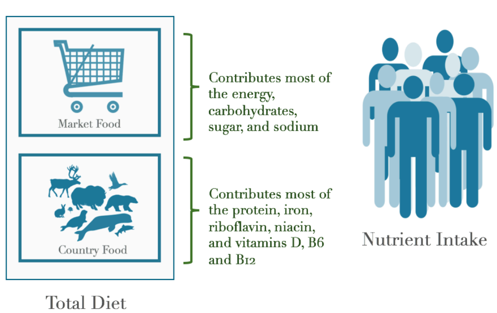
Chapter 10 concludes the dissertation. It provides a recapitulation of findings in chapters 3 to 9 of the dissertation. It discusses and the strengths, limitations, and challenges to the work undertaken throughout the thesis and describes the contributions and implications of the dissertation. Finally, the chapter concludes with avenues for future research.

10.1 Recapitulation of Thesis Findings

Food security and dietary adequacy remain elusive for Inuit communities. Changing biophysical conditions, globalization, and integration into market economies are collectively challenging access to both country foods and nutritious market foods in the Arctic. The nutrition transition may be conceptualized as mediated by two broad paradigms that involve: (i) the reduced presence of country foods in the diet, and (ii) broader sociocultural and economic factors that promote consumption of low-nutrient density market foods in lieu of country foods. Ecological and environmental factors, as addressed by this thesis, are important drivers of nutrition transition among Inuit in the Arctic.

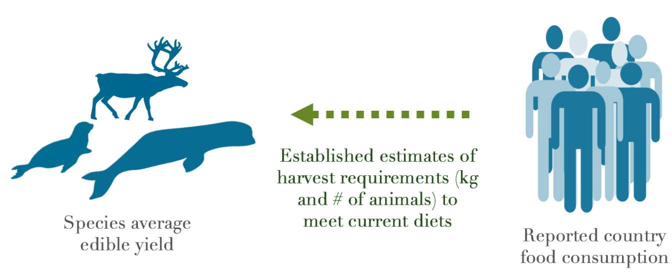
As recently as 1987, country foods provided up to almost half (44% of total diet energy) of the Inuit diet (based on data from men in the Qikiqtaaluk region) (Kuhnlein 1995). In contrast, the highest contribution of country food reported by participants of the 2007-8 Inuit Health Survey (for older Inuit men in the Nunavut) was just over a quarter of the total diet (28% of total diet energy) (**Chapter 6**). Despite their modest contribution to total diet energy, country foods represent a major source of protein (23-52% of total intake) and several micronutrients, including (but not limited to): iron (28 – 54%), niacin (24 – 52%), and vitamins D (up to 73%), B6 (18 – 55%), and B12 (50 – 82%) (**Chapter 6**). It is clear that country foods, in addition to their cultural significance (critically important but beyond the scope of the dissertation), are critical for the well-being of the Inuit.

Figure 10.1 The contribution of country foods and market foods to energy and nutrient intakes



Section 1 (Chapter 3 – 5) attempted to bridge the often disparate fields of human health and wildlife conservation by addressing several questions about the status and management of Arctic species, and the implications for human nutrition, food security, and health in Inuit regions. Significant research on the contribution of biodiversity to nutrition has been undertaken in some of the most biodiverse regions on Earth (reviewed in **Chapter 2**). Despite residing in some of the lowest species rich regions on the planet, Inuit adults across northern Canada reported consuming over 80 country food items (species and parts) (**Chapter 3**). Caribou (*Rangifer tarandus*) was both the most frequently reported country food species (reported as consumed by over 90% of participants) and the species consumed in highest amounts 29.6 – 122.8 kg/person/year, according to sex and region. In addition, consumption of beluga whale (*Delphinapterus leucas*) and ringed seal (*Pusa hispida*) were also very important, with a mean annual consumption of 5.9 – 24.3 and 4.1 – 25.0 kg/person, respectively (depending on sex and region). Based on this level of consumption, it was estimated that a mean total of 36,526 caribou, 898 beluga whales, and 17,465 ringed seals are required annually between the Inuvialuit Settlement Region, Nunavut, and Nunatsiavut to sustain current diets. This is the best estimate for the number of wildlife reported to be consumed by Inuit, and may provide important baseline data for communities, and wildlife management bodies, to plan for the sustainable harvest of country foods.

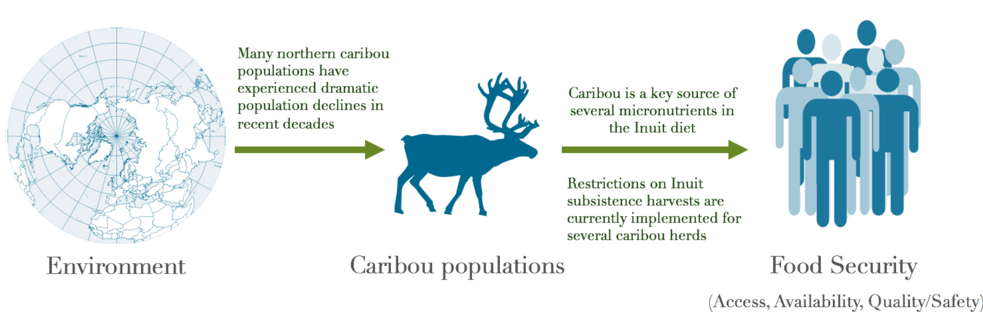
Figure 10.2 Establishment of harvest requirements based on reported food consumption



These levels of consumption raise questions regarding the capacity of Arctic ecosystems to provision this food provisioning service, as well as the sustainability of Indigenous subsistence harvests. These questions inspired the research of **Chapter 4-5** which jointly investigated species status, human nutrition, and health. Although Inuit Land Claim Agreements recognize the right of Inuit to harvest a wildlife stock or population up to the full level of his or her economic, social, and cultural needs (as part of the wildlife co-management process), a total allowable harvest may be established to protect species conservation interests (Natcher et al. 2012). Population status of Arctic species is increasingly threatened by the pervasive influence of human activities and climate change (Kutz et al. 2013). Although various factors including climate, habitat degradation, prevalence of disease and parasites, and levels of predation and harvest have been attributed to the observed population declines, wildlife management regimes have often focused on quota and other non-quota harvest restrictions to conserve the wildlife species.

Chapter 5 used a case study of northern caribou (*Rangifer tarandus*), a "cultural keystone: species" (Garibaldi & Turner 2004) in the Inuit food system, to investigate the implications of species status and conservation for human nutrition. Caribou has been fundamental to the diet and culture of Arctic Indigenous Peoples for thousands of years and remains critical to nutrient provisioning. Caribou was the number one source of iron (14 – 37%), zinc (18 – 41%), copper (12 – 39%), riboflavin (15 – 39%) and vitamin B12 (27 – 52%), as well as a top source of protein (13 – 35%), vitamin B6 (7 – 23%), and phosphorous (7 – 22%) in the diet of Inuit adults across the north. Most caribou herds across the circumpolar north have experienced dramatic abundance declines in recent decades. While some populations are currently stable from historic declines, others are enduring rapid and ongoing declines. Only rarely (e.g. Porcupine caribou) are populations exhibiting increasing abundance trends. Though hunting by humans is generally not understood to represent the principle cause of these declines, species conservation measures often take the form of quota (and other non-quota) harvest restrictions. Restrictions on Indigenous subsistence are currently enacted on several caribou herds whose annual range are within the Inuit regions in Canada.

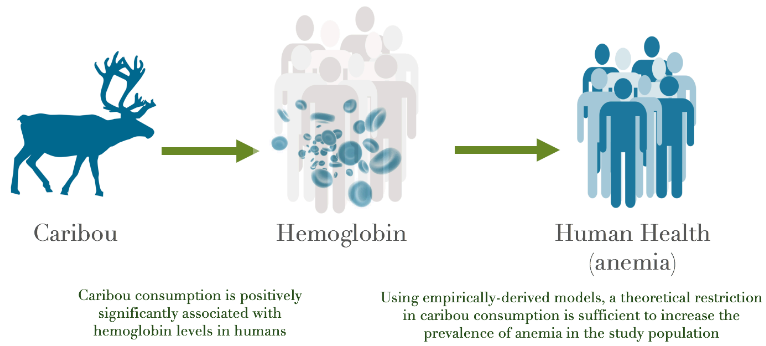
Figure 10.3 Examining the relation between caribou declines and food security



While these restrictions present potential implications for the food and nutrition security of tens of Inuit communities, it is unclear how public health has responded to these constraints. Although restrictions on Inuit subsistence harvest are (generally) adopted through a wildlife co-management process with Inuit harvester organizations (as required by Inuit Land Claims Agreements), these restrictions may nonetheless place Inuit communities at increased risk for adverse health and poor diet quality.

Building on the importance of caribou to Inuit nutrition – in particular, the importance of caribou to nutrients necessary to erythropoiesis (the creation of red bloods) – **Chapter 5** established a critical link between country food consumption and human health status in the Arctic. Anemia (a condition of low red blood cells or blood hemoglobin levels) is a moderate (25-30 %) (Jamieson & Kuhnlein 2008; Jamieson et al. 2016) to severe (40-43%) (Plante et al. 2011) public health problem among Inuit in Canada. An empirical model was developed to establish the link between caribou consumption and hemoglobin, and simulate the theoretical impact of restricted caribou access (whether through species decline, changing dietary preference, or harvest quotas) on the population distribution of hemoglobin – and the attendant change in anemia prevalence in the Inuit adult population. Average daily caribou consumption was positively associated (<0.001) with blood hemoglobin levels. The overall prevalence of anemia observed in the study population was 26.5% and a simulated restriction in caribou consumption (i.e. caribou=0) increased the overall prevalence of anemia by approximately 6%. The maximum negative effect of caribou restrictions was related to a complete restriction on caribou consumption, coupled with the substitution of caribou with other country food meat (35.4% prevalence).

Figure 10.4 Linking wildlife declines to human health outcomes

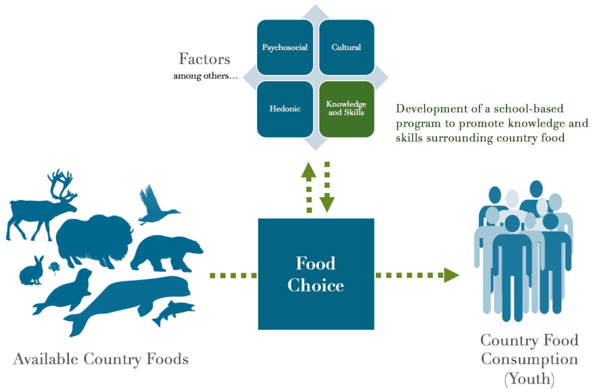


It is clear that species conservation policies (from habitat protection to harvest management) will either promote or suppress Inuit access to country foods, both in the short term and over the long term, with attendant consequences on food security, nutrition, health, and wellness. A holistic approach that integrates human and ecosystem health is therefore needed to maintain the sustainable harvest of wildlife while promoting the food security of Inuit communities. Yet, even in the theoretical circumstance of adequate species access, consumption of country food can be suppressed by broader sociocultural factors related to food choice and changing lifestyles. Establishing the link between biodiversity and human health/nutrition is, thus complicated by the underlying factors influencing food choice, such as capacity and skills, and "taste" preferences. Inuit possess a wealth of knowledge on local biodiversity; however, local and traditional knowledge is being lost at increasingly accelerating rates (Kuhnlein et al. 2009). Thus, knowledge, capacity, and skills are critical elements of the food system, and important mediators of the link between biodiversity and human nutrition.

Chapter 9 describes the development and implementation of a Traditional Food (TF) Project at East Three Elementary and Secondary Schools in Inuvik, Northwest Territories, Canada. The TF Project was developed as an action-oriented activity emergent from the author's food security research in the region, and was developed following a strategic planning process to convene researchers and representatives from Inuit community organizations with local and territorial governments in identifying programs and activities to support food security in the region (Fillion et al. 2014). The TF Project responded to several regional priorities: learning how to cook traditional foods and identify local vegetation;

recognizing traditional skills in school curriculum; and promoting experiential learning opportunities for students.

Figure 10.5 The importance of traditional knowledge and skills to support country food consumption

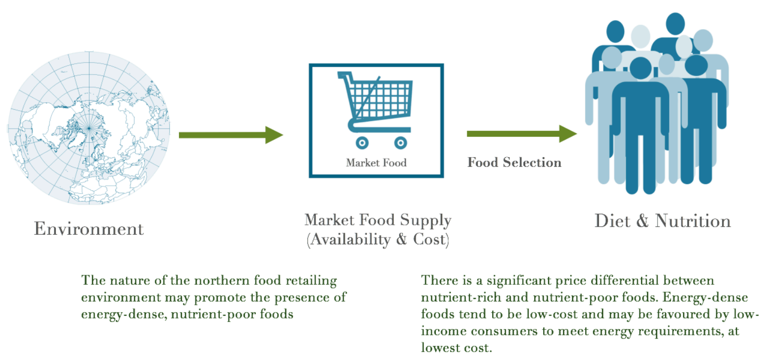


While restricted access to country food is an important determinant of the nutrition transition, consideration of the traditional dimension of the food system, exclusively is incomplete in describing the factors that have shaped adoption of the alternative market food consumption patterns. Although country foods are critically important for health and culture, it must be acknowledged that most Inuit adults (74% to 80%, according to region) today prefer eating a mix of market food and country food (Egeland 2010a; Egeland 2010b; Egeland 2010c). Dietary adequacy is theoretically possible upon the consumption of market foods of high nutritional quality. In practice, however, the remote and/or northern context of many Indigenous communities renders impossible the timely and economic transport of nutritious perishable foods.

Chapter 6 characterized the major components of the contemporary diet of Inuit adults, and identified the primary sources of dietary energy and essential nutrients. The three most popular energy-yielding market foods (i.e. sweetened beverages, added sugar, and bread) collectively contributed approximately 20% of total energy, while contributing minimally to most micronutrients. A notable exception was the contribution of these foods to calcium (13.2 – 21.4%), and vitamins E (17 – 35%), and C (as much as 50%). Solid fruits were consumed by less than 25% of participants across all regions, and while vegetables were reported by 38-59% of respondents, vegetable consumption was generally comprised of vegetable preparations (e.g. soup and sauce) and few solid/whole vegetables were reported in the dietary recalls.

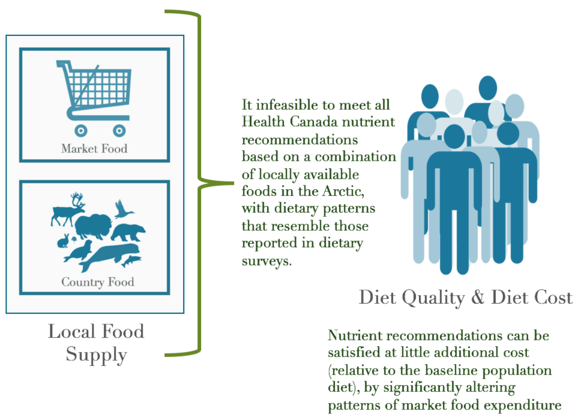
While considerable attention has recently been paid to the issue of the diet transition and food insecurity among Inuit, there has been limited study on the economic aspects of this transition. **Chapter 7** describes a participatory food costing study in which community research assistants systematically collected food prices in six communities of the western Arctic during a 14-month period (late 2014 to early 2016). Food prices in the region were markedly higher than the national average. The average cost of the Revised Northern Food Basket (to feed a family of four for one week) was CAD $410, over two-times the cost of feeding a family of four (CAD $192) in Ottawa, the nation's capital. More importantly, these results provide evidence of price differentials between energy-dense nutrient-poor foods and costlier nutrient-rich foods in a northern remote setting of Arctic Canada.

Figure 10.6 Relating factors of the market food environment to human nutrition in the Arctic



Although numerous studies have documented inadequacies of dietary fibre, calcium, and vitamin E among Inuit adults in Canada (Erber et al. 2010; Kuhnlein et al. 2007; Kuhnlein 2003; Hopping et al. 2010; Sharma et al. 2013), no previous research has documented the feasibility, and cost, of achieving a set of national nutrient recommendations using locally available foods (both market food and country food) in Arctic Canada. Using optimization modelling, **Chapter 8** demonstrated that it is mathematically impossible to generate a theoretical diet for the adult Inuit population that satisfied all nutrient requirements, within the 95th percentile of subgroup consumption, as reported in the dietary surveys. Calcium, dietary fibre, vitamin E, and sodium (upper tolerable intake level) were the most difficult requirements to fulfill. Only by relaxing the portion size constraint was it feasible to meet the requirements; however, significant (increases in consumption of several food groups (i.e. dairy products, fruit and vegetables, and grains and starches), coupled with significant reductions in consumption of sweetened beverages, as well mixed dishes and meat (market food), were necessary. Although the modelled nutritionally-adequate diets did not markedly increase the estimated cost of market foods (the maximum increase was approximately CAD $2/day, from the reported mean of roughly CAD $12), they required significant changes in expenditure on different market food groups (significantly decreasing expenditure on sweetened beverages and market food meat).

Figure 10.7 Examining the feasibility of meeting nutrient requirements in the Arctic



10.2 Limitations

This dissertation is an initial attempt to study the complex relationships between ecosystems, nutrition, economies, and health in the Arctic. The dissertation integrated multiple lines of inquiry and multiple scales of engagement in an attempt to address the complexities of the Inuit food system. While the multidisciplinary, systems-oriented focus of the dissertation constitutes one of its principle strengths, a number of conceptual and methodological challenges permeated efforts to integrate the often disparate fields of human nutrition, wildlife conservation, and economics. Indeed, the complexity of bicultural and socioeconomic systems has to date largely hampered empirical evidence establishing links between human nutrition and local biodiversity. This section presents an overview of the broad challenges of the thesis research. Specific study limitations are described in the discussion of the respective manuscript chapters.

Inuit Health Survey

Data presented in several chapters of the dissertation are derived from a cross-sectional health survey of Inuit adults (Inuit Health Survey). By nature of the survey design, causal inferences cannot be drawn (e.g. hemoglobin levels and caribou consumption, **Chapter 5**). Use of the survey data presumes the study sample is representative of the population. Although the IHS employed a stratified random sampling design, Inuit Health Survey Steering Committee members have cautioned that for some communities, data collection coincided with an important period of harvest. Consequently, harvesters (who generally consume more country food) may have been underrepresented in the study sample.

Scale of Inquiry

The Inuit Health Survey was designed to be regionally representative of Inuit diet and health, where regions were defined based on administrative/government jurisdictions (e.g. Nunatsiavut, the Inuvialuit Settlement Region). Even at the regional scale of inquiry, significant heterogeneity exists between Inuit communities. The Inuvialuit Settlement Region for instance, is comprised of four coastal and two inland communities that represent three Inuvialuktun dialects (Natsilingmiutut, Inuinnaqtun, and Siglitun) and several ecosystems and ecozones (e.g. Taiga Plains, Northern Arctic and Southern Arctic; Figure 10.8). Accordingly, regional scale inquiries obscure community-specific variables in the food system. Anthropological research has made significant and in-depth contributions to understandings of Inuit food systems (Collings et al. 2016; Condon et al. 1995; Wenzel 1995). However, community-scale inquiries may lack the broader focus to integrate the human dimension into broader studies of changing Arctic environments. Conversely, significant pan-Arctic research efforts have been conducted on biophysical and ecological dimensions of Arctic change (Russell et al. 2015; Meltofte 2013; Johannessen et al. 2004). These studies, while acknowledging human reliance on wildlife for culture and subsistence, generally do not integrate explicit considerations of human health.

Figure 10.8 Terrestrial ecozones of Canada

Source: Canadian Biodiversity: Ecosystem Status and Trends (Canadian Councils of Resource Ministers 2010)

Dietary Assessments

It is imperative to understand the seasonal nature of country food consumption (Mackey & Orr 1988). However, the Inuit Health Survey collected a single 24-hour dietary recall from each participant (late summer to fall). Consequently, all results in the dissertation pertaining to the 24-hour recall reflect consumption during the late summer/fall when the survey was conducted. While the food frequency questionnaire was designed to capture annual (both in season and out of season) consumption, it pertained almost exclusively to country foods (a very limited number list of market food items was also collected).

More fundamentally, data derived from dietary assessments (both the food frequency questionnaire and the 24-hour recall) are designed to capture foods *actually consumed* rather than *desired* diets. Reported food use reflects various economic and ecological facilitators/constraints in the food system. For example, low caribou consumption recorded by dietary assessments may reflect harvest quotas or changing species migration rather than inherent dietary preference. Although the Inuit Health Survey included a household questionnaire which solicited information pertaining to food security (based on an adapted form of the the 18-item United States Department of Agriculture (USDA) Food Security Survey Module (Bickel et al. 2000) and country food access, novel methodologies to integrate multiple sources of information (e.g. food prices and harvester data) are needed to derive meaningful relationships between constraints/facilitators in the food system and reported diets.

Reducing diets to nutrients

Human diets can be viewed in several ways: from chemicals (such as essential nutrients and contaminants), to foods, food groups, and holistic dietary patterns (Willett 2013). Deconstructing diet into mere nutrient intake (as is the case in several dissertation chapters) constitutes a reductionist (and rather limited) approach to understandings of human diet and health. As dietary patterns encompass the cumulative effect of multiple dietary components, they can yield more meaningful insights into the relationship between overall diet and chronic disease (Hu 2002). An analysis of Inuit dietary patterns and cardiovascular health was undertaken by the author during the course of research, but is beyond the scope of the dissertation.

Empirical focus

At several points, the dissertation qualifies the "importance" of country foods based on quantitative metrics relating to diet and nutrition. For example, the magnitude of consumption (e.g. kg/year) and the contribution of country foods to nutrient intakes are highlighted as justificatory of the importance of country foods to diet. These metrics, while relevant from a dietary standpoint, neither embodies the cultural importance of country food consumption nor the sociocultural nuances in the diet. Certain country food items may represent a negligible fraction of the diet when expressed on the basis of the aforedescribed metrics, but may articulate a critical link between biodiversity, food security, culture, and wellness. Although this link is perhaps best approached with participatory qualitative research methods, better integration of this knowledge within the field of human nutrition will provide important insights into the cultural dimensions of the dietary transition.

10.3 Implications

The FAO contends that "nutrition and biodiversity converge to a common path leading to food security and sustainable development" (FAO n.d.). Successful interventions to promote sustainable ecosystems, and support the use of biodiversity and for human health and nutrition are likely to involve biophysical, social, and economic dimensions of the food system. However, institutional, epistemological, and, disciplinary divides may challenge the capacity for researchers, practitioners and policy makers to address cross-cutting issues humans of nutrition.

This research is among a very limited body of scholarship (Rosol et al. 2016; Wesche & Chan 2010; Nancarrow et al. 2008) to consider the impact of environmental change and species declines on human nutrition and health in the Arctic and in other global regions. Furthermore, it is among a very limited body of scholarship on the economic aspects of Indigenous Peoples nutrition and diets worldwide (Brimblecombe & O'Dea 2009; Pakseresht et al. 2014). Food system diversity (from genetic to species and ecosystem diversity) has been proposed as a means of fostering food system resilience to mitigate the effects of environmental, social, cultural, and economic stressors (Powell et al. 2015; Johns & Sthapit 2004). However, most studies investigating the contribution of biodiversity to human nutrition have been conducted in the world's most biodiverse regions. This research, from an area of relatively low biodiversity and species richness, contributes to the broader literature investigating the contribution of biodiversity to human nutrition. When species decline in the Arctic some nutrients of concern may be available through consumption of other country food species; however, other nutrients may be limitedly available in alternate species or available market foods, and a reduction in intake may result in nutrient deficiency in some individuals (Wesche & Chan 2010; Rosol et al. 2016; Nancarrow & Chan 2010). Still, the relationship between biodiversity, food system diversity, and human nutrition is not readily translated. Despite residing in some of the world's most biodiverse and species rich areas, people in rural and forested regions in developing countries paradoxically experience very high burdens of food of insecurity and malnutrition (Boedecker et al. 2014). In the Democratic Republic of Congo (DRC), for instance, one of the most biodiverse countries on the planet, wild edible plants are insufficiently consumed to increase nutrition or dietary adequacy (Termote et al. 2012). As suggested previously (Johns & Sthapit 2004; Kuhnlein et al. 2009), traditional values and preferences may help to maintain and foster the links between diet, nutrition, biodiversity, and sustainability.

Thus, to better understand the relationship between nutrition and biodiversity, further research is needed to elucidate the conditions that support wild food use, as there may be significant disparities between the number and diversity of species reported as known/used and those actually reported as consumed in dietary assessments (Powell et al. 2015; Boedecker et al. 2014). Indigenous Peoples possess a wealth of knowledge related to biodiversity – but local and traditional knowledge is being lost at accelerating rates (Kuhnlein et al. 2009), and several authors have called for the promotion of underutilized Indigenous species for improved nutrition and health (Boedecker et al. 2014). Community-engaged work undertaken during the thesis highlights the need for better programs to support the acquisition of nutritional and traditional knowledge relating to wild species, particularly among youth. While teachers are strongly encouraged to integrate place-based education and traditional Indigenous ways of knowing within school curricula (Salokangas & Parlee 2009), limited formal mechanisms currently exist to support this process. There is a strong need for appropriate policy to sustain these activities over the long term.

Many systems approaches (the EcoHealth Approach) call for full participation of local populations in research. In addition to enhancing the awareness and capacity of communities, participatory approaches make significant contributions to research outcomes. This approach is consistent with the paradigm of Participatory Action Research (PAR), which affirms the merits of experiential learning as a legitimate mode of knowledge-acquisition (Baum et al. 2006). Although the author spent considerable time in the Arctic, much of this time did not result in outcomes that are readily translated into scientific publications. Nevertheless, the author deems these experiences as invaluable and necessary to both scientific rigor (i.e. appreciating nuances, strengths and limitations in the Inuit Health Survey database) and ethical/equitable research practice involving Indigenous communities. Curricular and funding structures of graduate programs should be designed to facilitate these experiences, rather than limit/hinder them.

10.3.1 Future Research

From a research standpoint, there is an unambiguous lack of longitudinal research examining diet and health transitions in Inuit communities and other Indigenous populations. In particular, there is a distinct absence of empirical evidence linking diet and health to species declines, in both the Arctic and in various global regions (e.g. "bush meat" context). Accordingly, critical questions such as "what are the consequences of harvest quotas or wildlife declines on Inuit food security, health, and diet?" cannot be satisfactorily answered until studies explicitly examine these issues, using longitudinal data or targeted case studies. Furthermore, few studies have documented desired or idealized diets among Indigenous Peoples in Canada (Wein 1996), or elsewhere. On one hand, studies of human diet and nutrition often employ pre-defined survey tools (e.g. food frequency questionnaire), and ask very narrowly defined questions. On the other hand, anthropological and sociological research, generally address broader questions, but present results in manner that is not readily accessible to the field of human nutrition. There is a need for better integration between the methodologies and results of distinct fields of study. There is also a need to develop novel methodologies to more appropriately measure the contribution of local biodiversity to human nutrition and health (Penafiel et al. 2011).

The nutrition transition experienced by Indigenous Peoples in developed countries such as Canada, Australia, and the United States may represent a distinct typology of the nutrition transition (for example, Indigenous Peoples in each of the afordescribed countries pay some of the highest food prices in each country and generally reside in rural/remote communities), yet, to the author's knowledge, no comparative or case study research has been undertaken to build on the knowledge and experiences in these respective countries. More broadly, further research is required to establish synergies and divergences between Indigenous food system research in different global regions.

Further research is required to make meaningful strides in projecting the human health consequences of ecosystem change and developing appropriate adaptation measures.

Although food system models are increasingly well developed for the agricultural context, to date no mathematical models have considered the context of Indigenous food systems.

Do we really need more research?

To provide a simple answer, yes. Nevertheless, the question warrants consideration for several reasons. Although there are innumerable gaps in available knowledge, and countless lines of future inquiry, the incremental gains of additional research must be weighted against "research fatigue" (Martin & Edwards 1985) and other competing priorities for resources and time in communities. Indigenous communities, including Inuit of northern Canada, have for several decades expressed resistance to further research (Martin & Edwards 1985). Although research paradigms have evolved considerably in recent decades – from research done *on* Indigenous People, to research done *with* and *by* Indigenous People, there remains significant gaps and researchers are perceived to derive greater benefit from research partnerships in the North relative to their community counterparts (Brunet et al. 2016). Furthermore, there are important gaps in the mobilization of existent knowledge into policy and practice. The Inuit Health Survey was designed to assist stakeholders and governments in prioritizing health issues for policies and programs aimed at improving health status Arctic communities. This raises some questions about the role and responsibility of researchers in not only the dissemination of research results, but also effective knowledge translation.

Important questions to consider moving forward include: (i) what is the appropriate balance between community participation in research and over-researching communities/research fatigue?; (ii) how can existing knowledge sources be rendered more accessible for both communities and researchers?; (iii) how can researchers better utilize available information to answer questions and respond to community priorities?; (iv), how might researchers better collaborate to build synergies between research projects, and mitigate the reproduction of studies; (v) what should the role of the researcher be in knowledge translation and practice in communities; and finally, (vi) how can research practice be ameliorated to confer greater benefits to communities, and how can research partnerships be rendered more equitable for communities?

10.4 Concluding Remarks

Inuit are experiencing a rapid transition in both diet and lifestyle, with negative consequences on health and wellness. The loss of traditional knowledge and the erosion of local ecosystems, on the one hand, are barriers to country food consumption for Inuit. Low per-capita income, coupled with the nature of private food retailing systems in remote communities, on the other hand, fosters reliance on energy-dense, nutrient-poor market foods. In this context, food is at once: a natural resource subject to management and conservation, an Indigenous right recognized by Land Claims Agreements and the Canadian constitution, a commodity subject to the influence and fluctuations of market economies and capital, and a universal human right affirmed by the United Nations. Reconciling these seemingly divergent interests for the promotion of environmental sustainability and human wellness necessitates innovative approaches founded in equity and justice.

10.5 References

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11 APPENDICES

- Appendix 1: Scientific Research Licenses
- Appendix 2: Ethics
- Appendix 3: Material Related to Community-Based Work
- Appendix 4: Copyright Information for Published Work

11.1 Scientific Research Licenses

Licence No. 15446
File No. 12 410 978
March 18, 2014

2014
Northwest Territories Scientific Research Licence

Issued by:	**Aurora Research Institute – Aurora College** Inuvik, Northwest Territories
Issued to:	Dr. Laurie HM Chan University of Ottawa 30 Marie Curie Ottawa, ON K1N 6N5 Canada Phone: (613) 562-5800 ext. 7116 Fax: (613) 562-5385 Email: laurie.chan@uottawa.ca
Affiliation:	University of Ottawa
Funding:	ArcticNet
Team Members:	Tiff-Annie Kenny; Myriam Fillion; Evelyn Storr; Shannon O'Hara
Title:	**Food Security, Ice, Climate and Community Health**
Objectives:	To develop an understanding of Inuit dietary change in Canada, with respect to environmental, cultural, economic and social constraints.
Dates of data collection:	March 18, 2014 to December 31, 2014.
Location:	Inuvik

Licence No.15446 expires on December 31, 2014
Issued in the Town of Inuvik on March 18, 2014

*** original signed ***

____
Pippa Seccombe-Hett
Director, Aurora Research Institute

Licence No. 15943
File No. 12 410 934
August 08, 2016

2016
Northwest Territories Scientific Research Licence

Issued by:	**Aurora Research Institute – Aurora College** Inuvik, Northwest Territories
Issued to:	Dr. Sonia D Wesche University of Ottawa Dept. of Geography 60 University Pvt. Ottawa, ON K1N 6N5 Canada Phone: 613-562-5800 x1052 Fax: (613) 562-5145 Email: swesche@uOttawa.ca
Affiliation:	University of Ottawa
Funding:	Mitacs Northern Scientific Training Program
Team Members:	Dr. Laurie Hing Man Chan; Tiff-Annie Kenny; Evelyn Storr; Shannon O'Hara; Jullian MacLean; Nicholas Girard; Dr. Myriam Fillion
Title:	**Food Security, Environment and Community Health: Integrating Participatory Methods, Tools and Knowledge to Promote Food Security in the Inuvialuit Settlement Region**
Objectives:	To examine quantitatively, the role of country foods in the contemporary Inuit diet, including their nutritional and economic importance, and the dynamics between the country and market food dimensions of the diet; and to better understand market food price variations across the region and seasonal fluctuations, and examine the role of food prices in dietary quality.
Dates of data collection:	August 9, 2016 to November 15, 2016.
Location:	Inuvik, Aklavik, Tuktoyaktuk, Paulatuk, Sachs Harbour, Ulukhaktok

Licence No.15943 expires on December 31, 2016
Issued in the Town of Inuvik on August 08, 2016

*** original signed ***

Jolie Gareis
Vice President, Research
Aurora Research Institute

11.2 Ethics Approval

File Number: H05-15-16 **Date (mm/dd/yyyy):** 05/25/2015

Université d'Ottawa
Bureau d'éthique et d'intégrité de la recherche

University of Ottawa
Office of Research Ethics and Integrity

Ethics Approval Notice

Health Sciences and Science REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

First Name	Last Name	Affiliation	Role
Laurie	Chan	Science / Biology	Supervisor
Tiff-Annie	Kenny	Science / Biology	Student Researcher

File Number: H05-15-16

Type of Project: PhD Thesis

Title: Simulation model of the Aboriginal Food System in Canada

Approval Date (mm/dd/yyyy)	Expiry Date (mm/dd/yyyy)	Approval Type
05/25/2015	05/24/2016	Ia

(Ia: Approval, Ib: Approval for initial stage only)

Special Conditions / Comments:
N/A

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Ethics Approval Notice

Health Sciences and Science REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

First Name	Last Name	Affiliation	Role
Laurie	Chan	Science / Biology	Principal Investigator
Shannon	O'Hara	Others / Others	Co-investigator
Sonia	Wesche	Arts / Geography	Co-investigator

File Number: H01-14-10C

Type of Project: Professor

Title: Food security, Ice, Climate and Community Health

Approval Date (mm/dd/yyyy)	Expiry Date (mm/dd/yyyy)	Approval Type
10/26/2015	10/25/2016	Ia

(Ia: Approval, Ib: Approval for initial stage only)

Special Conditions / Comments:
N/A

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11.3 Material for Community-Based Work

Inuvik Hunters & Trappers Committee

P.O. Box 1720
Inuvik, NT X0E 0T0
Tel: (867) 777-3671
Fax: (867) 777-2478
Email: inuvikhtc@hotmail.com

May 19, 2015

Tiff-Annie Kenny

Email: Tiff-Annie.Kenny@uOttawa.ca

RE: "Inuit youth empowerment through school-based traditional food, gardening, and nutrition programming" Project Location: Inuvik, Inuvialuit Settlement Region, NWT Community Partner: East Three Secondary School

Dear Tiff-Annie,

The Inuvik Hunters and Trappers Committee held a regular board meeting on May 13, 2015. The board of directors reviewed your project and would like to support the Inuit Youth Empowerment through school based traditional food, gardening and nutrition programming. And look forward to working with you in the future.

If you have any questions or concerns please contact the IHTC office.

Thank you,

Douglas Esagok
IHTC President

East Three Secondary School

February 19, 2015

RE: Letter of Support – Traditional Foods Snack Program

Please accept this letter in support of the implementation of a traditional foods snack program at East Three Secondary School. We are very excited at the opportunity to provide traditional and cultural foods for our students during break time.

The mid-morning break provides a time for our student to rejuvenate and gain nutrients to help them complete the morning learning activities. Many of our students do not come in time for the breakfast offering, so it is not until snack that they get their first food for the day. The offering of cultural foods is more than just 'food' in that it makes a cultural connection for our Aboriginal students, enhancing the feeling of belonging with the school. Although only 10 minutes in length, our students enjoy the opportunity to connect with each other and staff members, and the chance to bring cultural food into this experience is very valuable. There is much research on the value of providing food for students to enhance their learning. There is also much research on the value of providing a warm and welcoming experience for students to feel comfortable and secure in their school.

Thank you for accepting this letter of support of this wonderful opportunity!

Sincerely Yours,

Deborah Reid
Principal
East Three School (Secondary and Elementary)
Inuvik, NT
(867) 777-3030
http://eastthreesecondary.com
cell (867) 620 2297 deborah_reid@bdec.learnnet.nt.ca

Inuvialuit Regional Corporation

Bag Service #21
Inuvik, NT XOE 0T0
Telephone: (867) 777-7000
Fax: (867) 777-7001
Toll-free: 1-855-777-7011
www.inuvialuit.com

Feb. 25th, 2015

Traditional Food, Gardening, and Nutrition Programming
Patrick Gauley Gale
East Three Secondary School
Bag Service #3
Inuvik, NT XOE OTO
867 777 3030 ext. 3137

Re: Letter of Support

Dear Mr. Gauley Gale:

This is a letter of support for the Traditional Food, Gardening, and Nutrition Programming in Inuvik, which provides traditional food to students of Inuvik as well as teaches students Inuvialuit Ethnobotany.

The Community Development Division of the Inuvialuit Regional Corporation is pleased to provide advice and support during the duration of this program.

If you have any questions or concerns, you can contact me at (867) 777-7013 or by e-mail to jmaclean@inuvialuit.com

Sincerely,

Jullian MacLean
Regional Dietitian, IRC

11.4 Copyright Information for Published Work

THE ARCTIC INSTITUTE OF NORTH AMERICA
OF THE UNIVERSITY OF CALGARY
2500 UNIVERSITY DRIVE NW
CALGARY, ALBERTA, CANADA T2N 1N4

Warranty and Assignment of Copyright

I/we, Tiff-Annie Kenny, and Laurie (Hing Man) Chan
warrant that I am/we are the author(s) of the unpublished work entitled:

Estimating Wildlife Harvest Based on Reported Consumption by Inuit in the Canadian Arctic

that the Arctic Institute of North America is interested in publishing in *Arctic*. To the best of my/our knowledge, the work in no way infringes upon any copyright or proprietary right and contains nothing unlawful, libelous, or in violation of any right of privacy.

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(*place*) Ottawa, Ontario

(*date*) August 2, 2016