MONITORING THE VULNERABILITY OF INUIT SUBSISTENCE HUNTING TO CLIMATE CHANGE: A CASE STUDY OF ULUKHAKTOK, INUVIALUIT SETTLEMENT REGION

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Submitted in accordance with the requirements for
the degree of Doctor of Philosophy

The University of Leeds
Priestley International Centre for Climate
Sustainability Research Institute

March 2022

INTELLECTUAL PROPERTY AND PUBLICATION STATEMENTS

The candidate confirms that the work submitted is their own, except where work which has formed part of jointly authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

Chapters two, three, and four of this thesis comprise jointly authored publications. Authors are listed in order of contribution:

Chapter Two: Naylor, A.W., Ford, J.D., Pearce, T.D. and van Alstine, J. 2020. Conceptualizing climate vulnerability in complex adaptive systems. *One Earth*, **2**(5), pp. 444-454. doi: 10.1016/j.oneear.2020.04.011.

> A.W.N. and J.F. conceived and developed the approach with additional input from T.P. and J.V.A. A.N. produced the original draft and diagrams. All authors edited and approved the manuscript.

Chapter Three: Naylor, A.W., Ford, J.D., Pearce, T.D., Fawcett, D., Clark, D.G., and van Alstine, J. 2021 Monitoring the dynamic vulnerability of an Arctic subsistence food system to climate change: The case of Ulukhaktok, NT. *PloS One*, **16**(9), article number: e258084.

> Project development and data collection by A.N., T.P., D.F., the Hamlet of Ulukhaktok and the *Tooniktoyok* project team. Maps, tables and first draft produced by A.N. Subsequent drafts by A.N., T.P., J.F., D.C. and D.F. All authors edited and approved the manuscript.

Chapter Four: Naylor, A.W., Pearce, T.D., Ford, J.D., Fawcett, D., Collings, P., and Harper, S.L. 2021. Understanding determinants of hunting trip productivity in an Arctic community. *Frontiers in Sustainable Food Systems*, **5**, article number: 238. doi: 10.3389/fsufs.2021.688350.

> Project construction and data collection by A.W.N., T.P., D.F., and the *Tooniktoyok* Hunters. Data analysis and statistics by A.W.N. and S.L.H.

First and subsequent drafts of paper produced by A.W.N., T.P., J.F., D.F., P.C. and S.L.H. All authors edited and approved the manuscript.

The candidate is the lead author of all the above articles. They designed the research/conceptual approach and methodologies, and undertook the data collection and analysis. The articles were co-authored with supervisors and other researchers within the academic community; their contributions to each article are listed individually within each chapter.

Rationale for thesis by alternative format: This thesis is submitted in the alternative publication-based format for the following reasons:

- The stated objectives of this PhD lend themselves to the production of discrete articles that, although interrelated, can be targeted to address the specific research gaps identified.

- The relatively protracted nature of data collection involving participants, and close collaboration with the Hamlet of Ulukhaktok, required the dissemination of research findings throughout the research process in order to maintain stakeholder engagement.

- The primary funders of this research, Crown Indigenous Relations and Northern Affairs Canada, required regular analysis and dissemination of research findings to inform policy. In order to maximise the potential impact of this project, it therefore was crucial to publish the findings while the doctorate was in progress.

THESIS STRUCTURE

This thesis is divided into five chapters. The introduction develops a research rationale by highlighting existing knowledge gaps, key debates, and areas for theoretical and methodological development within the fields of Inuit studies and climate change vulnerability and adaptation. It then outlines the aims and objectives of this doctorate, before providing context on the traditions and evolution of vulnerability research, in addition to the context of colonisation in the North American Arctic and its relevance to contemporary research on Inuit livelihoods and mixed cash-subsistence economies.

The three chapters following the introduction comprise the published works of this doctorate, and are hereafter referred to as papers one, two, and three:

Paper one builds upon contemporary vulnerability thinking and advances a new conceptual approach to understand contextual, place-based climate change vulnerability. It conceives vulnerability to climate change as a dynamic, socially constructed phenomenon, rooted in processes and the passage of time, and combines this conceptualisation with principles governing complex adaptive systems theory. In doing so, a novel, generalisable basis for understanding and appraising place-based, differential vulnerability across multi-dimensional systems, communities, or societies is developed.

Paper two develops the methodological contribution of this doctorate by combining the new conceptual climate vulnerability approach with a participatory mixed-methods, real-time land-use monitoring methodology as part of the *Tooniktoyok* project. It should be noted here that the conceptual approach in chapter two *informs* the way that vulnerability is understood and conceptualised within this paper; it does not establish a rigid framework for prescribing methods or analysis. Spanning the period June 2018-June 2020, the paper applies GPS monitoring, participatory mapping sessions, semi-structured interviews, and secondary weather data to identify barriers and opportunities to hunting participation and success in the subsistence food system of Ulukhaktok, NT, Canada. The primary focus of this paper is on the determinants of hunting participation that occur *within* communities and between individuals, often over a sustained period. Conceptualising the food system as a 'foodshed', the paper demonstrates that climate change has considerable potential to affect harvesting activities spatiotemporally, particularly when its impacts manifest as anomalous/extreme events. However, when placed in the context of other stressors also affecting the community on a day-to-day basis, climate-induced environmental change is often not the most salient issue affecting harvesting. Instead, factors relating to financial capital, consumables and machinery availability, the wage-based economy, social networks and relationships, and institutional support for harvesting are found to have a greater influence, either as standalone factors or when acting synchronously to compound the effects of environmental change.

The third paper examines empirical data collected as part of the *Tooniktoyok* project further in order to assess drivers of hunting productivity on specific hunting trips. It presents a statistical analysis of one-year of data on harvest yield, combined with the characteristics of daily hunting activities collected between January 2019-December 2019. A multivariable linear regression model identifies whether factors such as consumables used (i.e. heating fuel, gasoline, oil, food), distances travelled, or the number of companions on a trip are associated with the mass of edible foods returned to the community on specific trips. Results indicate that, despite being positively associated with hunting trip productivity when assessed through a univariable linear regression model, gasoline is not a statistically significant determinant of standalone trip yield when adjusting for other variables in a multivariable linear regression. Instead, factors relating to seasonality, number of companions, and days on the land are found to exhibit greater explanatory power and are stronger predictors of productivity while out on the land. The findings of paper two support those of paper three in identifying drivers such as the wage-based economy and wider socially constructed factors as more substantive determinants of hunting success and productivity: these often take precedence over biophysical factors attributed to climate change.

The fifth chapter of this thesis discusses the implications of the three manuscripts. It first outlines their contributions to scholarship, before placing their key findings in the context of contemporary debates around the precedence of climate as a factor affecting food systems stability in Arctic communities and the efficacy of current governance approaches aimed at reducing foodshed vulnerability. This is followed by a reflection on conducting community-governed research in an Arctic setting. Specifically, the tensions that can arise from designating Western researchers as ‘research specialists’ are addressed, in addition to the obstacles associated with the development of research outputs with a Western valence in research involving Inuit stakeholders. The discussion concludes by outlining potential limitations identified during the course of the doctorate and a number of areas are highlighted as priorities for future research.

ACKNOWLEDGEMENTS

This research would not have been possible without the financial contributions and administrative support received from the following entities (in order of contribution):

i. **Crown Indigenous Relations and Northern Affairs Canada (CIRNAC)**
(Climate Change Preparedness in the North) (#1718-QC-000003)

ii. **Universities of Leeds, Northern British Columbia (UNBC), Guelph, and the Sunshine Coast**

iii. **ArcticNet**

iv. **United Kingdom Research and Innovation**
(ESRC White Rose Doctoral Training Partnership (#1948646))

I would like to extend particular gratitude to my supervisors, James Ford, James van Alstine, and Tristan Pearce, without whom I would have never had the opportunity to experience one-hundred-odd days of the Arctic, meet the incredible people I have along the way, present aspects of my academic work to the Food and Agriculture Organisation of the United Nations, or have the self-belief that I could produce research of this quality. Thank you also to the wider group of researchers involved in this work who over time became committee members in everything but name: David Fawcett, for preparing me to first go to Ulukhaktok, and who was the most dedicated and patient co-researcher anyone could ask for; Sherilee Harper, for her crucial assistance with the statistical and stylistic portions of the second paper; and Peter Collings and Tim Murray, for (quite literally) saving me from homelessness in the field, putting up with living with me for three months, and for providing vital insights from their own experiences of working in Ulukhaktok. Thank you also to the members of my examination committee, Professors Claire Quinn (University of Leeds) and Jackie Dawson (University of Ottawa), for the time they have taken to read and critique this work.

There are others at the University of Leeds who have also provided indispensable support for this doctorate. Anuszka Mosurska, you have quite honestly been my saviour on more occasions than I can count: be this dropping everything with me at 1pm on a Tuesday for a stress-beer and vent, or for reading and providing brilliantly comprehensive insights on my academic work. Melanie Flynn, you gave me one of the best crash-course introductions to the University of Leeds and PhD life anyone could ask for, and undoubtedly changed the way I think about and approach research. Katy

Davis, you have a relevant paper for every occasion, and have improved my critical approach to research immensely.

Beyond my North American Arctic research group at Leeds, there are also a number of friends who provided amazing social support and academic advice: Anthony Ramirez Salazar, Ingrid Arotoma Rojas, Dylan Clark, Ivan Villaverde Canosa, Sarah Filisikowski, Kristin Emanuelsen, Jessica Smart, Matt Wheelton, and many others! I would like to particularly acknowledge the input of Jake Fletcher, Sabrina White, Scott Wiseman, and Michael Margerrison, who have either proof-read, or provided critical insight and emotional support in producing this monograph. I would also like to recognise the importance of the support shown by Ben Fisher, who has been instrumental in broadening my academic horizons, shown me that not all biogeochemists are boring, and been an indispensable source of emotional support.

I am especially thankful for Alex Brownhill, my boyfriend, who has been a rock when helping me battle through the anxieties of working on the final stages of this doctorate and made living through the most recent part of the COVID-19 pandemic bearable! Hopefully one day I will be able to repay the favour for your own doctorate!

I am indebted to the community of Ulukhaktok for the kindness, patience, and support I was shown by so many people, particularly Adam and Melanie Kudlak, and Patrick Joss, but also the employees of the Hamlet of Ulukhaktok, Adam Kuptana, Laverna Klengenberg, Susan Kaodloak, Koral Kuptana, and the *Tooniktoyok* Hunters (Tony Alanak, Ross Klengenberg, Adam Kuptana, Isaac Inuktalik, Roy Inuktalik, Colin Okheena, Kelly Nigiyok, David Kuptana, Gibson Kudlak, Allen Joss, and Roland Notaina). I would also like to thank the Aurora Research Institute for their licencing of this research and CIRNAC for their flexibility surrounding funding during the coronavirus pandemic.

Finally, I would like to thank my ever-patient and ever-supportive family. Especially my parents David and Jill Naylor, without whose incalculable financial and endless emotional support none of this (or indeed any of my preceding degrees or achievements) would have been possible, and without whom I would never have pushed myself to take a leap into the unknown. To my grandma, Betty Challender, you were instrumental in ensuring that I had academic interests from a young age and have been a huge inspiration to me ever since. To my older brother, Matthew Naylor, you have always been and continue to be an inspiration and a role model to me.

Statement of project contributions

This research has been carried out by a team which has included Angus W. Naylor, Dr. Tristan Pearce, Dr. James Ford, Laverna Klengenberg, Adam Kuptana and the *Tooniktoyok* Hunters. My own contributions, fully and explicitly indicated in the thesis, have been the conceptual and methodological development of the project, and the majority of data collection and data analysis. The other members of the group and their contributions have been as follows:

- Project development, administration, funding applications and ethics:
  Laverna Klengenberg, Dr. Tristan Pearce, Dr. James Ford

- Data collection and analysis:
  Adam Kuptana, the *Tooniktoyok* Hunters, and Dr. Tristan Pearce

For paper-specific contributions, please see "author contributions" sections and "intellectual property and publication statements" contained within each published chapter.

ABSTRACT

MONITORING THE VULNERABILITY OF INUIT SUBSISTENCE HUNTING TO CLIMATE CHANGE: A CASE STUDY OF ULUKHAKTOK, INUVIALUIT SETTLEMENT REGION

This thesis examines the vulnerability and adaptive capacity of a subsistence food system to climate change in the Inuit community of Ulukhaktok, Inuit Nunangat (the Inuit homeland within Arctic Canada). First, a new generalisable approach to understand climate change vulnerability through the lens of complex adaptive systems (CASs) theory is developed. This is followed by a place-based case study applying the approach as part of a two-year, real-time monitoring initiative (the *Tooniktoyok* project) that examines the susceptibility of subsistence hunting in Ulukhaktok, Northwest Territories (NT) to climate change in the context of multiple social, cultural, economic and political stressors. Finally, a statistical analysis is undertaken utilising one calendar years' worth of data (2019) from the community to quantitatively identify socioeconomic and biophysical drivers that can affect the productivity of hunting trips taken by *Ulukhaktokmiut*[1].

Data were collected through mixed methods, including bi-weekly conversational semi-structured interviews and participatory mapping sessions (n = 76), and the GPS tracking of hunting routes with a cohort of 10 hunters; secondary weather and sea ice data; and a seven-month period of participant observation within the community. Results indicate that biophysical drivers relating to climate change hold the potential to substantively affect the *Ulukhaktokmiut* subsistence food system. This is particularly true for extreme weather or other events attributable to climate change, such as periods of drastically reduced snow cover or rapid alterations in biological productivity. However, (especially compared to incremental biophysical changes in the environment) socioeconomic, cultural and political factors are often found to hold a greater salience when examining determinants of day-to-day foodshed viability and when attributing statistical association to the productivity of *Ulukhaktokmiut* on individual hunting trips.

The insights developed from this work advance contemporary thinking at the interface of climate change vulnerability and complex adaptive systems scholarship. In particular, concepts relating to the role of multiple interacting and dynamic stressors within human-environment systems, and the

[1] *Ulukhaktokmiut*, meaning 'peoples from Ulukhaktok'.

ways through which seemingly simple interactions between stressors can generate complex, 'emergent' system-wide behaviours and phenomenon over time. The thesis' empirical findings also hold relevance for informing the provision of climate change adaptation, Inuit harvester support, and federal food subsidy programmes across the Canadian Arctic. Specifically, they point to the need for a more holistic and transformative approach, whereby initiatives should focus on ameliorating the root causes of *why* communities are experiencing threats to the stability of their subsistence livelihoods (e.g. systemically engendered poverty, acculturation, marginalisation of Indigenous economies), rather than attempting to work within a policy framework that in some cases can actively maintain them.

CONTENTS

TABLES, FIGURES, AND APPENDICES

ABBREVIATIONS

AC	**A**daptive **C**apacity
ARI	**A**urora **R**esearch **I**nstitute
BIC	**B**ayesian **I**nformation **C**riterion
AMAP	**A**rctic **M**onitoring and **A**ssessment **P**rogramme
CAS/s	**C**omplex **A**daptive **S**ystem/**s**
CBPR	**C**ommunity-**b**ased **P**articipatory **R**esearch
CCPN	**C**limate **C**hange **P**reparedness in the **N**orth programme
CHAP	**C**ommunity **H**arvesters' **A**ssistance **P**rogramme
CIRNAC	**C**rown **I**ndigenous **R**elations and **N**orthern **A**ffairs **C**anada
CIS	**C**anadian **I**ce **S**ervice
DEW	**D**istant **E**arly **W**arning
ES	**E**xposure-**s**ensitivity
ESRC	**E**conomic and **S**ocial **R**esearch **C**ouncil
GIS	**G**eographic **I**nformation **S**ystem
GNWT	**G**overnment of the **N**orth**w**est **T**erritories
GoC	**G**overnment **o**f **C**anada
HBC	**H**udson's **B**ay **C**ompany
HDCC	**H**uman **D**imensions of **C**limate **C**hange
ICC	**I**nuit **C**ircumpolar **C**ouncil
IGC	**I**nuvialuit **G**ame **C**ouncil
IHAP	**I**nuvialuit **H**arvesters' **A**ssistance **P**rogramme
INAC	**I**ndigenous and **N**orthern **A**ffairs **C**anada
IPCC	**I**ntergovernmental **P**anel on **C**limate **C**hange
IRC	**I**nuvialuit **R**egional **C**orporation
ISR	**I**nuvialuit **S**ettlement **R**egion
ITK	**I**nuit **T**apiriit **K**anatami
MvLRM	**M**ulti**v**ariable **L**inear **R**egression **M**odel
NGO	**N**on-**g**overnmental **O**rganisation
NISR	**N**ational **I**nuit **S**trategy on **R**esearch
NNC	**N**utrition **N**orth **C**anada
NT (OR **NWT**)	**N**orth**w**est **T**erritories
QIA	**Q**ikiqtani **I**nuit **A**ssociation

RCMP	**R**oyal **C**anadian **M**ounted **P**olice
RCP	**R**epresentative **C**oncentration **P**athway
SEW	**S**tandard **E**dible **W**eight
TB	**Tub**erculosis
TEK	**T**raditional **E**cological **K**nowledge
UKRI	**U**nited **K**ingdom **R**esearch and **I**nnovation
UNBC	**U**niversity of **N**orthern **B**ritish **C**olumbia
UNFCCC	**U**nited **N**ations **F**ramework **C**onvention on **C**limate **C**hange
V	**V**ulnerability
WRDTP	**W**hite **R**ose **D**octoral **T**raining **P**artnership

CHAPTER I

RESEARCH RATIONALE, AIMS, AND CONTEXT

1. Research rationale

1.1. *Arctic climate change and social-ecological systems*

Over the last half-century, the Arctic has experienced warming at two to three times the global annual average of 0.2°C per decade (Bush & Lemmen, 2019; IPCC, 2021) (Figure 1.1). Courtesy of positive feedback mechanisms related to the 'Arctic amplification' effect[2], warming of the region is expected to further accelerate (Flanner *et al.,* 2011; Dai *et al.*, 2019). By 2050, it is anticipated that cold-season surface air temperatures in the Arctic will rise in excess of 4ºC relative to 1986-2005, with some models suggesting - even under a scenario where policies are enacted to limit emissions and ensure that "radiative forcing is limited at approximately 4.5 Wm^2… by 2100" (RCP4.5) - a rise of between 5-9ºC above the Arctic Ocean by end of the century (AMAP, 2017a; IPCC, 2018a, p.556).

Rapid rates of warming in the circumpolar North are set to drastically alter marine, terrestrial, and biospheric social-ecological systems (Figure 1.2) (AMAP, 2019; Meredith *et al.*, 2019), and some authors suggest that palpable impacts arising from 'dangerous anthropogenic climate interference' in the Arctic are already in evidence (Ford, 2009a; Duarte *et al.*, 2012; Jodoin *et al.*, 2020; Constable *et al.*, 2022). Changing cryosphere and precipitation regimes, manifesting as early spring ice break-up, reduced snow cover, or increased rainfall and land icing, have already been associated with ecological changes for Arctic flora and fauna across the circumpolar region as a whole (AMAP, 2017b, 2017c). In the North American Arctic specifically, altered ringed seal body condition, fertility, and predation rates, potential declines in caribou populations (whereby icing events are affecting pasture productivity), and the northward expansion of shrub and other invasive species are but a few examples of observed changes that have been attributed to a shifting climate (Ferguson *et al.* 2017;

[2] The Arctic amplification effect refers to a situation of excess climate warming, brought about by excess absorption of solar insolation at the planet's high latitudes, which is attributable to (but also caused by) the sustained loss in high-albedo summer sea-ice and increased surface air water-vapour concentrations at the poles (Dai *et al.*, 2019).

DoE, 2015; AMAP, 2019). From a linked human-environment perspective, changes to species distribution and health, superimposed over broader impacts of climate change such as sea-ice loss or poorer weather conditions, are most readily felt by the Indigenous peoples of the Arctic (Tauli-Corpuz & Lynge, 2008; OHCHR, 2016).

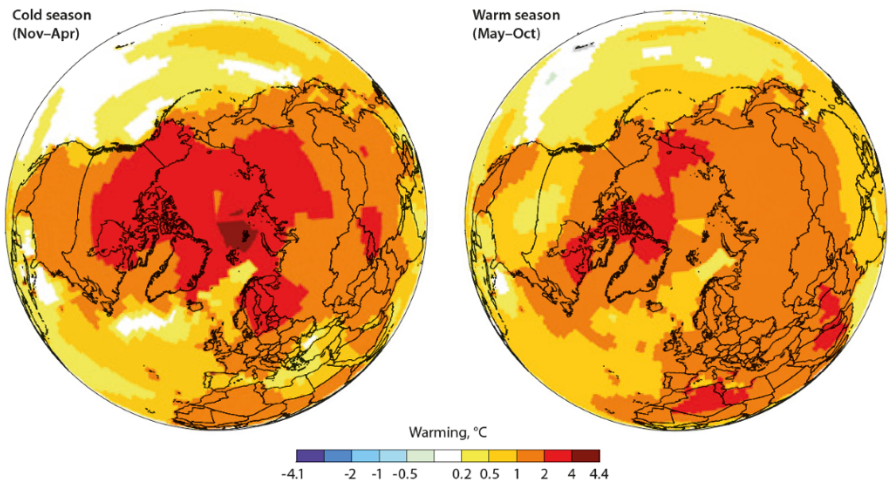

FIGURE 1.1: GLOBES INDICATING THE MAGNITUDE OF NORTHERN HEMISPHERE WARMING SPANNING THE PERIOD 1961-2014 IN BOTH WARM (MAY – OCT) AND COLD SEASONS (NOV – APR) (from AMAP, 2017b).

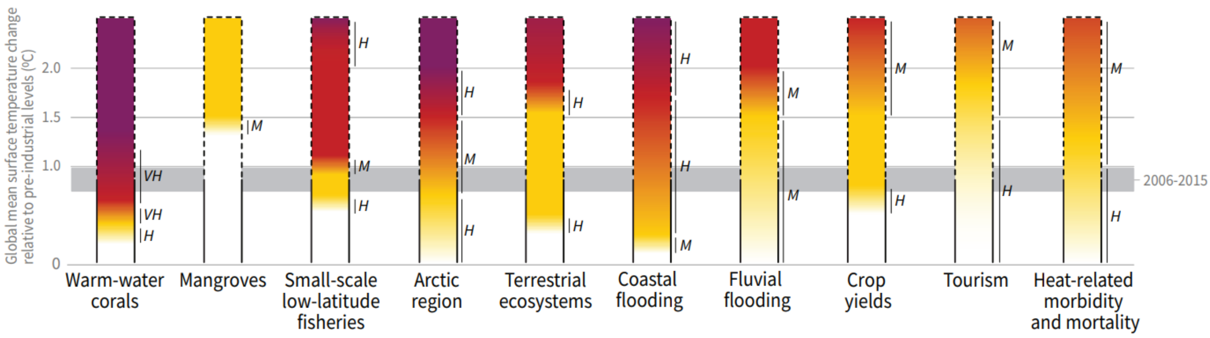

FIGURE 1.2: PROJECTIONS OF POTENTIAL IMPACTS AND RISKS THAT WILL DERIVE FROM DIFFERING MAGNITUDES OF GLOBAL MEAN SURFACE WARMING OF 1°C OR GREATER RELATIVE TO PRE-INDUSTRIAL LEVELS. Severity of impacts ranges from undetectable (white), through moderate (yellow) and high (red), to very high (purple), with confidence levels for these ranging from medium (M), through high (H), to very high (VH). This figure indicates that the Arctic region is already experiencing moderate impacts[3] from climate change, and is at a high likelihood of experiencing high-to-very high impacts as a result of global mean surface warming in excess of 1.5ºC. (from IPCC, 2018b).

[3] Climate impacts are defined by IPCC (2018a, p.551-552) as "effects on lives; livelihoods; health and well-being; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure" (IPCC, 2018a p.551-552).

Inuit are but one pertinent example of an Arctic Indigenous peoples, whose livelihoods, culture, food systems, and mental health and wellbeing remain strongly linked to the lands on which they live (Condon *et al.*, 1995; Middleton *et al.*, 2020). A considerable proportion of dietary intake among Inuit who live in the Arctic is still derived from climate-sensitive, culturally relevant harvesting practices that utilise subsistence species, such as caribou, whale or Arctic char to ensure adequate intakes of nutrients such as zinc, calcium and Vitamin D (Sharma *et al.*, 2010, Sharma, 2010; Kenny *et al.*, 2018). Changes to the health or abundance of certain subsistence species in light of climate change therefore also has significant implications for rates of malnutrition, food security, diet-related diseases and culture loss among Northern communities (Wesche & Chan, 2010; Rosol *et al.*, 2016; Ford *et al.*, 2019a). However, the biophysical impacts of climate change on Inuit livelihoods do not exist separate from broader societal, economic and political obstacles in the contemporary Arctic; many of which see their origins in the practice of colonisation (Huntington *et al.*, 2020; Ready & Collings, 2020). Indeed, so significant is the interaction between anthropogenic interference in the Arctic climate system and socially constructed stressors derived from colonisation, contemporary climate change is increasingly seen as a social justice issue and has been variably described or litigated by Inuit as a violation of human rights or a "civil conspiracy" (see Watt-Cloutier, 2005; *Kivalina v. ExxonMobil Corp.*, 2009; Crowley, 2011; *Sinnock et al. v. State of Alaska*, 2018; Coggins *et al.*, 2021).

Despite the significance of social constructions in understanding what might render individuals, communities or societies susceptible to Arctic climate change, past scholarship addressing the issue has been critiqued for portraying vulnerability as a static, temporally bounded, and biophysical-impacts-dominated state (Bennett *et al.*, 2016a; Fawcett *et al.*, 2017; Ford *et al.*, 2018). Depictions of vulnerability as monolithic and principally deriving from the effects of a changing natural world are a false representation of what is inherently a co-evolutionary process, comprising an amalgam of dynamic exposures and sensitivities at differing local, regional and national scales that derive from both natural *and* socially constructed phenomenon (Ribot, 1995; Lewis & Kelman, 2010; Thomas *et al.*, 2019). It is argued that ubiquity of improper characterisations surrounding vulnerability has limited the attribution of causality (the *why)* when addressing root causes - primarily through obfuscating societal inequalities and social constructions of risk - with implications for the efficacy of the adaptation strategies that derive from vulnerability assessments (Tschakert *et al.*, 2013; Ribot, 2014). New, novel methodologies and approaches are urgently called for to assess the multiplex role of climate-society interactions from a more dynamic, processual perspective (Ford & Pearce, 2010, 2012; Fazey *et al.*, 2011; Moser & Hart, 2015). To this end, there is considerable advocacy within literature for the greater application of vulnerability and adaptation tracking approaches that adopt longitudinal or real-time methodologies and methods, and for those that can work with colonised communities to co-develop culturally appropriate and emancipatory research practices relating to the study of climate change (Ford & Pearce, 2012; Fawcett *et al.*, 2017; Carter *et al.*, 2019; Wilson *et al.*, 2020).

2. Aim and objectives

The aim of this thesis is to examine and characterise the vulnerability and adaptive capacity of an Inuit subsistence food system to dynamic, contextual climate change in the community of Ulukhaktok, NT. Three key objectives will ensure that this aim is achieved:

1. Develop a generalisable approach to better characterise the dynamic, contextual and processual nature of vulnerability to climate change.

2. Combine the new conceptual approach with a participatory, real-time land-use monitoring methodology to understand the vulnerability of the *Ulukhatokmiut* food system to climate change in the context of multiple socially constructed stressors, and to characterise how this affects hunting participation and foodshed stability.

3. Quantify social-ecological determinants of hunting trip productivity in the *Ulukhaktokmiut* food system.

3. Research context

3.1. *Vulnerability research*

Vulnerability is one of three main approaches to studying climate risk – the other two being 'adaptation' and 'resilience' – that can support policy discourses and research relating to the socio-biophysical impacts of climate change (Ford and Smit, 2004; Janssen *et al.*, 2006; Vogel *et al.*, 2007). Vulnerability[4] is concerned with accounting for the issues of *why, where, and in what ways* social-ecological systems and their different agents are susceptible to harm (Ribot, 2014; Thomas *et al.*, 2019). In doing so, it places a particular emphasis on the ways through which susceptibilities might be mediated through the coping and adaptive capacity of individual stakeholders and their recovery potential (Blaikie *et al.*, 1994; Engle, 2011; Ford *et al.*, 2018). It is argued that knowledge of vulnerability is a necessary prerequisite to, and provides a springboard for, effective climate change adaptation (Ribot, 2011, 2014; Mikulewicz, 2018). Ergo, in light of recognition that national and international attempts to mitigate climate change have thus far been insufficient and that an equal or

[4] Hereafter, 'vulnerability' is a term used to describe a state of being (i.e. to be susceptible to harm), but also in reference to the broader theory/concept of vulnerability itself.

principal focus on adaptation to changing environments is now essential, vulnerability as a relational and organising concept is experiencing a renewed interest (Malone & Engle, 2011; UNFCCC, 2015).

Vulnerability approaches typically conceptualise vulnerability as a function of exposures, sensitivities, and adaptive capacities; the relative net positive or negative effect of these yielding the degree to which a system, object or individual is at risk (Ford & Smit, 2004; Gallopín, 2006; Thomas *et al.*, 2019). Here, 'exposure' describes the relative strength and application of climatic stimuli on the area of interest (often termed the 'exposure unit'), while 'sensitivity' refers to the susceptibility of said area of interest to climatic stimuli as a result of its pre-existing and developing conditions (Füssel & Klein, 2006; Bennett *et al.*, 2016a). Adaptive capacity, on the other hand, can be defined as the sum of relationships (including expertise, and entitlements) and their mobilisation, which allow for individuals, households, or institutions to prepare, cope, adjust, or alter a system to mitigate against exposure (Ford & Smit, 2004; Engle, 2011).

Despite a consensus that vulnerability represents susceptibility to harm in response of an applied stimulus or stimuli, wider conceptions surrounding exactly what it means to be 'vulnerable', or the degree to which vulnerability captures social relationships and power dynamics, remain part of a contested and problematised discourse (e.g. Adger, 2006; O'Brien *et al.*, 2007; Hinkel, 2011; Tschakert & Tauna, 2013; Tschakert *et al.*, 2013). Indeed, contention abounds as to the ways through which vulnerability manifests (*is it a binary, static state and a cause of risk, or is it a dynamic, variable process?* (Cutter, 1996; Voss, 2008; Tschakert *et al.*, 2013; Kelman *et al.*, 2015)); how it is assessed (*is it possible to create indicators to assess vulnerability, even if socio-ecological factors are intangible?* (Ericksen & Kelly, 2006; Hinkel, 2011)); and its potential for the privileging of some drivers over others (*do current vulnerability framings privilege biophysical factors at the expense of better understandings around hegemonic political drivers, marginalisation and broader-scale power structures?* (Cameron, 2012; Ford *et al.*, 2018; Mikulewicz, 2018)).

3.1.1. ***The development of climate change vulnerability as a concept***

In terms of its epistemological origins, Kelman *et al.* (2016) contend that vulnerability and its application to the study of climate change is rooted in the sociology of natural hazards and biophysical risk (e.g. Carr, 1932; White, 1942; Fritz & Willaims, 1957), and arose as a distinct concept and framing in the 1970s and 1980s through development in the disciplines of international development and entitlements theory (see also McLaughlin & Dietz, 2008). During this period, the application of case studies and broader theoretical development challenged the 'naturalness' of disasters and the 'dominant view' that the biophysical world was the primary stressor in social vulnerability (e.g. O'Keefe *et al.*, 1976; Lewis, 1977; Marshall, 1979). This was later followed by a broader incorporation of both Weberian and Marxist principles surrounding notions of class, power, social structure and entitlements (e.g. Sen, 1981; Hewitt, 1983; Wijkman & Timberlake, 1984; Kasperson *et al.*, 1988; Watts & Bohle, 1993), and a transition toward a human ecology, political economy, and later a political ecology stance when asking *why* individuals and/or specific groups were vulnerable (see Bolin & Stanford, 1999; McLaughlin & Dietz, 2008; Methmann & Oels, 2014). A political ecology framing led to an embrace of more critical perspectives (e.g. Kaijser & Kronsell, 2014; Osborne, 2015). In particular, the notion that exposure to natural hazards or harmful phenomena extends beyond simply place or location, and that it is peoples' variable *sensitivity* to exposure as a result of power dynamics, knowledge structures, and the intersectionality of their socio-cultural, economic, and political circumstances and identities that makes them vulnerable (see Bolin & Stanford, 1999; Smit & Pilifosova, 2003; Ford & Smit, 2004; Tschakert & Machado, 2012; Kaijser & Kronsell, 2014; Osborne, 2015).

3.1.1.1. *'Outcome' versus 'contextual' vulnerability*

O'Brien *et al.* (2004, 2007) note that competing lineages and the varied application of conceptualisations has led to two divergent approaches to climate vulnerability in the modern-day (see also Kelly & Adger, 2000; Brooks, 2003). The first is that of an 'outcome', or 'end-point' framing, whose route of enquiry is embedded in the risk-hazard approach of early literature, and places its principal foci on the biophysical world as a determinant of exposures, sensitivities and, therefore, vulnerability (O'Brien *et al.*, 2007; Colette, 2016; Okpara *et al.,* 2016). Popularised in a climate context through early iterations of the IPCC Assessment Reports (e.g. IPCC, 2001), outcome vulnerability understands risk through a positivist quantitative lens as the net linear impact of climate stimuli – in terms of mortality, financial cost, or ecosystems change – once a sequence of emissions trends, climate scenarios, and exposures and adaptations have been accounted for (Klein & Nicholls, 1999; Kelly & Adger, 2000; O'Brien *et al.*, 2004) (Figure 1.3). *Vulnerability as impact* is perhaps the most notable characteristic of outcome-based approaches, which are typically scenario-based, predicated on the downscaling of global or regional circulation models, and have mitigation or adaptation driven by top-down, institutional responses (Burton *et al.*, 2002; O'Brien & Wolf, 2010; Ribot, 2014).

While framing vulnerability in this way has utility for ascribing numerical value to, or quantifying the impact of, climate change, and for allowing multi-national and broad-scale comparisons of potential climate change impacts, outcome-based approaches are commonly critiqued in the social science literature (e.g. Burton *et al.*, 2002; O'Brien *et al.*, 2004, 2007; Ribot, 2014). It is argued that such approaches fail to recognise the importance of broader social constructions and structural root causes by situating vulnerability as distinct or separate from society, and that they limit the ability of assessments to inform decision-making (Methmann & Oels, 2014; Ribot, 2014; Colette, 2016). In part this is considered to be a result of an inadequate accounting of stakeholder agency in outcome framings, but also because adaptation initiatives are location-specific and often based on coping with extremes, whilst climate scenarios are instead global or regional, and often present most-likely or average conditions (O'Brien & Wolf, 2010; Colette, 2016; O'Neill *et al.*, 2020). Kelman *et al.* (2016) highlight that these critiques relating to social constructions are perhaps best demonstrated through the way the IPCC (2014a, p.1772) define the concept of 'sensitivity' in their outcome approach, wherein there is no mention of mediating factors outside of the global climate system: "[Sensitivity is] the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change". Moreover, broader criticisms of outcome-based approaches stem from their perceived inability to account for broader processual complexity within social systems, including the principles of feedback mechanisms, adaptive learning, and two-way, non-linear interactions (O'Brien *et al.*, 2004, 2007; Fawcett *et al.*, 2017).

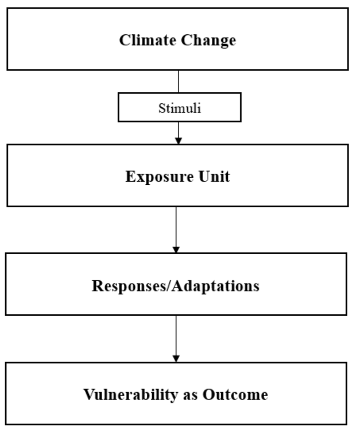

FIGURE 1.3: CONCEPTUAL FRAMEWORK FOR LINEAR ASSESSMENT OF VULNERABILITY AS AN OUTCOME (adapted from O'Brien *et al.*, 2007).

The second paradigm in contemporary vulnerability framings is that of 'contextual' vulnerability (O'Brien *et al.*, 2007). Otherwise known as 'starting point' or 'second generation assessment' (see Kelly & Adger, 2000; Füssel & Klein, 2006), contextual vulnerability is a typology whereby a greater focus is placed on the notion that exposures, sensitivities and adaptive capacities are multidimensional, non-linear and complex, and are heterogeneously distributed across societies as a result of their political ecologies (see Kelly & Adger, 2000; Adger, 2006; O'Brien *et al.*, 2007; Ribot, 2010, 2011; Tschakert *et al.*, 2013). Contextual approaches derive from the livelihoods/entitlements tradition in vulnerability research, and the idea of "hazard of place" (see Cutter, 1996), whereby vulnerability is understood to be a condition driven by – and modified in light of – socio-economic, political and cultural conditions of a system within a particular exposure unit, rather than a condition created by climate change in of itself (Kelly & Adger, 2000; O'Brien *et al.*, 2004) (Figure 1.4). Beyond simply a quantification of the impacts of climate change, contextual framings ask: *who is vulnerable, and why? How are socio-ecological conditions and their interactions synthesising or ameliorating against vulnerability? In what ways can vulnerability to climate change be reduced?* (see Ford *et al.*, 2010).

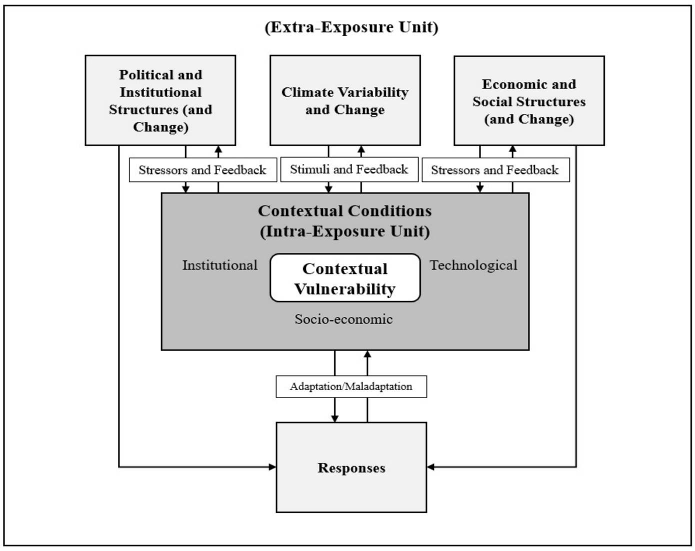

FIGURE 1.4: CONCEPTUAL FRAMEWORK FOR CONTEXTUAL VULNERABILITY ASSESSMENT (adapted from O'Brien *et al.*, 2007).

In order to address these questions, the temporal frame of reference for contextual vulnerability approaches also differs. Whilst outcome approaches focus on the use of models and scenarios to project future conditions, contextual approaches instead assess characteristics determining vulnerability in the present with the objective of making prognoses of susceptibility to future risk (Ford & Smit, 2004; Okpara *et al.*, 2016). The application of contextual vulnerability has become increasingly popular in recent years, stemming from an increased understanding that vulnerability does not come about as an impact of climate change, but is instead a pre-existing condition, governed by system characteristics, that determines climate impacts (Kelly & Adger, 2000; Eakin & Luers, 2006). Sharma & Ravindranath (2019), among others (Ford *et al.*, 2010; Okpara *et al.*, 2016), suggest that contextual framings are now the dominant form of vulnerability assessment, pointing to a "paradigm shift" in the most recent IPCC literatures (see IPCC, 2014b, 2018a, 2022), which they contend now also adopt this model. This is most evident in the case of the IPCC climate risk framework – also termed 'propeller diagram' – as used by Working Group II of the IPCC AR5 and built upon in AR6 (IPCC, 2014b, 2022) (Figure 1.5). Although this framework no longer places a linear, unidirectional focus on the impacts of climatic stimuli, it has been critiqued for its ability to account for the concepts of compound, cascading and aggregate risks across time and space – particularly when these derive as a result of responses to risks in the form of maladaptations (Simpson *et al.*, 2021). Moreover, the definition of risk that sits within framework still positions risk as rooted in climatic hazards: "[i]n the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change" (IPCC, 2022). Even the choice to use the term 'hazards' – which is derived from 'natural hazard' in this case – as opposed to using the term 'stimuli' could be considered the privileging of the biophysical. This makes sense for organisations such as the IPCC – whose main area of interest is the impact that climate change is having, or will have on society, and the natural world. However, for research where the role of the biophysical is not to be privileged, and could conceivably be having little effect relative to other socially-constructed stressors affecting a system (e.g. poverty, colonialism), the climate risk framework is perhaps less applicable (Ford *et al.*, 2018).

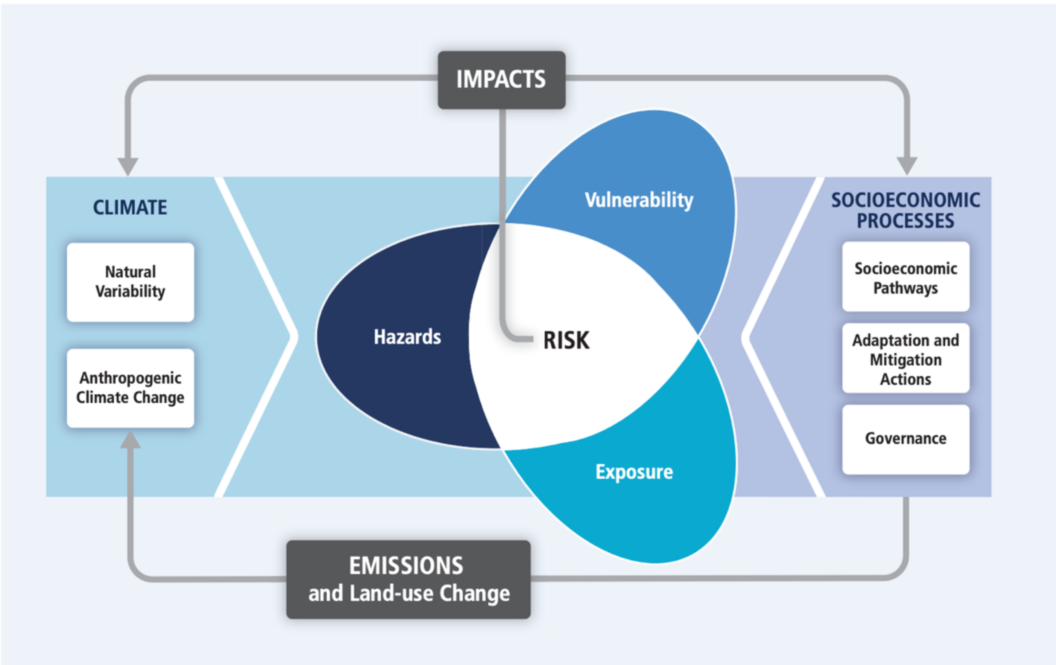

FIGURE 1.5: CONCEPTUAL FRAMEWORK FOR THE RISK OF CLIMATE-RELATED IMPACTS, AS ADOPTED BY IPCC IN AR5 (from IPCC, 2014b).

3.2. *The Arctic and the social sciences 'vulnerability approach'*

In an Arctic climate change and social ecological systems context, case studies in the form of community-based participatory research (CBPR) have frequently been adopted to address the contextual nature of climate vulnerability through a lens that has examined the 'human dimensions of climate change' (HDCC) (Ford *et al.*, 2010; Ford *et al.*, 2012a; Andrachuk & Smit, 2012; Ford *et al.*, 2013; Statham *et al.*, 2015; Archer *et al.*, 2017; Fawcett *et al.,* 2018). CBPR with a vulnerability/adaptation focus is seen as a means of developing and democratising research in line with community needs and priorities (Ford *et al.*, 2016a). Its objectives typically revolve around knowledge co-creation and mobilisation, community empowerment, and the consideration of community-researcher relationships, with the broader aim of informing decision-making and capacity building at the local level (Reid *et al.*, 2009; Ford *et al.*, 2018). The HDCC, on the other hand, refers to a multiplicity and heterogeneity of factors, viewed from a post-positivist lens, that relate to exposures, capacities and responses of societies to climate change (National Research Council, 1992; Ford & Pearce, 2012; Goldman *et al.*, 2018). Pertinent examples include, but are not limited to, resources and their allocation, power structures and the ability of agents to utilise power, wealth and financial stability, cultures and their role in affecting livelihoods, and social structures and demography (National Research Council, 1992). It is argued that through adopting this 'heterogeneity of factors', HDCC scholarship is well suited to understanding casual factors in vulnerability and linking research to policy outcomes (Ford & Pearce, 2012). This is particularly true for Indigenous peoples and their communities, whose susceptibility is complicated by colonial imposition and historical marginalisation and dispossession (OHCHR, 2016).

3.2.1. *The four dimensions of HDCC research*

In a review of scholarship relating to the Inuit subsistence sector in Inuit Nunangat, Ford & Pearce (2012, p.277) identify four key areas within which past HDCC research has been situated: '*Indigenous observations of climate change'*, *'impacts'*, *'vulnerability and resilience'* and *'intervention studies'*:

'Indigenous observations of climate change' research emerged as a foundation for early HDCC-focused Arctic vulnerability research within Inuit Nunangat (Ford *et al.*, 2012a, 2012b). Primarily focusing on the situated knowledges of community members and Inuit engaged in subsistence activities, this scholarship documents Indigenous understandings of how the Arctic environment is being altered by climatic change (e.g. Krupnik & Jolly, 2002; Nichols *et al.*, 2004; Nickels *et al.*, 2005; Waugh *et al.*, 2018). Case studies have recognised an altered cryosphere, including changing ice regimes and dynamics, such as early break-up and delayed freeze-up, and increasing permafrost melt; less

predictable weather and sea conditions; altered species populations and distribution; changes to precipitation concentration and frequency; and increased rates of coastal erosion (Nichols *et al.*, 2004; Laidler & Ikummaq, 2008; Cuerrier *et al.*, 2015; Huntington *et al.*, 2016; Henri *et al.*, 2020; Pettitt-Wade *et al.*, 2020). Much of the research in the '*Indigenous observations of climate change'* sphere in recent years has also augmented observations of the environment with Western scientific knowledge and empirical data on sea-ice, weather conditions and species health and distribution (e.g. Riewe and Oakes, 2006; Gearheard *et al.*, 2010; Peacock *et al.*, 2020; Fox *et al.*, 2020; Petzold *et al.*, 2020). Some have critiqued this development for its potential to use Western science as a means of 'validating' Indigenous knowledges, for its propensity to incorporate Indigenous knowledges minus their value systems or worldviews, or due to the requirement for scientific studies to still produce outcomes with a Western valence (and thereby perpetuate a hierarchy of knowledge systems) (Mantyka-Pringle *et al.*, 2017; Naylor, 2021). Others have advocated that the combination of multiple ways of knowing is essential for transdisciplinary knowledge co-production and developing effective wildlife co-management initiatives *vis-a-vis* climate change (the latter is now enshrined in legislation in Canada (Nunavut Land Claims Agreement Act 1993)), particularly when Western science and Indigenous knowledge systems can be 'bridged' and held as equals (Rathwell *et al.*, 2015; Kourantidou *et al.*, 2020).

A second key area of HDCC scholarship in the Arctic, often incorporating '*Indigenous observations of climate change'*, has focused on the biophysical '*impacts'* of climate change (Ford & Pearce, 2012). Much of this work has attempted to understand the ways through which climatic changes are directly affecting Inuit-environment interactions and the subsequent function and stability of subsistence food networks, often emphasising the negative effects of environmental change (Ford & Pearce, 2012; Downing & Cuerrier, 2011). Past examples have focused on the difficulties and safety implications associated with navigating land, sea and ice under changing or extreme conditions (Laidler *et al.*, 2009; Druckenmiller *et al.*, 2013; Driscoll *et al.*, 2016; Ford *et al.*, 2019b), the ways through which a decline in certain climate-sensitive subsistence species might affect nutrient intake in communities (Wesche & Chan, 2010; Nancarrow & Chan, 2010; Rosol *et al.*, 2016), or the potential for an altered climate to affect infrastructure and shipping in the North (Larsen *et al.*, 2008; Andrachuk & Smit, 2012; Hjort *et al.*, 2018). Clark *et al.* (2016), for instance, in a case study of search and rescue incidents across Nunavut, drew direct statistical correlation between unintentional injury while out on the land (a leading cause of morbidity in the territory) and environmental factors directly influenced by climate change: ice concentration, type and thickness, and daily ambient temperatures (see also Durkalec *et al.*, 2014). Earlier scholarship by Laidler *et al.* (2009), notes the impact of thinner ice during the hunting of seals in autumn months in the North, which, in addition to increasing the possibility of accidents, can also hold implications in relation to the distribution and availability of animals, by reducing the ability of marine mammals of rest on floes or build dens, and can also necessitate that hunters use alternate travel routes (see also Ford *et al.*, 2009).

Ford & Pearce (2012) contend that the fourth dimension of HDCC research, '*vulnerability and resilience',* (much like the epistemological turn in wider vulnerability research in the early 2000s) derives from a desire to move beyond an understanding of the mere biophysical impacts of climate change, and to instead comprehend its socioeconomic, health, political, and cultural context. Specifically, '*vulnerability and resilience'* approaches are seen as critical for understanding the ways through which factors such as financial capital, familial networks, political power, institutional support or other social constructs work collectively to affect - *and be affected by* - adaptive capacity and sensitivity to a changing climate in the Arctic (e.g. Ford *et al.*, 2009, 2013; Beaumier *et al.*, 2015; Bunce *et al.*, 2016; Archer *et al.*, 2017; Fawcett *et al.*, 2018). The work of Ford & Smit (2004) (see also Ford *et al.*, 2006) represents a seminal development in CBPR HDCC vulnerability framings; primarily through the application of their heuristic equation for exploring vulnerability at the localised scale for Indigenous communities across time (after Smit & Pilifosova, 2003):

$$\mathbf{V_{ist} = f\ (E_{ist}\ \ A_{ist})}$$

V_{ist} = vulnerability of a community (i) to climate stimulus (s) in time (t)
E_{ist} = exposure (and sensitivity) of community (i) to climate stimulus (s) in time (t)
A_{ist} = adaptive capacity of community (i) to climate stimulus (s) in time (t)

The central thesis of Ford & Smit's (2004) approach is that through understanding the vulnerability of a community to climate change in the present (t_1), it is possible to project how that community might subsequently experience vulnerability in the future (t_2) (Figure 1.6). In such a typology, the accuracy of projections for t_2 is a direct consequence of the quality, insights and findings of the data collected for t_1. Here, CBPR becomes critical, as it is a means of highlighting stakeholder perceptions as to *why* individuals might be vulnerable; for recognising nuanced socio-cultural, economic, poltical and environmental conditions that would otherwise be lost on lower resolution, non-participatory research approaches; and for integrating multiple knowledge systems and co-creating new knowledge to contextualise climate, weather and ecosytstems research (Laidler *et al.*, 2009; Pearce *et al.*, 2009; Ford *et al.*, 2010; Druckenmiller *et al.*, 2013).

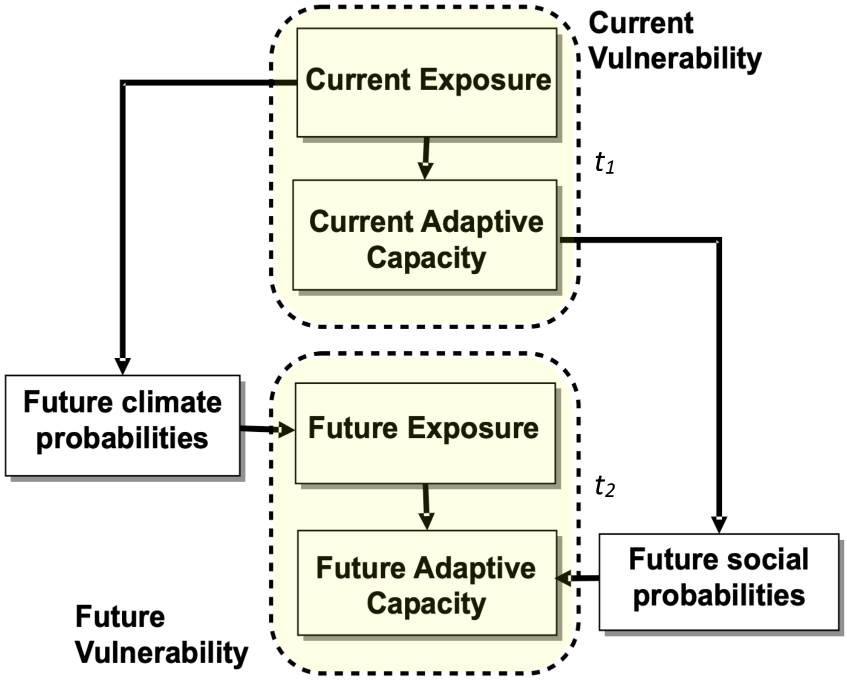

FIGURE 1.6: FORD & SMIT'S (2004) CONCEPTUAL APPROACH FOR COMMUNITY-BASED CLIMATE CHANGE VULNERABILITY ASSESSMENT, DEMONSTRATING THE UTILITY OF CURRENT KNOWLEDGE ON VULNERABILITY (*T1*) AS A MEANS OF PROJECTING FUTURE CONDITIONS (*T2*) (adapted from Ford & Smit, 2004).

Recent vulnerability research has examined how changing climate and weather patterns, primarily through their role in disrupting land-based activities, are "compounding existing environmental dispossession" to negatively affect Indigenous wellbeing and mental health (Durkalec *et al.*, 2015, p. 17; Middleton *et al.*, 2020). Other studies have identified the ways through which altered snow and land conditions, influenced by shifting seasonality and compounded by a need for mechanised travel, have affected the cash component of the persistent mixed economy; notably through the impact of factors such as boggy ground or powdery or inadequate snow depth on the fuel economy of vehicles and their propensity to result in damage (Ford *et al.*, 2008; Pearce *et al.*, 2010). In the context of harvesting species, researchers have explored the possible benefits or hazards associated with 'species diversification', whereby animals that might be in decline or susceptible to the impacts of climate change are substituted for more stable subsistence species (Wenzel, 2009; Pearce *et al.*, 2015). However, a number of studies have also pointed to the fact that this adaptation requires not only Inuit ecological knowledge of how to harvest different animal species – a factor affected by legacy colonialism – but may also risk disrupting ecosystem stability in other ways through affecting food webs (Wenzel, 2009; Organ *et al.*, 2014; Pearce *et al.*, 2015). Reduced knowledge transfer and lost ecological knowledge of the environment has also been linked to a decrease in hunting success, whereby some hunters now no longer have the knowledge required to engage in certain harvesting activities regardless of species diversification (e.g. Pearce *et al.*, 2011a). Panikkar & Lemmond (2020) in a recent study assessing vulnerability of land- and sea-ice-based travel to environmental change in the communities of Kugluktuk and Cambridge Bay, Nunavut also note the role of reduced intergenerational knowledge transfer about the environment as a factor increasing risks when travelling and navigating in inclement weather. This is considered to be particularly true when snowmachines, GPS, and weather forecasts are used as opposed to dogsleds and Inuit knowledge systems. While GPS can provide a crucial safety net should hunters be caught in a whiteout or inclement weather, some authors have questioned whether having the option to navigate in poor conditions has the potentially maladaptive effect of encouraging risk-taking behaviour and decreasing preparedness prior to travel (Ford *et al.*, 2008; Pearce *et al.*, 2015; Clark *et al.*, 2016).

'Intervention studies' characterise the final domain of Arctic HDCC scholarship (Ford *et al.*, 2012a, 2012b). This area of research focuses on the 'adaptation challenge' or 'adaptation deficit' in the Arctic, whereby communities in the North are considered more vulnerable to environmental change as compared with those in the sub-arctic or central North America (see Ford *et al.*, 2015). '*Intervention studies'* are aimed at exploring strategies and opportunities for successful small-scale, informal adaptations and larger, policy-level adaptation initiatives; often focusing on the concept of projecting future exposure-sensitivities from an understanding of contemporary conditions and adaptive capacities (Ford & Pearce, 2012). Past scholarship has characterised '*intervention studies'* as a nascent body of research, with recent literature reviews on this topic suggest little progress has taken place beyond attempts at capacity building, adaptation planning, or groundwork initiatives (Pearce *et al.*, 2011b; Ford *et al.*, 2014, 2017; Labbé *et al.*, 2017; Canosa *et al.*, 2020). Labbé *et al.*, (2017), for instance, note that following the creation of six climate change adaptation planning documents developed for six communities in Nunavut in 2010 (e.g. Hayhurst & Zeeg, 2010; Nasmith & Sullivan, 2010), no new adaptation documents for different communities have been developed, nor have the existing documents been updated. Similarly, a recent review by Canosa *et al.* (2020) points to the fact that a majority of adaptation initiatives focusing on subsistence in the Arctic remain reactionary and responsive rather than percipient, and infrequently provide evidence that they have integrated projections of future climate change into their interventions, raising questions as to their long-term sustainability.

3.2.2. *HDCC-vulnerability research and its contentions*

Despite the ubiquity of HDCC/contextual climate change framings in vulnerability research focused on the Canadian Arctic, the validity of such approaches as alternative or complimentary to other research frameworks - particularly from adaptation or resilience scholarship - has become increasingly contentious (Ribot, 2011; Cannon & Müller-Mahn, 2010; Miller *et al.*, 2010). Methodologically, vulnerability assessments have been critiqued as to their efficacy in capturing spatiotemporally dynamic, cross-scale stressors, exposures and impacts, and for a lack of recognition that climate susceptibility is a processual (as opposed to static) state (Thomalla *et al.*, 2006; Ford *et al.*, 2018; Tschakert *et al.*, 2013). Adger (2006, p.276, my italics) for instance, identifies vulnerability as " manifest in *specific places* at *specific times*". Kelman *et al.* (2016) argues that this framing of climate vulnerability has failed to acknowledge that: *i)* vulnerability develops *over time* as a result of competing stakeholder agency, politics, social processes and resource distribution, and *ii)* that vulnerability is comprised of sensitivities and adaptive capacities, which are determined by factors *both exogenous and endogenous* to specific locales in social-ecological systems. Ford *et al.* (2018) echo similar concerns, suggesting that the role of fast versus slow drivers in vulnerability, and their role as compounding actors, are lost in many vulnerability approaches, both applied historically and in the present day (see Chapin *et al.*, 2009). In instances where Inuit ecological knowledge has been incorporated into assessments (e.g. Pearce *et al.*, 2015), some have argued that framing ways knowing as 'traditional' (e.g. traditional ecological knowledge (TEK)) has also led to a static or anachronistic framing of knowledge systems, and a perception that they cannot address rapid change (Ready & Collings, 2020).

Mosurska & Ford (2020) delve deeper into the fundaments underlying the research approach of much vulnerability scholarship by questioning the notion of CBPR; they lament that much of scholarship championing community engagement in the Arctic fails to ask not only '*who participates*?', but also develops homogenistic framings of what exactly constitutes 'a community.' To this end, Wolf *et al.* (2013) suggest that past vulnerability approaches have also failed to incorporate values systems, both material and cultural, which has hindered understandings surrounding "what is worth saving", and therefore the validity of adaptive strategies that stem from vulnerability assessments (see also O'Brien & Wolf, 2013).

Beyond methodology, authors such as Brown (2011) have also taken issue with the term 'vulnerable' itself. Suggesting that - despite its popularity in the lexicon of academics and policymakers - it has the potential to problematise and victimise peoples and their livelihoods if applied without due consideration. Designating a circumstance of 'vulnerability', if so desired, can provide a rationale for external intervention or assistance and thereafter be a pretext for legitimating ideas of patriarchal control and societal, economic and political exclusion (Brown, 2011; Thomas & Warner, 2019; Marino & Faas, 2020). Haalboom & Natcher (2012), among others (see also Cameron, 2012; Hall & Sanders, 2015), reinforce the central thesis of Brown's (2011) work. Raising concerns regarding recent vulnerability and HDCC scholarship among Indigenous peoples in Arctic Canada, they suggest that 'labelling' people as vulnerable, in combination with the use of place-based, non-participatory methods, risks perpetuating hegemonic stereotypes of Rousseauian, "local" ways of life for Indigenous peoples, develops undertones of relict and present-day colonial practices[5], and evokes impressions of "underdevelopment" (see also Hall & Sanders, 2015; Lindroth & Sinevaara-Niskanen, 2018). Cameron (2012) further contends that, despite the often well-intentioned framing of vulnerability approaches and HDCC-focused research, non-critical, technocratic applications that have disregarded the above critiques endanger Inuit research priorities surrounding participation and self-determination (ITK, 2018; Wolf *et al.*, 2013). More recent applied research by Ready & Collings (2020) perceives that – much like work globally that privileges the biophysical nature of climate change when assessing vulnerability – the *a priori* focus of much Arctic HDCC vulnerability scholarship on the severity of stressors in the natural environment has worked to obfuscate and cloud the root causes of vulnerability *vis-à-vis* climate change (see also Wenzel, 2009; Collings, 2011). Much of this, it is argued, is rooted in the deleterious impacts of colonialism, the muddying of which leads to its "invisibilisation" and "responsibilise[s] Indigenous peoples for their own resilience" (Cameron, 2012; Mackay, 2018; Young, 2020, p.4).

Advocates for vulnerability research have largely rebutted the assertions of Cameron (2012), Brown (2011) and others. Ford *et al.* (2018), for example, point out that vulnerability approaches do not pre-emptively denote a negative focus to the region of study, or designate populations as more or less vulnerable *a priori*. Vulnerability research is instead a mechanism for attributing causality and understanding *whether*, but also *why* peoples might be differentially at risk (Ford *et al.*, 2018). Ribot's (2011) work highlights the utility of this understanding when working with Indigenous peoples. They posit that knowledge of causality allows for the politicisation of drivers in vulnerability – something that is often missing from alternative adaptation and resilience framings (see Cannon & Müller-Mahn, 2010; MacKinnon & Derickson, 2012; Weichselgartner & Kelman, 2013) – with implications for promoting self-determination, self-governance, and anti-colonial approaches. Moreover, in suggesting and embracing the fact that some people are indeed sometimes victims of circumstance, Ribot (2011,

[5] For a discussion on the use of 'vulnerable' status as a means of legitimating patriarchal control among Indigenous Canadian groups see also Damas (2002).

p.1161) proposes that whilst individuals or groups may indeed be seen as 'vulnerable' this also means that they are *not* expected to bear "the burden of response"; i.e. they are *not* 'responsibilised' for their own resilience (Young, 2020).

Notwithstanding the theoretical debates around vulnerability, there remains recognition that, both conceptually and methodologically, novel changes and advances in scholarship are critically needed that remain cognizant of vulnerability's strengths and potential, but also recognise its limits as an analytical tool and organising concept. Crucially, in relation to the semantics and approaches to vulnerability, Marino & Faas (2020, their italics, p.41) call for a new need to "articulate vulnerability in terms of the *relationships and assemblages, which produce inequitable risk themselves*… which are therefore the proper loci of investigating vulnerability". They argue that contemporary scholarship overlooks the fact that vulnerability arises at the system scale and has a causality that resides within the web of systemic relations and assemblages that can create and perpetuate 'vulnerability as violence' for subaltern peoples or marginalised places (Marino & Faas, 2020). Moreover, critiques that vulnerability has historically placed insufficient emphasis on colonial legacies are valid: as Cameron (2012) rightly notes, the phrase "colonialism" was largely absent from Arctic HDCC studies pre-2012, with most scholarship instead electing to use more depoliticised phrases such as 'government imposition' or 'Westernisation'. Methodologically, there is advocacy for new literature that better addresses the issues of dynamism, values systems, feedback mechanisms, cross-scale spatiotemporal and human-environment interactions at the community-scale (Ford & Pearce, 2012; O'Brien & Wolf, 2013). It is argued that this will require not only new approaches to how we think about vulnerability (e.g. Fawcett *et al.*, 2017) but also the development of new participatory methods, such as scenario planning, longitudinal initiatives, real-time monitoring, or repeat cohort/trend observations over years to decades (Archer *et al.*, 2017; Ford *et al.*, 2018; Flynn *et al.*, 2018; Singh *et al.*, 2019). There has been a particular growth in support for the development of Inuit-led CBPR approaches (Carter *et al.*, 2019; Wilson *et al.*, 2020). Specifically, research agendas that are co-designed between Western researchers and community members, build research capacity within communities, and adhere to Inuit ethics and funding priorities (Pearce *et al.*, 2009; ITK, 2018).

Despite a rapid expansion of HDCC research since the mid-2000s, both geographically and epistemically, a number of subject-specific research gaps also exist within Arctic subsistence-focused vulnerability research. For instance, past HDCC case studies have long recognised that climate change can synthesise sensitivities relating to both 'sudden-shocks' that manifest as climatic extremes (e.g. Statham *et al.*, 2015) or more incremental changes (e.g. Andrachuk & Smit, 2012) (see Ford *et al.*, 2009). However, a lack of longer-term monitoring and a propensity for research to be conducted as part of one-off 'parachute' field seasons means that little research has captured both of these phenomena within the same study (see Ford & Pearce, 2012; Fawcett *et al.*, 2017 for a critique). This has led to knowledge gaps as to the relative coping capacity of communities between more day-to-day incremental changes versus more substantive, low-frequency, high-magnitude events, and subsequently a lack of knowledge as to the relative precedence that climate change should be afforded versus other intra-community factors. Objectives one and two of this thesis, in addition to the conceptual approach established in paper one and the empirical research conducted in paper two, are designed to address this research problem.

In addition to biophysical drivers as determinants of Inuit hunting success (i.e. the suitability of ice for seal reproductive cycles, the health of animals, ice safety etc.), social factors have also been found to affect hunters' relative productivities, and therefore their potential vulnerability to food scarcity (Collings, 2009a; Natcher *et al.*, 2016). However, considerable knowledge gaps also exist relating to what factors might determine the success and productivity of Inuit hunting groups - be these social or climate change related – or factors that limit hunting participation on a non-life course timescale (i.e. *what affects participation on a day-to-day basis*) (Collings, 2009a). A majority of past research has concentrated on how the characteristics of hunters as individuals, or those arising from colonial legacies, might affect hunting success (e.g. Smith & Wright, 1989; Collings, 2009a); this comes despite the fact that hunting is typically a group activity, occurring with multiple party members. The most-recent substantive body of research examining Inuit hunting group productivity was undertaken as long ago as the 1980s (see Smith, 1980, 1983). Research gaps relating to the subsistence hunting and harvesting sector are made even more stark in the contemporary Arctic, with recognition as to the climate-sensitive nature of many activities and their links to food security and health (Harper *et al.*, 2015). Objectives two and three, and papers two and three of this thesis have been designed to address this research gap.

Thirdly, the efficacy of government programs aimed at promoting adaptive capacity and coping capacity within subsistence-focused food systems remains poorly understood in the North (Ford & Pearce, 2012; Ford *et al.*, 2019a). This is despite significant annual investments in Harvesters' Assistance Programmes[6] by the federal government, a changing landscape relating to food policy surrounding the sale of traditional foods and its associated controversies (Ford *et al.*, 2016b), and the

[6] In 2020, the federal government announced an additional CAN$40,000,000 in funding, spread across 5 years, as part of a 'Harvester's Support Grant' for Inuit and First Nations peoples in Canada. Land claim organisations and self-government recipient organisations in Inuit Nunangat will receive CAN$28,737,000 of this fund (Government of Canada, 2020). These funds are separate from other pre-existing regionally administered funds, such as the Inuvialuit Harvesters Assistance Program or other Community Harvester Support programmes.

variable provision, funding, and success of community freezer initiatives across Inuit Nunangat (Organ *et al.*, 2014). Understanding how institutional factors aimed at sustaining wild foods access and availability are intersecting with a changing social and climatic landscape in the Arctic is critical. This research gap is addressed in paper two and objective three of this thesis.

3.3. *Inuit livelihoods*

The impacts of anthropogenically-induced climatic change are now apparent and readily felt in Inuit Nunangat (the Inuit homeland of northern Canada) (Duarte *et al.*, 2012). However, understanding the ways that climate change and its impacts currently manifest for Inuit in the Arctic requires a more nuanced understanding of the longer term socioeconomic, cultural, and political contexts affecting the region. Hereafter, this section reviews scholarship on Inuit livelihoods in the context of subsistence hunting. Specifically, it examines the setting of historical colonisation, and how this has contributed to the enmeshment of hunting within capital markets and the Westernised cash economy, before discussing the importance of modern-day hunting to Inuit communities and the current state of the knowledge on how climate change is currently affecting mixed cash-subsistence hunting practices.

3.3.1. *The historical setting of settlement and colonisation*

Inuit are linguistic, biological and cultural ancestors of the semi-nomadic Thule peoples (Damas, 2002; McCannon, 2013). Often referred to as 'proto-Inuit', the Thule settled in the Low Arctic and Subarctic regions of the central and western North American Arctic during a period known as 'The Little Ice Age' between 1200-1300CE (Condon, 1996; McCannon, 2013). Through the progressive differentiation of Thule culture and ways of life, based upon location, relative isolation between groups, and the differing conditions of their local environments, populations of distinct Indigenous peoples had emerged in the Arctic by 1600, including Inuit, Iñupiat and Yup'ik (McCannon, 2013; Laugrand & Oosten, 2015). First contact between European explorers and Inuit populations within Inuit Nunangat – the area of Northern Canada considered to be the Inuit homeland (Figure 1.7) – also occurred during the 1600s, otherwise termed the Western 'Age of Discovery' (Damas, 2002). Contact tracked roughly east-to-west from modern-day Nunatsiavut to the Inuvialuit Settlement Region over the next 300 years, with some Copper Inuit (modern day Inuvialuit) remaining uncontacted until the late 1800s to early 1900s (Damas, 2002; Jenness, 1922).

It was not until far later in the 20th century, during an era commonly referred to as the 'Contact-Traditional Period' in literature, that an increased interest by the Canadian Government to assert sovereignty over the then Northwest Territories[7] resulted in a concentration of Inuit into regions that would later form the basis for today's permanent settlements; the implications of which on subsistence harvesting are still seen to this day (see Helm & Damas, 1963; Damas, 2002; Wenzel, 2008). Spanning the early-1920s to the mid-1950s, the Contact-Traditional Period describes a phase over which trading posts - established by companies such as Hudson's Bay (HBC) and Canalaska - missions, run by Roman Catholic and Moravian missionaries, and detachment posts, coordinated by the Royal Canadian Mounted Police (RCMP), were sited across the Canadian Arctic (Helm & Damas, 1963; Damas, 2002; Wenzel, 2008).

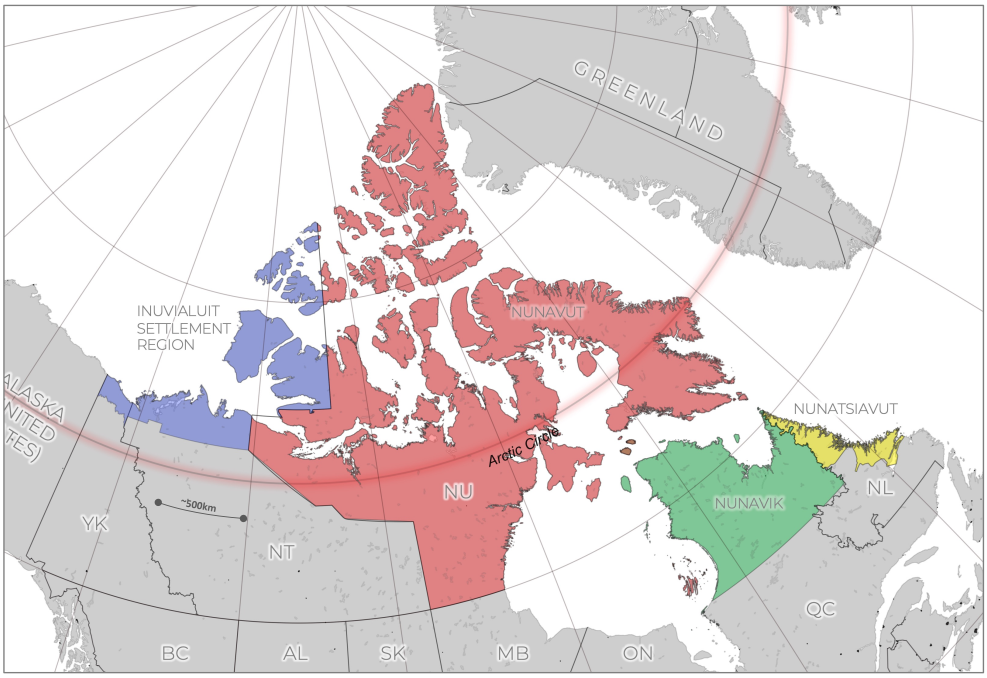

FIGURE 1.7: MAP OF INUIT NUNANGAT - THE INUIT HOMELAND IN CANADA. Comprised of four regions – Nunatsiavut, Nunavik, Nunavut and the Inuvialuit Settlement Region - delineated by either land claims or final agreements signed between 1978-2005.

Despite a 'policy of dispersal', agreed upon by HBC and various departments within the Government of Canada (GoC), representing an attempt to keep Inuit population distributed and decentralised across the North[8], the effect of siting permanent structures with newfound economic, political and

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[7] Until 1912, the Northwest Territories (NT) included all regions of Inuit Nunangat, with the exception of Nunatsiavut, and included what would become the Inuvialuit Settlement Region and Nunavut up until 1999.
[8] The rationale behind such a policy at the time was one of both economics and a philosophy of benevolence (Damas, 2002). Government ministers believed that population accumulations were hotspots for the transmission of diseases, such as tuberculosis; might limit access to traditional foods; and could increase reliance on welfare -

religious significance had a largely antithetical effect (Helm & Damas, 1963; Damas, 2002). An ability to purchase rifles, ammunition, and traps from HBC or Canalaska during this period increased the productivity of the fur trade and initiated a transition from wholly subsistence hunting livelihoods among Inuit to a positive feedback effect of engaging in commercial hunting and trapping (Usher, 1965; Collignon, 1993; Damas, 1993). More efficient hunting and trapping through the use of rifles, ammunition, and manufactured leg-hold traps had the potential to generate an income, from which further equipment or new soon-to-be staples such as tea, tobacco or flour could be purchased. As a result, patterns in land use gradually changed from seasonal travel between traditional locations to market-oriented travel, organised around time spent trading furs and purchasing commodities at posts, which, along with missions, became the loci for social gatherings during times such as Christmas and Easter (see Collignon, 1993). The extension of credit by HBC or other traders at specific posts, which allowed Inuit to acquire equipment in lieu of furs being brought in at a later date, or the extension of aid by the RCMP during periods of famine or hardship[9], also limited the distances hunters were able to travel or trap, knowing that they might need to return to these locales should their situations change (Collignon, 1993; Condon, 1996). Usher (1965, p.62) would later describe this practice as akin to Inuit being "virtually that of a bonded servant" to traders. The degree to which HBC activities changed Inuit livelihoods during the Contact-Traditional period – even in a relatively short space of time – is highlighted by Damas (2002, p.33) in recounting the closure of the Arctic Bay HBC post in 1927 (itself sited in traditional hunting grounds) whereby "removal of the post meant longer distances to trading centres… [and] subsequent hardship, including actual starvation".

Later into the 1940s, following the passing of the 1944 Family Allowances Act, there was further extension of government welfare, whose distribution was frequently coordinated by HBC (Nixon, 1990; Damas, 2002). Whilst this was at first only issued periodically or as an emergency measure when "prevailing local conditions require[d]", by the 1950s broader welfare policies, such as the Old Age Pension Act of 1927, were applied to the North with greater regularity (Wright, 1946 quoted in Damas, 2002, p.108; see also Nixon, 1990). Some posts, such as Rankin Inlet, Frobisher Bay, or Cambridge Bay, provided a further pull factor at this time by offering employment opportunities to Inuit, either permanent or temporary, in order to assist in stores or to unload stock shipments

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thereby making Inuit 'wards of the state' and depressing the profitability of a burgeoning fur trade (Helm & Damas, 1963; Damas, 2002).

[9] HBC posts and RCMP detachments also offered relief to the infirm or those who were unable to effectively hunt/trap, in the form of either medical assistance or food and clothing, which also encouraged accumulation in the vicinity of these locations (Nixon, 1990; Damas, 2002). Some authors have drawn direct association between the siting of permanent structures and a transition to market-driven systems with increased food insecurity, though this assertion remains contentious (see Weissling, 1991; Damas, 2002).

(Damas, 2002). The establishment of the Cold War Distant Early Warning (DEW) line in the 1950s, and the creation of mines in locations such as Rankin Inlet is further attributed by some authors in having affected migration and population accumulation (Damas, 2002; Tester, 2010).

Difficulties associated with increasing and unstructured population accumulations, including concerns over public health and education; the rising cost of relief in trading areas following a depression in fox fur prices (Figure 1.8); and a gradual rise in support for welfare reform in post-WWII Canada brought about the end of the GoC's policy of dispersal in the North (Usher, 1965; Damas, 2002; Tester & Kulchyski, 2011). It was in the years following, during the implementation of the 'welfare state policy' across Canada, that initiatives relating to healthcare, education and housing would develop the 'quasi-urban' settlements that exist in the region to this day (Usher, 1965; Damas, 2002).

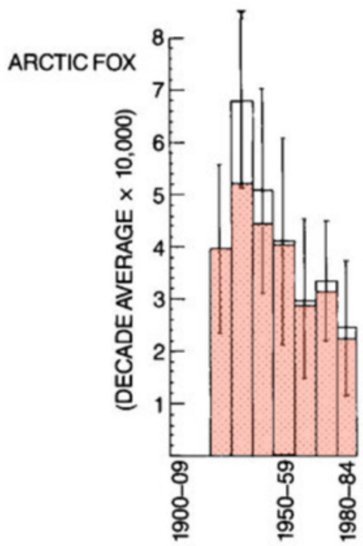

FIGURE 1.8: NUMBER OF ARCTIC FOX FURS HARVESTED IN N. AMERICA, 1900-1984. Canadian furs highlighted red. Note the reduced trend in harvest commencing <1950, which lead to a reduction in price and the reduced efficacy of trapping (from Obbard *et al.*, 1987, recoloured).

3.3.2. *The 'welfare state' and impacts of sedentarisation and centralisation*

Pre-welfare state policy, Inuit settlement patterns in Canada had primarily still been semi-nomadic: typified by seasonal movement between meat caches and hunting grounds, with intermittent periods spent near settler outposts, sometimes in shack-like wooden accommodation or skin tents (Tester, 2006; Debicka & Friedman, 2009). Moving into the 1960s, however, an end to the policy of dispersal brought about the implementation of a mass welfare housing programme for the North (Tester 2006;

Debicka & Friedman, 2009). Predicated upon the belief of Indian and Northern Health Service employees that poor public health and epidemics resulted from a lack of adequate or permanent housing, and that the construction of houses would expand upon an "Northern vision" of exerting Canadian sovereignty over the High Arctic, 125 permanent homes were constructed across 14 communities in 1960, with further mass home construction throughout the 1970s (Tester 2006; Debicka & Friedman, 2009). Notwithstanding the often-substandard provision of homes - many of which were seen to also have culturally inappropriate designs (see Stern, 2005; Cameron, 2015), and involved a significant burden of debt for their new owners (Tester, 2006). The rapidity with which settlements were constructed and people 'came off the land', had drastic livelihoods implications for the traditional subsistence hunting/trapping economy of Inuit (Condon, 1996; Collings, 2005).

Müller-Wille (1978), among others (see Kemp, 1971; Wenzel, 2000; Tester, 2010), argues that permanent settlement into communities had the effect of concentrating land-use patterns into smaller areas with more constrained resource bases, and indirectly brought about the development of a more capital-focused, "mixed" wage-based and traditional economy. Centralisation resulted in a need to travel significant distances from villages to increase the radius of access to resources that would ordinarily have been reached by seasonal migration; especially as the siting of settlements was often not based upon their proximity to subsistence resources, and its later stages were contemporaneous to an influx of mechanisation into the Canadian North throughout the 1970s (Müller-Wille, 1978; Pavri, 2005). Progressive uptake of snowmachines, motorised whale boats and ATVs, which were seen to have greater utility than sled dogs, tied Inuit subsistence practices to the broader, external global and national economy of resource use and capital accumulation (Kemp, 1971; Smith & Wright, 1989; Wenzel, 2019). Mechanisation not only had significant up-front costs associated with initial purchases, but also had ongoing costs relating to gasoline, oil and the costs of repair; all of which were dictated by global commodity markets (Smith & Wright, 1989; Wenzel, 2019). Apropos the capital costs of hunting during this period, there is debate as to whether "ecological advantages of modern equipment were offset by higher operating costs" (Duffy, 1988 in Wenzel, 1991, p.114). However, there is a general consensus that increased economic pressures relating to practicing subsistence during the 1970s and 1980s began to necessitate either an increased profitability in fur trading, or engagement of other family members in the wage-based economy to support hunting (Kemp, 1971; Müller-Wille, 1978).

Concomitant to the GoC's increased interest in the Arctic following WWII and the onset of the 'welfare state' was a large-scale desire to culturally assimilate the region's Indigenous peoples. A tactic now understood to have been a means of asserting sovereignty and mineral rights in the North by making Inuit 'naturalised Canadians' (TRC, 2015a). Although the formal schooling of Inuit children had been established by missions in the North as early as 1936 – with the notable siting of a residential school in Aklavik – it was not until the 1950s, when the federal government decided to expand schooling in the North, that considerable numbers of Inuit were subject to a Western, evangelised system of education (TRC, 2015b). Between 1949 and 1959 Inuit enrolment in residential schools increased by an order of magnitude (111 to 1,165) in the then Northwest Territories, with children taken away from their families, often forcibly, and transported *en masse* to schools often hundreds, or in some cases thousands, of kilometres away from their settlements (TRC, 2015c, p.82). Curricula within schools aimed to obfuscate and eliminate Inuit cultural norms and practices (ITK, 2005; TRC, 2015b, 2015c). In many cases, Inuit children were prohibited from speaking their respective languages and dialect or practicing and holding non-Christian spiritual beliefs or ways of knowing, and were frequently subject to verbal or physical abuses[10] (Igloliorte, 2011; TRC, 2015d).

The legacy of the residential schooling system for the North had significant ramifications for Inuit livelihoods and subsistence practices (Irwin, 1989; Amagoalik, 2008; TRC, 2015c, 2015e). In many cases Inuit who attended schools lost command of their respective *Inuktut* languages, and upon returning home were often less effective at hunting and trapping, having been excluded from traditional ecological knowledge (TEK) systems and a worldview that would otherwise have imbued them with the necessary skills to be out on the land (Igloliorte, 2011; Pearce et al., 2011a; TRC, 2015c, 2015e). Moreover, difficulties associated with reintegration and a loss of traditional livelihoods are also understood to have led to cultural divides between elders and youth, increased rates of substance abuse and domestic violence as a result of poorer mental health, and intergenerational trauma and poverty (Krümmel, 2009; TRC, 2015e; Wilk et al., 2017). Many of these issues have been linked to negative outcomes relating to hunting success, social cohesion and country foods[11] security among Inuit (see Chan et al., 2006; Kral et al., 2011; Elliot et al., 2012; Beaumier *et al.*, 2015; Hackett et al., 2016).

> 'Cause they never taught us that, you know, how to [live on the land after residential school]. At that time, there was no welfare, there was, there was no running waters or lights, so we had to do

[10] As of 2014, the Indian Schools Settlement Agreement, established in 2006 following the closure of the residential schools system to mediate claims of class-action lawsuits, had resolved 30,939 cases of physical or sexual abuse in schools, with CAN$2,690,000,000 awarded in compensation (TRC, 2015d, p.76).

[11] This doctorate adopts an amended definition of country foods established by Luongo *et al.* (2020, p.289): country foods may be defined as "foods gathered or harvested from local plant or animal sources, and possess cultural [and spiritual] meaning as traditional food to Indigenous peoples".

> all those things by ourselves, but we didn't know how. So, the people that went back had to relearn how to survive. And at that time, survival was fishing, hunting, and trapping. To this day, I don't know how to hunt. I can trap, I can fish, but I don't know how to hunt, 'cause I, I was never taught that. (Victor Paul in TRC, 2015e, p. 107).

The impact of residential schooling on Inuit culture and livelihoods was compounded by the effect of tuberculosis (TB); in the 1950s it is estimated that in excess of one third of the Inuit population of Canada became infected with the disease (Grygier, 1994). TB – in part believed to be spread by the sub-standard housing provision in many Arctic Canada communities over the subsequent decades (Dickerson, 1992; Cameron, 2015) – required treatment that was not available in new settlements. Therefore, owing to the long recovery period of the disease, Inuit requiring treatment were expected to spend months, or even years, in southern sanatoria (QIA, 2013). For children this time spent in southern hospitals was particularly acculturative (Grygier, 1994; QIA, 2013). For Inuit youth who returned to their communities, often years had passed since they had spoken their respective *Inuktut* languages, they had lost valuable time learning how to survive and harvest foods from their traditional lands, and some, including adults, were left with permanent disabilities that prevented their participation in hunting activities (QIA, 2013). Although the direct impacts of TB on communities is much reduced[12] in contemporary Inuit Nunangat, its indirect impacts, along with those of many of the other colonial practices outlined heretofore, such as the residential schools programme, manifest in the form of intergenerational trauma relating to mental health and ecological knowledge transfer, elevated rates of substance misuse, social disconnects, elevated rates of suicide, and the attrition of traditional cultural practices (Elias *et al.*, 2012; MacDonald & Steenbeek, 2015).

3.3.3. *The contemporary importance of Inuit subsistence and the nutrition transition*

Arguments relating to modernisation theory in the mid-to-late 20th century contended that subsistence practices among Inuit were not part of "a viable political economy", and that hunting and its associated social structures would "run their course" as a result of gradual Eurocentric modernisation, monetisation, and the extensive acculturation policies imposed by the GoC (Murphy & Steward, 1956, p.336; Morehouse, 1989, p.20; p.336; Chabot, 2003; see also Wenzel, 2019). However, despite assumptions that "high engagement in the cash economy [would result in] low engagement in subsistence production and diminished social relationships", modern Inuit livelihoods in the Canadian North and their associated subsistence practices are now understood to have adapted

[12] It should be noted that despite improved healthcare provision in the North, the spectre of colonialism in the Arctic means that rates of TB relative to the rest of Canada are still substantially greater. Of the approximately 1,600 cases of TB recorded per year in modern-day Canada, 90% of these are among its Indigenous populations or foreign-born individuals (Ghanem *et al.*, 2019).

into a "persistent mixed economy" (Kruse, 1991; BurnSilver et al., 2016, p.121; Wenzel, 2019). Often seen as an amalgam of Westernised external market forces, subsistence practices, and traditional sociocultural norms surrounding sharing and the distribution of country foods, the principle of the persistent mixed economies argues that there are in fact "two currencies" that now govern contemporary Inuit livelihoods (Wenzel 2019, p.568). The first is derived from the formal global market economy: money, which is used to purchase food from stores, cover capital costs associated with subsistence and purchase goods or services that are not provided through entitlements (Gombay, 2010; Wenzel, 2019). The second is a product of subsistence practices: country food, whose distribution is typically less directly transactional in nature and remains governed by cultural norms, sharing, and social expectations (Wenzel, 2000, 2019).

Although an increasing predominance of market currencies did not result in the *total* eradication of hunting practices toward the end of the 20th century as predicted by anthropologists[13], the development of the persistent mixed economy was enough to instigate a paradigm shift in food systems[14] across Inuit Nunangat that persists to this day (Mead *et al.*, 2010; Little *et al.*, 2020). The increased importance of money and availability of market foods has seen an increasing proportion of dietary intake being derived from market-based products, rather than those sourced from traditional land-based subsistence practices (Kuhnlein & Receveur, 2007; Council of Canadian Academies, 2014). This phenomenon is frequently described as 'the nutrition transition', and a wealth of research points to its net negative implications for Arctic Indigenous peoples (Damman *et al.*, 2008; Little *et al.*, 2020). Dieticians, for instance, have noted that country foods, such as arctic char, caribou, muskox and seal, are often high in Vitamin D, iron folate, zinc and many other essential nutrients, while conversely the number of significant food miles for store-bought foods means that they are often sugar saturated, preservative and calorie rich, and nutritionally inferior (Sharma et al., 2009; Egeland et al., 2011; Fares & Weiler, 2016). As a result, a reduction in the intake of traditional foods and subsequent replacements by nutrient-poor, often sugar-rich alternatives, compounded by more sedentary lifestyles, has been linked to increased disease susceptibility and obesity in Inuit Nunangat, particularly the conditions of type-two diabetes, strokes, cardiovascular disease, and anaemia (Kelly *et al.*, 2008; Mead *et al.*, 2010; Kolahdooz *et al.*, 2017; Jamieson *et al.*, 2016). Moreover, beyond the simple nutritional importance of country foods, research has also linked the practice of hunting and

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[13] As recently as 2017, the *Aboriginal Peoples Survey* reported that 65.3% of Inuit aged 25-54 in Inuit Nunangat region had either hunted, fished, or trapped foods from the land in the previous year, with rates ranging from 59.9% in the Inuvialuit Settlement Region to 73.0% in Nunatsiavut (Arrigada & Bleakney, 2019).

[14] A 'food system' can be defined as the full range of activities, inputs and outputs and actors involved in the production and harvesting of foods, through processes of their aggregation and preparation, to their distribution and consumption (Ericksen, 2008).

harvesting from the land with improved mental health and wellbeing; notably as an "important integrating mechanism… providing social continuity with the past and a vital sense of self-worth to those struggling with a new identity in a changing northern world" (Condon *et al.*, 1995, p. 43; Newell *et al.*, 2020). Gray *et al.* (2016, p.254), in a statistical analysis of determinants of Inuit youth wellness in Nunavik, found empirical association between participation in traditional activities and improved mental wellness, noting that their results "were likely generalisable to other Inuit communities".

In order to better understand changing food systems in the North, the concept of 'food security' has been frequently applied to past research addressing the nutrition transition (e.g. Lawn & Harvey, 2003, 2004; Ford, 2009b; Beaumier & Ford, 2010). Food security, according to the FAO (2020, p.254), describes "a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." However, the utility of such a concept to Arctic Indigenous food systems has also received considerable critique (Gerlach & Loring, 2013; ICC-Alaska, 2014; Ready, 2016) and studies have produced conflicting results when attributing the significance of traditional foods to rates of food security/insecurity (e.g. Guo et al., 2015 vs. Ford, 2009b). Few studies adopting the concept centre their research around nutrition or cultural considerations, with a majority of food security assessments taking an objective calorific focus (i.e. 'have you eaten enough [calories]', rather than what have you eaten). The mismatch between the concept of food security and its application to Inuit food systems has led to calls for new approaches and conceptualisations to assess the vulnerability and susceptibility of food systems; often advocating for a more holistic, emic approach that can understand place and culture-specific nuance (Power, 2008; Ready, 2016; ICC-Alaska, 2014).

In recent years there has been an increase in the application of the 'foodshed' concept to traditional and place-based food systems in the Arctic (Loring, 2007; Loring & Gerlach, 2009; Ford & Beaumier, 2011; Gerlach & Loring, 2013). Analogous in many ways with the metaphor of a watershed, the term foodshed was first developed in 1929 by Walter P. Hedden when attempting to understand the multitude of ways through which food flowed into New York, and to qualify the susceptibility of the city to a 1921 nationwide railroad strike (see also Kloppenberg *et al.*, 1996; Cohen, 2010). In an Arctic context, the term foodshed has subsequently been defined as: "comprising the local processes and actors involved in the production, processing, distribution and exchange of food within a specific geographic area" (Ford & Beaumier, 2011, p. 57). Loring & Gerlach (2009) link the foodshed to the nutrition transition as part of a phenomenon known as "coming out of the foodshed" in Arctic North America, whereby market foods in Northern communities are providing a more reliable source of foods, but are also reducing engagement in the traditional subsistence economy, and can develop "new vulnerabilities and economic dependencies" in light of questions around affordability, health and wellbeing, and nutrition (see also Gerlach & Loring, 2013). Understanding the impediments to the stability of the subsistence component of Northern foodsheds has therefore become essential (Council of Canadian Academies, 2014). This is especially true in relation to barriers that exist surrounding the sourcing of traditional foods, such as difficulties involved in accessing hunting grounds, rates of hunting participation, and the ways through which foods are subsequently shared within communities and made available to individuals (Council of Canadian Academies, 2014; Hoover *et al.*, 2016; Ready & Power, 2018). This research gap is addressed in both objectives two and three, and papers two and three of this thesis.

4. Research design

4.1. *Research approach*

This thesis adopts a critical realist paradigm as its philosophy of science. Critical realism argues for an objective reality or environment, but states that the knowledge created about that environment, the ways it is measured, and the notion of 'truth' about phenomenon within it are subjective (Bhaskar, 1978; Sayer, 2004). Specifically, it contends that all knowledge about a reality is "historically, socially, and culturally situated", and influenced by the antecedent knowledge and stance of its creators (Archer *et al.*, 2016, p. 6). This principle is often referred to as 'epistemic relativism', and reconciles well with research involving multiple knowledge systems, such as those with Western scientists and Indigenous knowledge holders, as it forces researchers to recognise their positionality and the fallibility of human perception and methods of perception (particularly Western) that have historically been obscured or concealed through the application of more positivist approaches (Archer *et al.*, 2016). In doing so, critical realism allows for multiple ways of knowing and narratives to exist about the same phenomenon and attempts to seek explanation as opposed to empirical truths (Thompson *et al.*, 2010). Both of these concepts represent key tenets of contemporary research agendas in the Arctic relating to the co-production of knowledge, decolonisation, and knowledge mobilisation (Flynn & Ford, 2020; Wilson *et al.*, 2020), and resolve well with a heuristic vulnerability-focused approach. The latter focuses on attributing causality, and understanding the mechanisms and contexts that create susceptibility to climate change as opposed to developing indicators or attempting to quantify vulnerability (Ribot, 2011; Tschakert *et al.*, 2013).

4.2. *The Tooniktoyok project*

The outputs, aims and objectives, and research design for this doctorate were developed as part of the *Tooniktoyok*[15] project: a longitudinal, real-time participatory land use monitoring initiative, with a data collection period spanning June 2018 – June 2020. *Tooniktoyok* was led and administered by the Hamlet of Ulukhaktok and received funding through a joint community-researcher application to Crown Indigenous and Northern Affairs Canada's (CIRNAC) *Climate Change Preparedness in the North Program* to the value of CAN$100,000 per annum. The project was co-developed between the Hamlet Council and an international research team from the universities of Leeds (Naylor, Ford), Guelph (Fawcett) and Northern British Columbia (Pearce), with an explicit focus placed on non-Indigenous researchers holding a facilitatory – as opposed to directive – role in the stages of project development, the development of aims and objectives, and the process of data collection, analysis, and dissemination. The overall aim of *Tooniktoyok* was to:

> "facilitate the generation, documentation, and two-way sharing of observations, experiences and knowledge of changing climatic conditions, determinants of hunting success, and the costs of hunting among hunters, researchers and decision-makers, to enhance the safety and success of Ulukhaktokmiut hunters and provide timely information for decision-making" (Tooniktoyok carry-over funding proposal to CIRNAC-CCPN, 2021).

Inuit control over Arctic research initiatives provides opportunities to develop self-determination and build capacity in research, improve the rigour of applied methods, and close the "credibility gap" that currently exists between Inuit and Western knowledge systems in Western institutions and policy-making spheres (Pfeifer, 2018, 2020; Carter *et al.*, 2019; Naylor, 2021). Project construction, in terms of research questions, study design, and data collection methods, analysis, and dissemination was guided by *Ulukhaktokmiut* knowledge and Inuit values, with information needs and priorities for research identified by hunters and the wider community in a 2017 scoping trip, conducted by Pearce, and agreed with the funding body as part of the proposal. During this scoping trip – at a stakeholder meeting between elders, hunters, and researchers – discussions were held to explore how the community might source funds for their strategic research priorities. It was decided that any funded project should comprise a component of real-time, or 'near-real-time', data collection so as to allow hunters to share knowledge of the land between themselves over the course of the project lifecycle, rather than simply hearing what other participants reported as part of a results dissemination trip by researchers, which

[15] In *Kangiryuarmiut Inuinnaqtun* – an *Inuktut* dialect spoken within the Inuvialuit Settlement Region – '*tooniktoyok*' describes an action or effort undertaken "with extreme determination" and is commonly used to describe activities relating to hunting, harvesting and fishing; *Ulukhaktokmiut* hunters express *tooniktoyok* when they travel and hunt for food.

often happens at the conclusion of most research projects. Moreover, council members stated that any project should also focus on increasing the community's own capacity for research (through the funding and training of a local project co-ordinator's position within the Hamlet of Ulukhaktok). In addition to expressing a preference for a research project geared toward understanding the impacts of climate change, hunters also expressed a desire to explore 'the numbers' that underlie hunting participation and success. There was particular support for the project to develop knowledge on issues relating to the costs of hunting, and the role that gasoline and other supplies (and their affordability) might play in influencing hunters' abilities to get out on the land. Hunters and council members noted that in relaying research findings to the government in the past the community felt that 'numbers talk', providing a rationale for the statistical work conducted as part of paper three (chapter four).

Research was undertaken in line with the principles of the "5 Priority Areas" of the *National Inuit Strategy on Research* (NISR)[16] and according to Inuit Tapiriit Kanatami and the Nunavut Research Institute's guidance on *Negotiating Research Relationships with Inuit Communities* (ITK & NRI, 2006; ITK, 2018). Ethical approval for the research was granted by the respective research organisations involved (Leeds (AREA 18-117) (Appendix A), Guelph (REB 17-12-012), UNBC, Aurora Research Institute (No. 16533)). However, the degree to which non-Indigenous or non-community-based research ethics boards hold the expertise to assess projects involving Indigenous peoples or specific communities is contentious – panels require an appreciation of the experience of the colonised, and an understanding of how research misconduct in the past has appropriated knowledge and exploited and marginalised Indigenous voices (Kovach, 2009; Castleden *et al.*, 2012). Therefore, the project also established a four-person Inuit Oversight Committee within the community who served in an advisory role during project implementation.

In terms of programmatic structure (and as per NISR priorities one, three, four and five) the Hamlet retained control over *Tooniktoyok*'s finances, administration (hiring of Inuit project coordinator/s, cohort selection, data collection and storage), and overall research direction. Inuinnait control and oversight over the project was designed to ensure that the results can inform community concerns for research in a culturally appropriate way, attenuate some inequity in power dynamics that can be symptomatic of some participatory research projects, create opportunities for bi-directional learning, maintain protections for Indigenous intellectual property, and prevent the development of an

[16] The *National Inuit Strategy on Research* is a document, produced by Inuit Tapiriit Kanatami – the Inuit NGO representing the socio-political interests of 65,000 Inuit in Canada – that provides a roadmap of h ow institutions and research organisations can conduct ethical and partnership-oriented research in the Arctic.

"extractive" or exploitative research model (Pearce *et al.*, 2009; Castleden *et al.*, 2012; David-Chavez & Gavin, 2018).

In addition to the three published papers comprising this thesis, the funding agreement and community-designated outcomes for *Tooniktoyok* also included:

1. A policy brief detailing the costs of hunting in the community (Appendix B)
2. Production of a 1:250,000-scale map displaying the traditional place names surrounding Ulukhaktok and the trails tracked by the cohort between June – 2018 – June 2020 (Appendix C).
3. A final project report to Crown Indigenous and Northern Affairs Canada and the Hamlet of Ulukhaktok, detailing project outcomes and future research directions (in preparation).

4.2.1. *A note on terms used in this thesis*

Although the use of the term 'longitudinal' may be a somewhat unconventional descriptor for a study of *Tooniktoyok's* length (24 months), it is not unprecedented for social sciences research to use the term to describe projects that have run in-depth data collection for a period of one-year or more (e.g. Milfont, 2012; Hall *et al.*, 2018; Thorndike *et al.* 2022) – particularly if this dataset is especially large or collected more or less continuously. The rationale for describing *Tooniktoyok* as longitudinal was threefold. First, although the primary dataset was collected over a two-year period, it was supplemented by secondary weather data at the decadal scale (1987-2019) and multi-year sea-ice data spanning forty years (1968-2018). Second, within the primary interview dataset itself (see section '4.5 *Methods*'), participants often reflected on trends, both biophysical and social, that they had observed over a decadal or multi-decadal scale, meaning that they were often speaking to a context far greater than simply the period of primary data collection. Thirdly, there are considerable difficulties associated with both the funding and logistics of multi-year continuous data collection for the social sciences in the Arctic (Fawcett *et al.*, 2017; Ford *et al.*, 2013). To the author's knowledge, *Tooniktoyok* is one of the longest community-based human dimensions of climate change research projects with continuous multi-year data collection in existence. Therefore, for the specific context of Arctic social sciences research, the use of the term 'longitudinal' should be considered appropriate.

Similarly, the phrase 'real-time monitoring' requires further explanation and expansion. In hindsight, following the publication of the papers that comprise this thesis, the term 'near-real-time' may in fact be a more appropriate descriptor for *Tooniktoyok*. Although some data was frequently collected in real-time, through the use of the GPS monitoring, and could be viewed by participants in the *Strava* cloud platform immediately after the conclusion of a hunting trip, the sharing of knowledge between participants and to researchers occurred at a frequency of once every two weeks (see section '4.5 *Methods*'), and data was not immediately analysed by researchers. The term 'real-time monitoring' was chosen based on the fact that sharing their observations of what they were currently experiencing on the land that week would allow other hunters to react to what they were being told and respond or adapt accordingly; thereby having almost immediate practicable impact. This could range from changing their travel routes to avoid hazards (e.g. rough or thin ice), or the area where they were searching for country food based on the information shared by others in order to improve their potential productivity. This differs from other HDCC research, where travel constraints on southern researchers can lead to an appreciable period of time before research participants are able to have findings (even preliminary ones) or data shared with them (Pearce *et al.,* 2009). To ensure continuity between chapters (published work cannot be edited), the term 'real-time monitoring' is retained in this thesis, but it should be understood that the term is hereafter used in the context laid out above.

4.3. *Case study selection*

The rationale for selecting Ulukhaktok, NT as the case study community for this research was fourfold. Firstly, the community has a long-standing research relationship with the primary investigator on *Tooniktoyok*, Pearce, who has undertaken collaborative or participatory research relating to vulnerability to climate change in Ulukhaktok since 2005 (see Pearce, 2006). Secondly, the community indicated their desire to co-produce and administer a research project over a prolonged period (three years, with a two-year period of data collection) that would cater to their research priorities and demonstrated the capacity and administrative ability to do so. Thirdly, compared with other communities within the Inuvialuit Settlement Region, residents of Ulukhaktok are often far more frequently engaged with hunting and fishing – making the community a strong candidate for a study assessing the impact of climate change on harvesting. As of 2018. 75.9% of Ulukhaktokmiut stated that they had hunted or fished in the previous calendar year, as compared with an average of 36.3% in the Northwest Territories, and the remoteness of Ulukhaktok, notably its fly-in, fly-out transport system, means that it is a good facsimile for similar remote High Arctic communities further east in Nunavut (NWT Bureau of Statistics, 2018; Statistics Canada, 2018). Fourthly, the magnitude of projected climatic change for Ulukhaktok is particularly severe, even for the Northern regions: between 2021-2050 annual average temperatures in Ulukhaktok (-9ºC) are projected to be 2.3ºC and 4.6ºC warmer than recorded values for the periods 1951-1980 and 1981-2010 respectively (CCCS, 2021) (Figure 1.9).

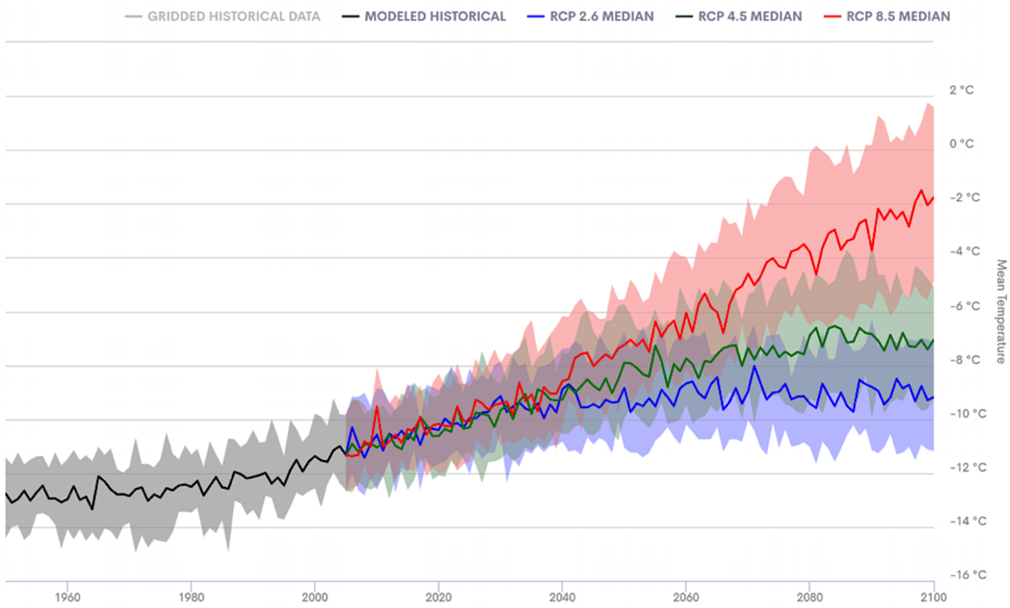

FIGURE 1.9: PROJECTED AND OBSERVED MEAN DAILY TEMPERATURE IN ULUKHAKTOK, 1950-2100 (FROM CCCS, 2021).

4.4. *Sample selection/participant recruitment*

Commencing at the start of the project's first field season, May of 2018, the Hamlet Council advertised 11 positions on *Tooniktoyok*: 10 Inuit hunters, and one local project co-ordinator. The desired characteristics of the cohort (i.e. land-based knowledge holders, regularity of hunting) were not uniformly held across the community (see Condon *et al.*, 1995; Collings, 2009a; Pearce *et al.*, 2011a), precluding the use of random sampling or other similar techniques. Therefore, those who expressed interest were selected based upon the purposive criterion sampling method (Palinkas *et al.*, 2015). Informed by the primary investigator's 15-years' experience of working in the community, and guided by community elders on the Hamlet Council, hunters were selected based upon a) the regularity and prolificacy with which they harvested, b) their degree of traditional ecological knowledge (TEK) on harvesting and travelling on the lands around Ulukhaktok, and c) their perceived ability to communicate their views and experiences about hunting in the community. Purposive sampling as a method provided more freedom to select a cohort that better represented a broad social, demographic and economic cross-section of hunters within Ulukhaktok, and also addressed concerns pertaining to inter-community power relations and elite capture; both of which can arise from techniques such as snowballing (van der Riet & Boettiger, 2009). The selected cohort comprised 10 male hunters, aged 26-82 (in 2018), from a range of socioeconomic backgrounds. The local project coordinator was selected last, based upon their familiarity with members of the cohort, their ability to take notes in English, and their understanding of the modern and historical context of hunting within the community. The latter point was considered especially important, given that Collings (2009b) in his work – also conducted in Ulukhaktok – points to the success of "phased assertion" elicitation techniques with Inuit communities. Phased assertion establishes with the participants that the interviewer has a pre-existing baseline knowledge within the topic of interviews, and is premised on the notion that participants who adjudge the interviewer to already be knowledgeable will display greater openness, establish a rapport more quickly, and have an increased likelihood of correcting an interviewer should they make an incorrect statement (Agar, 1980; Collings, 2009b).

4.5. *Methods*

Primary data collection methods for *Tooniktoyok* included the use of GPS tracking technology, and bi-weekly semi-structured interviews and participatory mapping sessions, conducted between June 2018-June 2020. The selected methods addressed a current gap in knowledge by capturing the dynamics of climate change vulnerability and adaptation at high resolution and in real-time. Moreover, in not exclusively relying on what individuals say, and through monitoring their physical activity and what they do, *Tooniktooyk* aimed to develop a more comprehensive picture of how Indigenous subsistence hunters are directly experiencing and adapting to climate change, underlying drivers of hunting group productivity, and the vulnerability of Inuit food systems as a whole (Collings, 2011).

It could be argued that examining the role of climate change in a single location, over the course of a two-year period, represents somewhat of a spatial and temporal mismatch. These limitations are symptomatic of the landscape for much early-career Arctic social sciences research, which is restricted both by the length of a UK doctorate (<4 years including writing), but also the exceedingly high cost (~CAN$100,000 per annum) of multi-year projects in the Arctic comprising multiple research trips. In order to ameliorate against potential mismatches, the methods of this thesis were designed to incorporate a high degree of long-term secondary weather and sea-ice data, available from the weather stations at the Ulukhaktok airport and the Canadian Ice Service's 'Egg Code' charts. This allowed the research team to contextualise observations made by participants against an established baseline spanning more than 30 years; thereby allowing them to assess whether environmental conditions encountered or commented upon could be considered within a normal or expected range, or whether they were manifesting as new extremes. In addition to utilising long-term environmental data, data on the spatial and social context of hunting in Ulukhaktok is also available, courtesy of research conducted in the early 1990s and 1970s (Collignon, 1993; Freeman, 1976). This was used to assess the degree to which hunting practices and routines had changed in the community. Specifically, the data, in the form of maps, allowed the delineation of the spatial extent of harvesting around Ulukhaktok in the Contact-Traditional Period (Damas, 2002), and how this has changed between 1935-2020.

Regarding the issue of space, it is crucial to note that this research is a case study. Therefore, whilst its findings are in some ways generalisable to other communities in the Arctic regions, especially Canada, there are also aspects of its findings that are distinct to Ulukhaktok or the Inuvialuit Settlement Region. Ford *et al.* (2010) note the importance of case studies and place-specific research in HDCC, which develop in-depth and contextualised understandings, and identify nuanced and complex processes that might be lost in research occurring at a less granular scale. This thesis as a standalone body of work cannot claim to speak to the context of climate change globally or even for the whole of the Arctic region, especially given its cultural and geographic diversity. However, it adds to a burgeoning scholarship of case studies and systematic reviews in HDCC (e.g. Ford, 2009b; Ford & Pearce, 2010; Archer *et al.*, 2017; Fawcett *et al.*, 2018; Gilbert *et al.*, 2021), from which it is possible to identify which observed phenomenon may be specific to Ulukhaktok, and which have already been identified as occurring elsewhere in other Arctic communities.

Chapters three and four of this thesis outline the published empirical contributions of this doctorate. Although these papers include information on methods used, in light of the word limits and brevity required for journal article publications the following section on methods has also been included to provide further detail and context. This is in order to develop a rationale behind the use of certain methods, in addition to describing their application and the means of data analysis that were also adopted. Table 1.1 below outlines the data collection method and means of analysis used to address the empirical research objectives of this thesis, and the chapter/paper in the thesis where the objective is addressed.

4.5.1. *Data collection*

4.5.1.1. *Participatory GPS tracking*

Quantitative data on the spatial component of subsistence in Ulukhaktok was captured through the use of smartphones with real-time GPS tracking capabilities. The cohort of 10 Inuit hunters were provided with *Nokia 5* smartphones and were trained in the use of the *Strava* mobile app (Strava Inc., 2019) by

TABLE 1.1: DATA COLLECTION METHODS FOR EMPIRICALLY-FOCUSED RESEARCH OBJECTIVES.

Research Objective	Data used	Method of data collection	Means of data analysis	Respective paper/ chapter
1. Develop a generalisable approach to better characterise the dynamic, contextual and processual nature of vulnerability to climate change.	N/A	N/A	N/A	Chapter 2/ Paper 1
2. Combine the new conceptual approach with a participatory, real-time land-use monitoring methodology to understand the vulnerability of the *Ulukhatokmiut* food system to climate change in the context of multiple socially constructed stressors, and to characterise how this affects hunting participation and foodshed stability.	- Hunters' documented experiences of travelling and hunting in a changing climate and society. - GPS data on distances travelled, locations of harvests. - Secondary datasets on ice stability, and weather and temperature (e.g. Canadian Ice Service data).	- Participatory GPS tracking (*Strava*) - Participatory mapping sessions and semi-structured/ conversational interviews - Secondary instrumental data - Participant observation	- Provisional and Structural coding framework, informed by participant observation and conceptual framework, applied across two rounds of coding in NVivo. - *Strava* data extracted, downloaded, and imaged in QGIS3.12 - Mann-Kendall statistical test in R to identify significant changes in temperature, precipitation and wind at an inter-annual scale	Chapter 3/ Paper 2
3. Quantify social-ecological determinants of hunting trip productivity in the *Ulukhaktokmiut* food system.	Primary numerical dataset of hunting group productivity and hunting trip characteristics, extracted from interview data on participatory mapping sessions and GPS tracks.	- Participatory GPS tracking (*Strava*) - Participatory mapping sessions and semi-structured/ conversational interviews	- Multivariable linear regression model constructed in SPSS to identify possible association between social-ecological variables and hunting group productivity.	Chapter 4/ Paper 3

research lead, Naylor, in May of 2018, with subsequent 'refresher' sessions in August 2018 and May 2019. GPS tracking within *Strava* collected information on distance and direction travelled, time spent on the land, time spent moving, elevation, and speed. Participants were asked to share their data with the project co-ordinator and research team on a bi-weekly basis by uploading their trail data (in .gpx format) into the *Strava* storage platform, for which a Wi-Fi network was made available through an agreement with the Helen Kalvak Elihakvik School, and to which researchers could gain access remotely when they were not present in the community. The rationale for use of the *Strava* app, as opposed to simple GPS handsets was four-fold:

1. The route that an individual tracks through *Strava* does not require cellular signal and can be viewed immediately upon its completion, both within the app and on a computer.
2. Data collected through *Strava* can be directly uploaded into the cloud, which allows remote access by researchers whilst not in the community. Researchers are notified each time a new trail is uploaded to the database.
3. The use of the app provides project participants with full control over their data and its visibility to others; each individual's data is password protected, can be hidden, and can be remotely withdrawn or deleted at any time of their choosing.
4. The open-source nature of the system reduced overall project costs and opened up the possibility for its wider application from a 'citizen science' perspective across multiple Arctic communities in the future if successful.

The application of *Strava* in this context is novel. However, the use of technologies and GIS systems as a form of Indigenous empowerment, whereby maps are made from an Indigenous perspective, or 'valence', and counter conventional cartographic norms, has become established and best-practice for GIS studies involving non-Western groups (e.g. Kwan & Ding, 2008; Eades & Zheng, 2014). This notion of adopting Western methodologies and adapting them for Indigenous contexts is seen by some as facilitating an improved platform for Indigenous voices; particularly in instances where such methodologies are typically afforded significant credence in public or bureaucratic discourse. Eades (2015) notes the critical significance of GIS for Indigenous groups, and points to the utility of maps with Indigenous valence in significant public policy and land-rights debates (e.g. *Delgamuukw v. British Columbia*, 1997), while Barbeau *et al.* (2015) suggest that maps can provide a critical medium for knowledge transfer within Indigenous communities.

4.5.1.2. *Participatory mapping sessions and semi-structured/conversational interviews*

Interviews within Arctic social sciences research are critical for developing baseline information, particularly if combined with longitudinal study design and spatial data (Ford *et al.*, 2013). In addition to undertaking GPS tracking, the cohort were asked to attend group semi-structured/conversational interview and participatory mapping sessions at the Hamlet of Ulukhaktok offices, convened and chaired by the local project co-ordinator on a bi-weekly basis for the duration of the project data collection cycle. All interviews were conducted at the Hamlet offices, documented through the use of a voice recorder, and conducted in the presence of a 1:250,000-scale map upon which participants described and annotated their subsistence practices, the location of their harvests, or any anomalies that they noted whilst out on the land. The rationale behind mapping sessions being conducted concurrently with interviews was to a) improve the quality of the *Strava* data by adding information to specific geo-coded phenomena (e.g. thin ice, tracks of invasive species, animals in poor health, locations of places of cultural significance); b) provide greater insights into how Ulukhatokmiut navigate and why specific trails are used; c) counter the fact that the use of GIS approaches in the past without interviews has inadequately accounted for Indigenous worldviews (Grenier, 1998); and d) act as a proxy for GIS data, should participants have not tracked their activities over the past two weeks using *Strava*.

Sessions were convened with the whole cohort in order to reduce the potentially intimidating influence of one-on-one interviews with an individual outside researcher (van der Riet & Boettiger, 2009). However, in instances where participants may have felt less comfortable discussing certain factors within the group – as can be the case with elders and youth together – one-on-one interviews were also offered when requested. Interviews were conducted primarily in English, however, a number of older participants elected to speak in *Inuinnaqtun* at times, after which other members of the cohort would often offer to translate. In return for their participation, members of the cohort were reimbursed for their time with a remittance of CAN$150 every two weeks. A copy of the semi-structured interview guide is included as Appendix D – further information on the structure and format of sessions is also covered in paper two (chapter three) and an overview of the question themes is included below:

- hunting conditions (land, ice, weather) and their relative abnormality/normality;
- equipment/supplies taken and used (including costings for fuel, oil, naphtha, food);
- whether anything was borrowed for trips;
- problems encountered, risk perception and associated decision-making;
- specific trail use, and the plotting of *Kangiryuarmiutun* place names;

- observations of environmental change;
- difficulties within the community that affected hunting that week;
- harvest (type, volume, distribution)

In light of a number of considerations, it was decided that interviews should be *semi*-structured, otherwise termed 'conversational'. As per Adams (2010) and others (Andrachuk & Pearce 2010; Gadamus and Raymond-Yakoubian, 2015), this more conversational approach to interviewing, extending beyond a conventional questionnaire format, allows a greater attribution and description of meaning to the experiences described, reduces the possibility of framing bias or that the researcher will pre-empt specific areas where vulnerability might manifest, and increases the likelihood of collecting data that is not pre-existent within published literature (see also Huntington, 1998; Veland *et al.*, 2010). Ferguson and Messier (1997, p.18), in a study also evaluating Inuit subsistence, attributed the need for semi-structured or conversational forms of investigation to the fact that "written questions did not mesh well with the manner in which Inuit informants relayed information, often through detailed accounts of hunting trips". Collings (2009b) expands on this, suggesting that predetermined direct questions either written or asked, are invasive and could be considered coercive given the cultural expectation among Inuit that direct requests cannot be denied. Kovach (2010) and Veland *et al.* (2010) further note the significance of oral storytelling traditions as a means of imparting knowledge and establishing ontologies within Indigenous cultures, which cannot be explored through traditional lines of questioning and enquiry. The former argues that a true understanding of Indigenous worldviews requires "dialogic participation", through a lens of "conversational method", particularly as in many cases Western and Indigenous modes of navigation and perspectives on landscapes are seen as a dualism (see also Kovach, 2009; Bessarab & Ng'andu, 2010; Eades, 2015).

4.5.1.3. *Secondary instrumental data*

Data collected from GPS tracking and semi-structured interviews was cross-referenced with, and supplemented by, secondary datasets on ice stability, and weather and temperature. Examples of these included the Egg Code 'stage of development' and 'concentration' daily ice-charts for Amundsen Gulf, courtesy of the Canadian Ice Service (CIS) (see GoC, 2016), daily temperature and weather data from the 'Ulukhaktok' and 'Holman' weather stations on Victoria Island, and satellite imagery, courtesy of Environment Canada and NASAWorldview. It has become established practice to combine primary observations and Indigenous knowledge with secondary weather and environmental data when conducting analyses of climate change in the Arctic (e.g. Gearheard *et al.*, 2010; Prno *et al.*, 2011; Ignatowski & Rosales, 2013; Williams *et al.*, 2018). Not only does this integration improve the accuracy of observations, it also provides opportunities for improved collective understandings of environmental phenomenon (Gearheard *et al.*, 2010).

4.5.1.4. *Participant observation*

Participant observation did not comprise a mode of direct data collection. However, in line with the rationale presented for participant observation by Musante & DeWalt (2015), and with much Arctic social sciences vulnerability research (see Collings, 2009b; Forbes *et al.,* 2009; Archer *et al.*, 2017), participant observation was key for developing reflexivity within the research process, and for contextualising findings (see also Veland *et al.*, 2010). Participant observation on *Tooniktoyok* involved accompanying hunters on harvesting trips, helping with trip preparation and post-trip food sharing, and volunteering (e.g. at the community food bank). The experience gained from these activities informed questions asked during participatory mapping sessions, guided the interpretation of data across the project as a whole, and added a more concrete perspective to the conceptual framing of the project (Musante & DeWalt, 2015). Critical areas where participant observation was intended to improve understandings were:

a) the lived experience of subsistence in an Arctic context;

b) the significance of traditional knowledge and financial capital as a prerequisite for subsistence and land-based activities in a mixed economy;

c) the role of climate change as a mediating factor affecting hunting success and participation.

The immersive nature of prolonged field research – which totalled 7 months across the two-year period – combined with participant observation and the discursive nature of interviews, was intended to address critiques that value systems are not readily incorporated in vulnerability assessments (O'Brien & Wolf, 2010; Wolf, 2013). Research conducted in this context was also intended to develop "relational accountability" between the researcher and research participants, bring greater balance to power relationships, improve self-reflexivity, and occur in a setting where research and non-research related activities (i.e. participating in the running of the food bank) were "part of an on-going service within the community" (Gifford & Boulton, 2007, p.34; Wilson, 2008).

4.5.2. *Data analysis*

4.5.2.1. *Participatory GPS tracking and participatory mapping*

Data from GPS units was downloaded from the *Strava* secure database in the form of .gpx files. These were then inputted into QGIS 3.12 and overlain over re-coloured open-source satellite imagery of Amundsen Gulf to produce a composite map of hunters' trail routes. Due to some instances where a route wasn't fully completed (i.e due to the increased likelihood of loss of satellite signal closer to the poles, where a full vector line wasn't produced), tracking points were instead used to develop high-resolution heat maps from *Strava* data. In instances where trails were recorded retrospectively through the use of 1:250,000-scale maps in participatory mapping and interview sessions, these were traced manually into QGIS at the conclusion of the data collection period, and distance travelled for these was calculated through use of the program's vector measure function.

In addition to trails and harvest, Inuit placenames were also plotted on the map. By the end of June 2020, 101 *Kangiryuarmiutun* placenames had been located and marked by hunters. The rationale behind the plotting of *Kangiryuarmiutun* place-names, which are often literal descriptions of the location in question – i.e. *Aahangiqtuq* means 'where there are long-tailed ducks' – was fourfold. Firstly, maps produced and shared with the community could provide opportunities to educate youth about the lands surrounding Ulukhaktok and allow them to locate areas discussed by elders. Secondly, the "memetic" (descriptive) nature of traditional placenames (Müller-Wille, 1989; Aporta & Higgs, 2005; Eades, 2015) could provide further indicators on altered land-use patterns or environmental change – *did the relict meaning of some names no longer correspond to the contemporary environment?* Thirdly, Inuit travel and navigation on the land is based on the concept of waypoints – i.e. denoting and naming characteristics of the environment (e.g. cairns, hills) as they occur on trails. Therefore, rather than mapping trails, the utility of place names and waypoints along trails is likely of greater utility for younger Inuit who want to learn how to navigate the land (Müller-Wille, 1989; Aporta, 2005). Fourthly, the oral tradition of Inuit societies has resulted in a loss of knowledge surrounding place names in other communities. As such, the mapping of placenames in this way also provided an opportunity to document contemporary knowledge of placenames; this practice has also been used elsewhere in the Arctic to allow communities to better assert their claims of sovereignty over their respective regions (QIA, 2012; Bennett *et al.*, 2016b).

4.5.2.2. *Group/individual semi-structured interviews*

Recordings from group and individual semi-structured interviews were transcribed verbatim and analysed through the use of thematic content analysis, with transcription and analysis undertaken in consultation with the local project co-ordinator (Esterberg, 2002). In total, transcription yielded 509 pages of text. These were imported into NVivo (QSR International) qualitative analysis software and a Provisional and Structural coding framework was applied across two rounds of coding (Saldaña, 2016, p.98, p.16; Guest et al., 2012). First, themes within the coding framework were derived deductively from a narrative review of previous vulnerability assessments conducted in an Arctic context (e.g. Pearce *et al.,* 2010; Ford & Beaumier, 2011; Durkalec *et al.*, 2015), through researcher's own experiences, notes and observations collected during the research process and interviews, and through the recurrent emergence of new subjects occurring during analysis of the transcripts themselves (see Boyatzis, 1998; Crabtree & Miller, 1998). Themes were then sub-coded to denote the specific driver identified, how it related to a specific component of vulnerability, and its speed of onset (e.g. "exposure-sensitivity – slow: Indigenous knowledge: loss of knowledge relating to food preparation" or "adaptive capacity – fast: economics: bricolage repairs on machinery due to lack of funds") (Table 1.2). After the first round of coding, the annotated transcripts were re-coded a second time according to the same criteria, and for those that remained more specific notes on the characteristics of specific circumstances affecting exposure-sensitivity or adaptive capacity were made. As themes were identified or coded from the analysis of raw data – and given that the context of these themes was derived from differing worldviews and expressions – any presentations of data used direct quotes where possible in order to best try and preserve and convey Indigenous perspectives (Pearce *et al.*, 2010).

In addition to the coding of themes relating to adaptive capacity and exposure-sensitivity, statistics on 23 variables relating to, *inter alia*, supplies used, the frequency of problems encountered whilst out on the land, observations of environmental change, and the number and mass of edible weight of animals harvested by hunters were also extracted from interview data for 132 individual hunting trips. Mass of harvested weight was back-calculated through knowing the frequency and type of animal harvested and then deriving the mean edible weight (kgs) from these based on past surveys conducted by Usher on commonly hunted animals the Inuvialuit Settlement Region (see Usher 2000 in Ashley 2002). Data were inputted into SPSS 26 and a multivariable linear regression model was then constructed to assess any potential relationships between socio-economic and biophysical (independent) variables and the productivity of hunting groups (dependent variable) with the intention of identifying determinants that underlie hunting success. Assumptions of the multivariable linear regression model (Osborne & Waters, 2002) – normally distributed variables, linearity of continuous independent variables, independence of variables/multicollinearity, and homoscedasticity (variance in residuals is similar across all levels of the independent variable) – were tested using standard residual plots (homoscedasticity), frequency distribution histogram and Q-Q plots (normality), Loess smoothing (linearity of continuous variables), and Spearman's rho and variance inflation factor (multicollinearity) (Appendix E). For continuous independent variables that did not have a linear relationship with the dependent variable, these data were recoded into ordinal data. Ordinal and categorical variables were then tested for significance through their individual categories and as a collective group using Global significance tests (Dymova *et al.*, 2009; Bishop-Williams *et al.*, 2018) (Appendix F). Outliers, leverage of individual observations and influence of observations on the model were assessed using Cook's distance (Appendix E). (See paper three (chapter IV) for a full description of the statistical analysis and testing).

TABLE 1.2: PROVISIONAL AND STRUCTURAL CODING FRAMEWORK FOR TRANSCRIPT ANALYSIS, WITH EXAMPLES AND KEY.

Component of vulnerability			
	➥ speed of onset		
		➥ specific driver/theme	⇒ notes
Exposure-sensitivity			
	Slow		
		Indigenous knowledge	Environmental change limiting the applicability of once established traditional ecological knowledge (TEK).
		Institutions	Historic under-funding of harvester's assistance initiatives in favour of store-bought food subsidies.
		Sedentarisation	Centralisation of semi-nomadic livelihoods into permanent year-round community, increased distance to travel to traditional hunting grounds, causal relationship with social welfare issues that affect hunting participation.
	Fast		
		Environmental change	Anomalously shallow snow depth during winter 2018/19 affecting land access, creating land-use bottlenecks.
		Wildlife management	Disagreement over how char fishery should be regulated in light of drastic inter-annual changes in community harvest.
		Economics	Increasing year-on-year costs of consumables (i.e. gasoline, naphtha, engine oil).
Adaptive capacity			
	Slow		
		Economics	Community integration into the wage-based economy (at decadal scale) in order to sustain and fund mechanised subsistence.
		Indigenous knowledge & Institutions	Transition of educational curriculum in school to increase focus on land-camps and land-based education rooted in Indigenous pedagogies.
		Technology	Gradual technology uptake to increase hunting range (e.g. snowmachines) and safety (GPS, SPOT devices) (potential for maladaptation)
	Fast		
		Economics	Bricolage repairs on machinery due to lack of funds (also potentially maladaptive)
		Social relationships	Borrowing of equipment/supplies when machinery is broken or when running low on funds to purchase consumables.

4.5.2.3. *Secondary instrumental data*

Sea-ice data from the CIS and weather data from the weather stations on Victoria Island were extracted and graphed to identify potential trends. Where possible, time series weather and temperature data were subject to statistical testing in the R Statistical package (R4.1) using the Mann-Kendall statistical test to identify significant changes in temperature, precipitation and wind at an inter-annual scale (Laidler *et al.*, 2009). As Huntington *et al.* (2004) points out, combining observations in this manner is not intended as a means of validating or reconciling differing knowledge systems, but is instead designed as a means of increasing the confidence of, and providing additional context to, parallel observations, and to provide potential insights on adaptation planning or mechanisms of change over differing scales (Gearheard *et al.*, 2010). In some instances, missing records in weather station data – particularly the 'Ulukhaktok 1987-2005' series – precluded statistical analysis of certain factors (e.g. snow depth). In these instances, data was used for descriptive statistics purposes.

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CHAPTER II
(PAPER I)

CONCEPTUALISING CLIMATE VULNERABILITY IN COMPLEX ADAPTIVE SYSTEMS

'Perspective' article, published as:

Naylor, A.W., Ford, J., Pearce, T., and van Alstine, J. 2020. Conceptualizing climate vulnerability in complex adaptive systems. *One Earth*, **2**(5), pp. 444-454.

Introduction to the manuscript

Published in 2020 in One Earth, this manuscript accomplishes the first objective of this doctorate by developing "a generalisable approach to better characterise the dynamic, contextual and processual nature of vulnerability to climate change". It comprises the primary theoretical contribution of this thesis and informs the way conceptual basis upon which empirical vulnerability research is subsequently conducted in chapter three.

Abstract

This Perspective develops a novel approach for assessing the vulnerability of complex adaptive systems to climate change. Our characterisation focuses on the dynamic nature of vulnerability and its role in developing differential risk across multi-dimensional systems, communities, or societies. We expand on past conceptualisations that have examined vulnerability as processual rather than a static or binary state and note the necessary role of complexity and complex adaptive systems theory as a basis for effective vulnerability assessment. In illustrating our approach, we demonstrate the importance of factors such as modulation (connectedness), feedback mechanisms, redundancy, and the susceptibility of individual components within a system to change. Understanding the complexity of potentially vulnerable systems in this manner can help unravel the causes of vulnerability, facilitate the identification and characterisation of potential adaptive deficits within specific dimensions of complex adaptive systems, and direct opportunities for adaptation.

Keywords: *dynamic vulnerability; climate change*; *complex adaptive systems; exposure-sensitivity; adaptive capacity*; *vulnerability approach*

1. Introduction

Climate change has been identified as a major global challenge of the 21st century (IPCC, 2018). Current warming trends and their associated impacts represent a complex problem, which cannot be understood independently of their socioeconomic, political, and cultural contexts or without an appreciation of the broad heterogeneity of agents, communities, and environments that comprise them (Low *et al.*, 1999; Gunderson & Holling, 2002; Liu *et al.*, 2007). The ways through which climate change interacts with societies, ecosystems, and the environment are of particular interest when asking why and in what ways some communities or regions, and the people within them, are more or less susceptible to the impacts of climate change.

Over the past 30 years, vulnerability approaches have emerged as a critical means of better understanding differential susceptibilities to the impacts of a warming planet (Blaikie *et al.*, 1994; Watts *et al.*, 1994; Kelly & Adger, 2000; Turner *et al.*, 2003; Ford *et al.*, 2006; Füssel, 2007, Tschakert *et al.*, 2013; Bennett *et al.*, 2016). "Vulnerability" as a relational and organising concept has highlighted the role of multiple interacting stressors and their influence on variable magnitudes of exposure sensitivity and adaptive capacity (Watts & Bohle, 1993; Adger & Kelly, 1999; O'Brien *et al.*, 2004), illustrated the role of multi-scalar, nested, and teleconnected vulnerabilities in affecting change at both proximal and distal scales (Eakin *et al.*, 2009; Adger *et al.*, 2009), and demonstrated the importance of assessments themselves in promoting capacity building and decision making through participation (Fazey *et al.*, 2010; Flynn *et al.*, 2018). However, such approaches have not also been without controversy (Marino & Faas, 2020). Some authors have questioned the epistemological basis of vulnerability, its potential to reinforce hegemonic power structures, or its perceived "deficit" focus (Bankoff, 2001) (see Ford *et al.*, 2018 for a review); others have highlighted a failure in past research to produce a comprehensive understanding of the ways through which the dynamic and multi-scale nature of climate change affects societies and livelihoods (Räsänen *et al.*, 2016). Symptomatic of studies has been a reliance on limited methodological toolkits (Ford & Pearce, 2012; Hewitson *et al.*, 2014), which have inadequately evaluated or tracked the nuances of vulnerability or its constituent dimensions across time (Ford *et al.*, 2018, Jurgilevich *et al.*, 2017). This has resulted in characterisations of vulnerability as a static, immutable, and a binary state as opposed to a process of interlocking exposures, sensitivities, and adaptive capacities that operate over a range of spatiotemporal scales (Oliver-Smith, 1994; Comfort *et al.*, 1999; Lewis, 1999; Lewis & Kelman, 2010; Kelman *et al.*, 2016).

This Perspective develops an innovative, generalisable approach for vulnerability assessment in complex adaptive systems (CASs). Our framing conceptualises CASs as composed of multiple dimensions, categorised according to function, whose subsequent operability is determined by the strength of smaller, interdependent "exposure units" that are contained within them. Exposure units are understood as subcomponents within dimensions with the aim of highlighting the non-linearity of vulnerability within different parts of the CAS across time and space. The relative viability and vulnerability of exposure units are governed by the interaction of multiple stressors operating across a range of sociopolitical, economic, cultural, and biophysical spheres. The novelty and utility of such an approach are evident through (1) its ability to identify transient or persistently at-risk components within CAS, which can then be prioritised to streamline decision making for adaptation; (2) its visualisation of time as a continuous variable; and (3) its focus upon not only pinpointing areas of vulnerability but also assessing their relative magnitude and causality. Our framing is not tied to a set of methods per se but has been designed with the use of longitudinal, real-time monitoring methodologies in mind in order to better characterise the role of additive or non-linear stimuli, adaptive learning, and feedback mechanisms over time.

We begin by reviewing the concept of vulnerability and its use in the literature, placing it in the wider context of theories surrounding CASs. This is followed by a presentation of the approach itself, an example of how it might be used, and a more in-depth discussion on the approach's utility, potential application, and contribution to current scholarship within vulnerability and the sustainability sciences.

2. Conceptualising vulnerability

2.1. *The evolution of vulnerability thinking*

Vulnerability is often defined as the degree to which a system, individual, or other entity is susceptible to the impacts of a hazard or adverse event. Such a framing is evident in past assessment reports of the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2001, 2007) and remains part of a common vernacular adopted by much academic and scientific discourse aimed at informing policy and decision making around climate change. However, the fundaments underlying vulnerability as a concept represent far more than a mere simplification into ambiguous terminologies and short definitions (Costa & Kropp, 2012; Kelman *et al.*, 2016; Wisner, 2016; Ribot, 2017). Past and contemporary political ecology critiques of vulnerability demonstrate that many notions of what it means to be "vulnerable" are often dissonant and pluralistic (Timmerman, 1981; Gaillard, 2010; Kelman *et al.*, 2016; Wisner, 2016). Contention abounds as to the ways through which vulnerability manifests, which constituent components of vulnerability exist, and the methods through which vulnerability might be classified or better understood (Ribot, 2011; Hinkel, 2011; Costa & Kropp, 2012). At the same time, more nuanced debates center around the ways in which vulnerability is considered to develop and alter through social, institutional, and political contexts; the breadth and precedence that is afforded to climate as a driving factor; and the concept of multiple as opposed to double exposures as drivers in susceptibility (O'Brien *et al.*, 2007; Ribot, 2014; Joakim *et al.*, 2015; Kelman *et al.*, 2015, 2016).

The application of the vulnerability concept to society and the environment emerged in the 1970s and early 1980s, primarily through political ecology framings of natural hazards and a focus on the sociopolitical root causes of un-"natural" disasters (O'Keefe *et al.*, 1976; Oliver-Smith, 1977; Hewitt, 1983). This epistemology of vulnerability (Liverman, 1990; McLaughlin & Dietz, 2008) saw further development in the 1980s and 1990s with broader application in food systems and international development discourse and thereafter to the issue of climate change and the role of its human dimensions in creating differential risk (Sen, 1981; Chambers, 1989; Watts & Bohle, 1993; Bohle *et al.*, 1994). By the time the IPCC's Third Assessment Report (IPCC, 2001) was published in 2001, vulnerability had become firmly established in the climate literature, and the mid-2000s then experienced a proliferation of debate examining what "vulnerability" was and proposed a variety of assessment frameworks from both "top-down" and "bottom-up" perspectives (Adger & Kelly, 1999; Turner *et al.*, 2003; Brooks, 2003; O'Brien *et al.*, 2004; Ford & Smit, 2004; Füssel & Klein, 2006).

O'Brien *et al.* (2007) among others (Kelly & Adger, 2000; Brooks, 2003), contend that debate within post-1990s climate vulnerability discourse has arisen from two divergent research foci and ideologies stemming from the variable embrace of either biophysical-focused or political economy-focused approaches to vulnerability assessment. The biophysical tradition, sometimes equated with the "risk-hazard approach" in wider vulnerability literature, represents an empirical positivist-science basis for vulnerability analysis, which is concerned with vulnerability as the "outcome" of climate-environment interactions. Here, vulnerability is seen as an endpoint denoting the sum of projected impacts of climate change on a given set of exposure units once potential adaptations have been accounted for (O'Brien *et al.*, 2007; Räsänen *et al.,* 2016; van den Berg & Keenan, 2019). Such an approach is strongly event focused, and the role of humans in modifying impacts arising from climate change (beyond large-scale adaptations) receives little emphasis in such a characterisation (Turner *et al.*, 2003; Brooks, 2003; Ford & Smit, 2006; van den Berg & Keenan, 2019).

An alternative framing to the outcome-oriented vulnerability assessments involves those that take a sociopolitically focused "contextual" approach (O'Brien *et al.*, 2004; Räsänen *et al.*, 2016). In the contextual framing—also termed "second generation" (Füssel & Klein, 2006) —vulnerability is considered through a "starting point," "social-ecological system," or "human security" lens, whereby risks are assessed from a linked and cyclically interacting social-biophysical perspective (Brooks, 2003; O'Brien *et al.*, 2007; Bennett *et al.*, 2016). Contextual vulnerability looks at not only how individuals or groups may be vulnerable because of the way the biosphere interacts with humans and society but also the context through which this interaction occurs and how social constructs within societies might develop vulnerability across multiple hierarchical scales (e.g., through relative strength or weakness of political economy, wealth, or strength of social networks) (Tschakert, 2007; Tuler *et al.*, 2008; Adger *et al.*, 2009; Ribot, 2014). Assessments are primarily "place-based" because of the fact that contextual vulnerability assessments focus on "multiple stressors" and "micro-level" interactions. This allows for the appraisal of causal mechanisms that develop from the interface between climatic, socioeconomic, political, and cultural stressors and an exploration of how these create differential exposures, sensitivities, and adaptive capacities (McDowell & Hess, 2012; McCubbin *et al.*, 2015; Gautam & Andersen, 2017, Zavaleta *et al.*, 2018; Li & Ford, 2019). Importantly, stressors within contextual framings of vulnerability can act as both additive and deleterious factors in the development of exposures, sensitivities, and adaptive capacities; are not temporally discrete; and are liable to develop feedback mechanisms (Ford & Smit, 2004; Bennet *et al.*, 2016; Räsänen *et al.*, 2016). The incorporation of multiple stressors or exposures over time permits a better understanding of how differential vulnerability develops among populations (Turner *et al.*, 2003; Ford & Smit, 2004; Kelman *et al.*, 2015; Whitfield *et al.*, 2019). Smit and Pilifosova (2003), among others (Ford & Smit, 2004; Luers, 2005; Debortoli *et al.*, 2018), have attempted to frame this contextual, social vulnerability approach through the following (or a similar) heuristic equation:

$$\mathbf{V_{sit} = f\ (ES_{sit} - AC_{sit})}$$

Here, ES refers to exposure sensitivity, which describes the degree and magnitude of stress experienced within the system (s) in response to a stimulus or stimuli (i) in time (t) and the susceptibility of the system to the direct or indirect effects of that stimuli or stimulus. Adaptive capacity (AC) refers to the potential of the system (s) to adapt in response to applied stimuli (i) in time (t) and works to mediate the potential impact of exposure sensitivity (Smit & Pilifosova, 2003). Increasing adaptive capacity, therefore, improves the ability of a system to cope with a wider range of conditions and absorb a greater magnitude of exposure sensitivity (Smit & Pilifosova, 2003).

Despite a rapid growth and proliferation of contextual assessments, some scholars have critiqued the efficacy of the methodologies and methods associated with them, particularly their effectiveness at capturing the multiple, dynamic stressors that affect vulnerability and the nature of its evolution through time (Jurgilevich *et al.*, 2016; Whitfield *et al.*, 2019; Windfeld *et al.*, 2019). Tschakert *et al.* (2013) for example, contend that vulnerability assessments have "lost their way" in recent years first through having reduced their focus on structural and relational stressors, such as poverty and marginalisation, and second through the application of social vulnerability indicators that continue to "reinforce the static notion of vulnerability." Further to this, Ford and Pearce (2012) highlight an over-reliance on the retrospective documentation of climate hazards and coping strategies from interviews and focus groups over a short period of time in the Canadian Arctic when pointing to similarly fixed and "static" characterisations (see also Fawcett et al., 2017).

It has been argued that, in addition to ineffectual indicators and methods, many assessments fail to capture the complex subtleties and plurality of stressors that affect, and are affected by, vulnerability and adaptation temporally as a result of short data collection periods and a methodological dependence on "word of mouth" as opposed to direct observation (Ford & Pearce, 2012; Jurgilevich *et al.*, 2016; Ray & Webb, 2016). Not only have these methods historically generated an inadequate accounting of recall bias as a factor (Figure 2.1), but they also preclude wider understandings related to the onset of slow versus fast variables as stressors, the concept of accumulative stressors, and the potential that adaptations at the time of study could in fact develop into maladaptive responses (Penn *et al.*, 2016; Duvat *et al.*, 2017).

Fawcett et al. (2017), among others (Ford & Pearce, 2012; McDowell & Hess, 2012), suggest that long-term, longitudinal approaches to vulnerability assessment can provide a more dynamic, in-depth understanding of how communities or regions experience and respond to change in the context of multiple climatic and non-climatic stresses. Real-time monitoring can provide in-depth insight on fast (e.g., week-to-week or year-to-year changes in exposure, sensitivity, or adaptive capacity) versus slow (e.g., long-term, cumulative structural trends and effectors) variables (Ericksen, 2008; Chapin *et al.*, 2009; Whitfield *et al.*, 2019) as underlying determinants of vulnerability and improve the tracking of maladaptive adaptation trajectories (Ford & Pearce, 2012; Ford *et al.*, 2013). Moreover, in assessing human-environment relations over a prolonged period, the interrelated and compound nature of converging stressors can be evaluated for different contexts and across multiple scales. By extension, this facilitates a stronger understanding of the nuanced, dynamic ways in which vulnerability might manifest itself differentially between individuals (Fawcett *et al.*, 2017). Despite their utility and application to multiple core components of vulnerability research, longitudinal vulnerability assessments—particularly those utilising real-time monitoring—remain uncommon (Windfeld *et al.*, 2019). McDowell et al. (2016), for example, note that between 1990 and 2015 just 6% (n = 17) of papers assessing climate vulnerability at the community level utilised real-time monitoring, and the application of longitudinal methods overall decreased from 2005 onward.

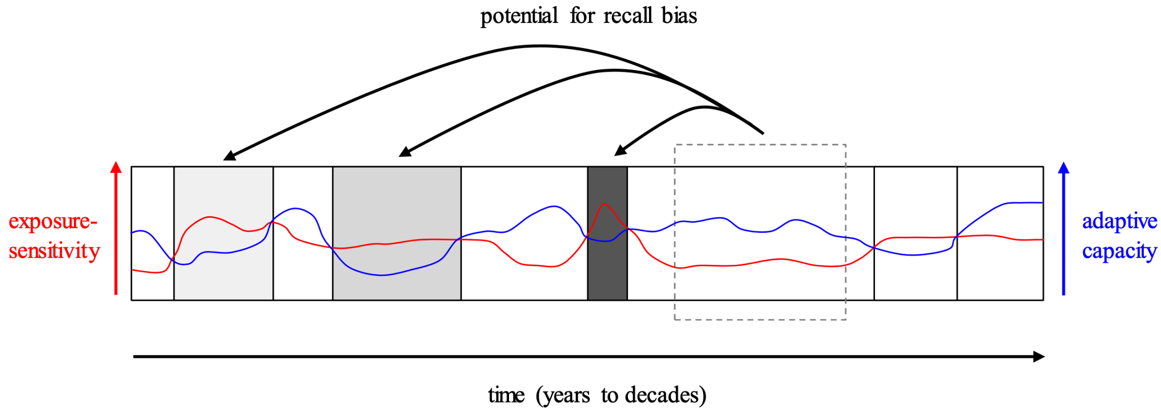

Figure 2.1: Diagrammatic representation of the challenges encountering "static" place-based vulnerability assessments:

Here, the dotted box represents the period over which fieldwork is conducted and is superimposed over the area of research interest (often called the "exposure unit"). Shaded boxes represent manifestations of excess vulnerability, where exposure sensitivity (red line) is greater than adaptive capacity (blue line). The length of boxes refers to the time over which vulnerability is manifest. The degree of shading represents likelihood of recall bias, where the lightest represents the most susceptible.

2.2. *Complexity, complex adaptive systems, and vulnerability*

Notwithstanding its broad application to the study of geography and the environmental sciences, complexity theory has been infrequently drawn upon in the vulnerability assessments relating to climate change. This comes despite the clear applicability of its insights, drawn from resilience and adaptation literature, which have utilised the concept for improving the understanding of the causal factors in systemic change and linked behavior and feedback mechanisms, and for supporting decision-making and adaptation initiatives (Levin & Lubchenco, 2008; Timmermans *et al.*, 2012).

Complexity theory is concerned with non-linear relationships in changing, disordered systems whose stability is transient (Norberg & Cumming, 2008). It seeks to understand "how complex behavior evolves or emerges from relatively simple local interactions between system components over time" (Manson, 2001). Complexity theory therefore aligns strongly with the place-based focus of many vulnerability studies given that, unlike a conventional systems theory grounding, complexity theory postulates that structures are not in a constant state of equilibrium and are constructed relationally (Preiser *et al.*, 2018). This prevents the static characterisation of interrelated processes and products by focusing on factors such as the development of feedback loops, the crossing of thresholds, and the diversity of actors and processes involved (Norberg & Cumming, 2008; Cairney, 2012). To understand the system as a whole as well as its emergent properties in complexity theory, it is therefore necessary to examine changing relationships between different elements of a system with time as well as the movement of stocks and flows between its components (Manson, 2001).

Theories of complex systems have been applied to sustainability sciences and the study of human-environment interactions through the lens of CASs (Norberg & Cumming, 2008; Preiser *et al.*, 2018). CAS and complexity theory more often than not share a number of general rules: both argue that systems are composed of diverse components that are independent but whose micro-interactions and properties develop emergent wider behaviors (Levin, 1998; Cairney, 2012). CASs, however, have a strong focus upon adaptation and the ability of systems to self-organise and modify their behaviors; in doing so, they can acclimatise to changes in their environment and develop co-evolutionary potential (Rammel *et al.*, 2007; Norberg & Cumming, 2008). In addition, CAS theory postulates that systems are inherently governed by economies of scale and that small interactions are often also governed by larger broad-scale trends (Preiser *et al.*, 2018). Key concepts within CAS theory include modulation (i.e., the degree to which nodes of a system can be decoupled into relatively discrete components and reassembled), redundancy (i.e., the degree to which nodes can substitute for one another), hierarchical endogenous-exogenous interaction (i.e., the system is open and can interact with external factors), and emergence (the origin and development of unexpected or unpredictable phenomena) (May *et al.*, 2008; Preiser *et al.*, 2018). CASs are also seen to have the ability to not only adapt but also learn, comprehend, and respond to feedbacks both institutionally and ecologically.

CAS theory is drawn upon within some framings of risk (Allen & Holling, 2010; Berkes & Ross, 2013; Kalaugher *et al.*, 2013; Schoon & Van der Leeuw, 2015), and some basic tenets underlying it are ubiquitous enough to fit within almost any vulnerability approach or framing. Examples include the principle that a system can self-organise after a perturbation to reprise its initial role (Walker *et al.*, 2004) or can develop a new role when a stressor is applied, which reduces its subsequent susceptibility through an increase in its coping range (Smit & Wandel, 2006; Kates *et al.*, 2012). Other CAS concepts, however, are less frequently drawn upon in vulnerability work. For example, the principles that (1) systems exist in a majority-disequilibrium state, (2) can exhibit stochasticity, or (3) can experience rapid and immediate, or slow and transitional, changes in state as a result of emergent interactions remain infrequently incorporated into contemporary vulnerability research.

Moreover, studies of vulnerability commonly fail to adequately address issues related to adaptive learning within their approaches (Ford & Pearce, 2012) or theories pertaining to feedback loops, webs of specific causality, variable thresholds of change, or exogenous versus endogenous stimuli (Miller *et al.*, 2010; Joakim *et al.*, 2015). This comes despite the fact that (1) adaptive learning is considered a primary driver in sustaining adaptive capacity and developing suitable adaptive strategies and derives from interactions between subjects that commonly form foci within vulnerability discourse, including systemic processes and structures and institutions of knowledge (Davidson-Hunt & Berkes, 2003; Ford & Pearce, 2012; Wise *et al.*, 2014); and (2) feedback can have significant multi-scale, hierarchical effects that can be location specific and/or have wider exogenous impacts (Adger *et al.*, 2009; Wise *et al.*, 2014). All of the above provide rationale for critiques on the viability of contemporary vulnerability approaches, particularly with regard to their frequent characterisation of climate-society interactions and their associated risks as “static” (Fawcett *et al.*, 2017; Ford *et al.*, 2018)

3. Climate vulnerability in complex adaptive systems

In this section, we propose an innovative conceptual approach to vulnerability assessment that draws upon thinking from CAS theory, including exogenous and endogenous hierarchies of risk, feedback loops, and intercomponent interactions. Our CAS vulnerability approach focuses on the notion that vulnerability derives from, and cannot be separated from, a pluralistic context of multiple, synchronously acting stressors (origins of stress) and perturbations (spikes in stress). These are considered to operate over non-linear trajectories, with differing spatial and temporal scales, and have variable magnitudes of impact that affect both the totality of a system and its subcomponents. Although it is possible to understand or appraise vulnerability at a particular time or in a particular place through a number of pre-existing approaches (Ford & Smit, 2004; Füssel & Klein, 2006), our conceptualisation builds upon wider perspectives, primarily from the disaster sciences, that vulnerability is a dynamic state of susceptibility to harm that is process driven and is therefore, over time, a process in and of itself (Lewis, 1999; Lewis & Kelman, 2010; Kelman *et al.*, 2016). Through compartmentalising a system to assess the vulnerability of its specific dimensions before reconstructing it and appraising it as a whole, our approach allows for the tracking of vulnerability and adaptation across specific exposure units and can pinpoint priorities for adaptation (refer to Table 2.1 for a complete list of definitions for terms used in our framing).

Our approach is visualised through two key stages. The first subdivides the CAS that is the object of study into “dimensions,” which represent groups of exposure units within the system that share a common function. Exposure units, also referred to as “nodes” in our approach, denote specific sites within system dimensions where vulnerability has the potential to manifest (Figure 2.2). The exact number of nodes or dimensions is not fixed and can vary depending on the CAS or even the time scale over which research takes place. The classification of nodes within the system is based on the following criteria:

TABLE 2.1:

DEFINITIONS ADOPTED BY THIS CONCEPTUAL APPROACH.

APPROACH TERMINOLOGY	DEFINITION	REFERENCE/S
Adaptive capacity (AC)	A prerequisite for adaptation. Adaptive capacity refers to the total sum of relationships, expertise and entitlements, and their ease of mobilisation and utilisation, which allow for individuals, households, or institutions to prepare, cope, adjust, or alter a system to mitigate against an applied stimulus or stimuli and the potential for damage that may arise from this application.	Ford & Smit, 2004; Ford *et al.*, 2006; Engle, 2011
Adaptation	The practice of implementing or utilising adaptive capacity to alter behavior or remove drivers in order to decrease vulnerability and to cope with possible impacts of adverse change.	Fazey *et al.*, 2010; Kates *et al.*, 2012; Bennett *et al.*, 2016;
Exposure (E)	The rate and nature through which individuals, communities or regions differentially experience multi-scalar changes, trends or shocks. Intrinsically linked to, and almost inseparable from, sensitivity.	Ford & Smit, 2004; Luers, 2005; Smit & Wandel, 2006; Bennett *et al.*, 2016;
Exposure Units	The specific components of a human-environment system, including its actors and social, technological and natural components, which in total form the focus of a vulnerability framework or assessment.	Eakin & Luers, 2006
Sensitivity (S)	Sensitivity describes pre-existing and developing conditions within an entity that govern its susceptibility to the effects of an exposure.	Füssel & Klein, 2006; Bennett *et al.*, 2016; Debortoli *et al.*, 2018
Coping capacity/ range	The range over which a system may deal with or accommodate the application of stresses, perturbations or applied stimuli. Whilst typically presented as a positive value, which also serves as a proxy for a component of adaptive capacity (see references), we visualise that coping range may be either positive (able to cope) or negative (unable to cope) (see also Adaptive surplus/deficit).	Smit & Pilifosova, 2003; Smit & Wandel, 2006
Slow variables	Variables that emerge from broader, long-term trends, which result in gradual changes to exposure, sensitivity, or adaptive capacity within a system (e.g. currency inflation and alteration to interest rates, sociocultural transformations). These are determined by factors and processes external to the system.	Chapin *et al.*, 2009; Ford *et al.*, 2013; Fawcett *et al.*, 2017
Fast variables	Variables that are superimposed over, and governed by, slow variables, which result in rapid changes to exposure, sensitivity, or adaptive capacity within a system (e.g. pests in agro-pastoral systems, day-to-day financial income). Determined by factors both internal and external to the system.	Chapin *et al.*, 2009; Ford *et al.*, 2013; Fawcett *et al.*, 2017
Adaptive Surplus/Deficit	The degree to which a system has a positive or negative coping range. Adaptive surplus represents a positive coping range, brought about by an adaptive capacity that exceeds present exposure-sensitivity. Adaptive deficit represents a circumstance whereby exposure-sensitivity is greater than adaptive capacity and represents a circumstance of excess vulnerability.	Ford *et al.*, 2006; Smit & Pilifosova, 2003

(1) They exhibit a degree of modulation (i.e., the nodes can be decoupled into relatively discrete components, allowing individual appraisal, and then recombined to reconstruct the system).

(2) They have definable but porous boundaries that allow them to be interconnected with other (often multiple) exposure units (thereby allowing feedbacks, webs of causality, and redundancy between nodes).

(3) They are liable to experience adverse impacts when a set of system-wide or exposure unit-specific stressors are applied.

Upon subdivision of the CASs, vulnerability is examined for each dimension's constituent nodes on the basis of the notion that multiple stressors interact and augment to affect exposure sensitivity and adaptive capacity within the exposure units. The role of these stressors can be either fast or slow onset, characterising the ways through which stakeholders experience exposure sensitivity and adaptive capacity across time, and can derive from sources both exogenous and endogenous to the system. Examples of multiple stressors might include, among other things, economics, resource availability and use, entitlements, technology, and social relations and knowledge systems (Figure 2.2).

Much like the number of nodes or dimensions and the structure of their interactions within the CASs, our approach does not designate specific stressors a priori because they are most likely system and situation dependent. Therefore, although Figure 2.2 provides examples, the stressors included therein should not be considered exhaustive. Moreover, the primary purpose of this approach is as a heuristic to highlight areas both of significant deficit in coping capacity and of manifestations of compound vulnerability across multiple dimensions within a CAS. As such, we do not propose specific indicators to assess variables because they are context dependent on available data, chosen methods, and the quantitative tangibility of certain characteristics within dimensions and nodes of the system in question. We do, however, note that numerical ratings for vulnerability could theoretically be applied to our approach through the calibration of tangible and intangible vulnerability indicators for a specific system (de Andrade & Szlafsztein, 2018).

In assessing vulnerability for constituent nodes and dimensions of the CASs, with iterative reappraisal it is possible to track specific adaptive capacities and exposure sensitivities with time. This facilitates the creation of node-specific and dimension-specific vulnerability profiles with longitudinal scope for all entities within the system. This is done with the objective of highlighting surpluses (where adaptive capacity exceeds exposure sensitivity) or deficits (where adaptive capacity is less than exposure sensitivity) in adaptive capacity in terms of both magnitude and time scale across both specific dimensions, as well as within the system as a whole. Furthermore, it allows for the identification of the most impactful drivers of potential vulnerability on individual aspects of the system in time, pinpoints priorities for capacity building and adaptation, and highlights possible slow versus fast variables in vulnerability and maladaptive trajectories (Kates *et al.*, 2012).

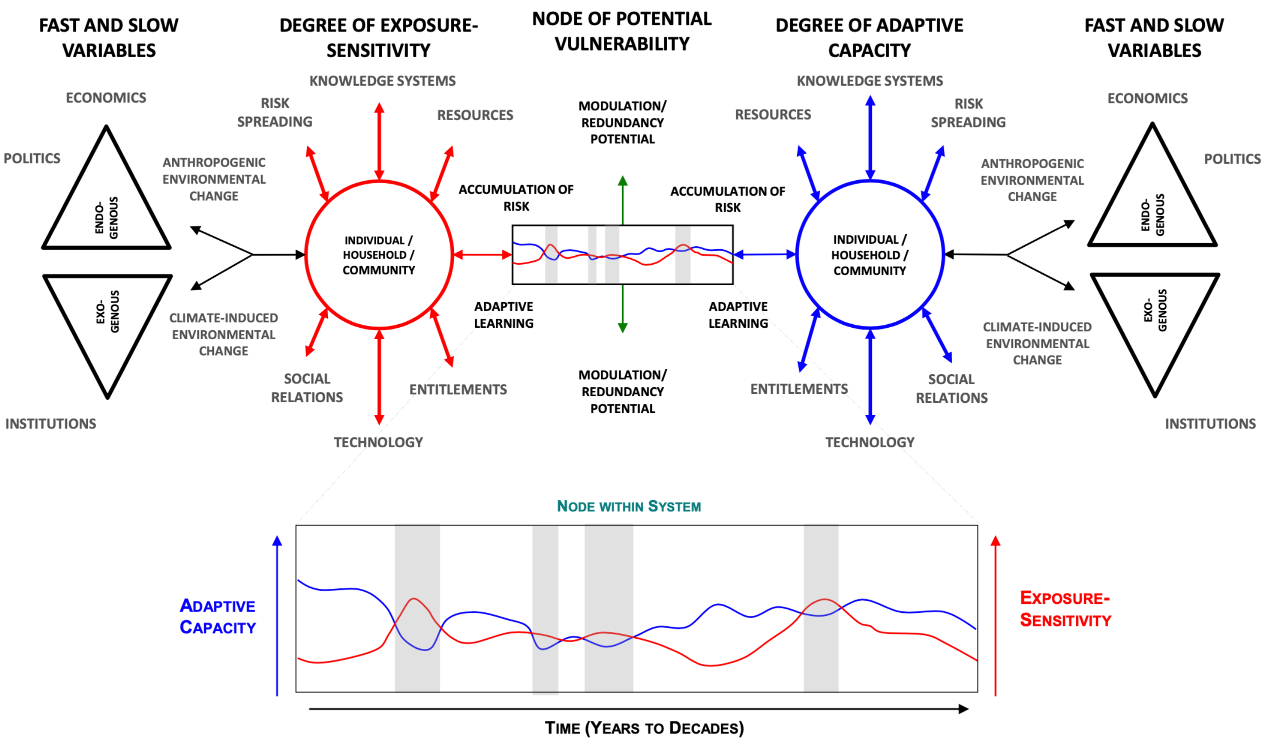

FIGURE 2.2: DIAGRAM OF THE EVALUATION OF VULNERABILITY WITHIN DIFFERING EXPOSURE UNITS OR NODES WITHIN THE CAS:

Gray sections within the "vulnerability profile" highlight periods of vulnerability experienced over the course of a study period—in this case, years to decades. For definition of concepts, see Table 2.1 and the section *Complexity, Complex Adaptive Systems, and Vulnerability* (ch. II, section 2.2.).

After the accounting of manifestations of vulnerability within individual exposure units and dimensions of the system, the second stage of our approach develops a whole-system composite temporal vulnerability profile, or "fingerprint," for the CAS by combining the vulnerability profiles created for its constituent parts and accounting for their interconnectedness and relationships. When accounting for interactions, the approach should also consider nodes within the reconstructed system for feedback (both positive and negative), their redundancy potential, and their modularity (see *Complexity, Complex Adaptive Systems, and Vulnerability*). Redundancy potential is critical in determining the overall vulnerability of the system because it permits specific nodes within the network to be placed outside of their coping capacity while still maintaining overall system stability (Norberg & Cumming, 2008). Modularity describes the degree to which nodes within the system can be detached and separated from one another and therefore is a measure of the degree to which risks might cascade or transfer across nodes (Norberg & Cumming, 2008).

By focusing explicitly on the temporal, process-based nature of vulnerability, adoption of this approach can help address concerns directed at previous vulnerability assessments discussed in *Conceptualising Vulnerability*, particularly that they have had an overt focus on single, static points in time and have privileged the biophysical impacts of climatic change at the expense of other exogenous and endogenous sociopolitical drivers (Ford & Pearce, 2012; Tschakert *et al.*, 2013; Kelman *et al.*, 2016). Figure 2.3 outlines a network of node interactions within a hypothetical system and provides a composite vulnerability profile for all of the system's exposure units. A worked example of a CAS in Box 2.1—in this case the traditional food system of Inuit in the Arctic—illustrates how the approach might be applied.

Knowledge surrounding why vulnerability occurs is an essential springboard for identifying and understanding opportunities for adaptation (Ribot, 2011). Our CAS vulnerability approach, catered to a specific system in the manner outlined in Box 2.1, directly addresses the question of why vulnerability manifests in a specific area and for certain people, is of a specific magnitude, and occurs at a specific time. From this, it is possible to gain an understanding of adaptation opportunities (e.g., direct economic investment, entitlements, and building social cohesion). The identification of entities with a high modulation potential, in conjunction with knowledge of the causal factors underlying potential vulnerability, will highlight nodes where an adaptive response might have a lower likelihood of maladaptive effects than other areas of the system or where an increase in vulnerability might have fewer knock-on impacts. In addition, through iterative reappraisal of exposure units and their interactions across time, the likelihood of capturing the role of feedback in affecting vulnerability between dimensions, and within the system as a whole, is increased. Construction of a total system vulnerability profile (or subdivisions therein based on modularity) and the creation of a "vulnerability fingerprint" are important in our framing because they allow for the tracking of vulnerability across an entire system across any given period of time. Furthermore, producing a vulnerability fingerprint also identifies "quick-win" areas where the magnitude of an adaptive deficit is small and, by extension, so too is the increase in coping capacity required to overcome it. Alternatively, in areas where it becomes evident that significant increases in adaptive capacity are required to overcome excess exposure sensitivity, the approach can identify "weakest link" areas within a CAS (Tol & Yohe, 2007).

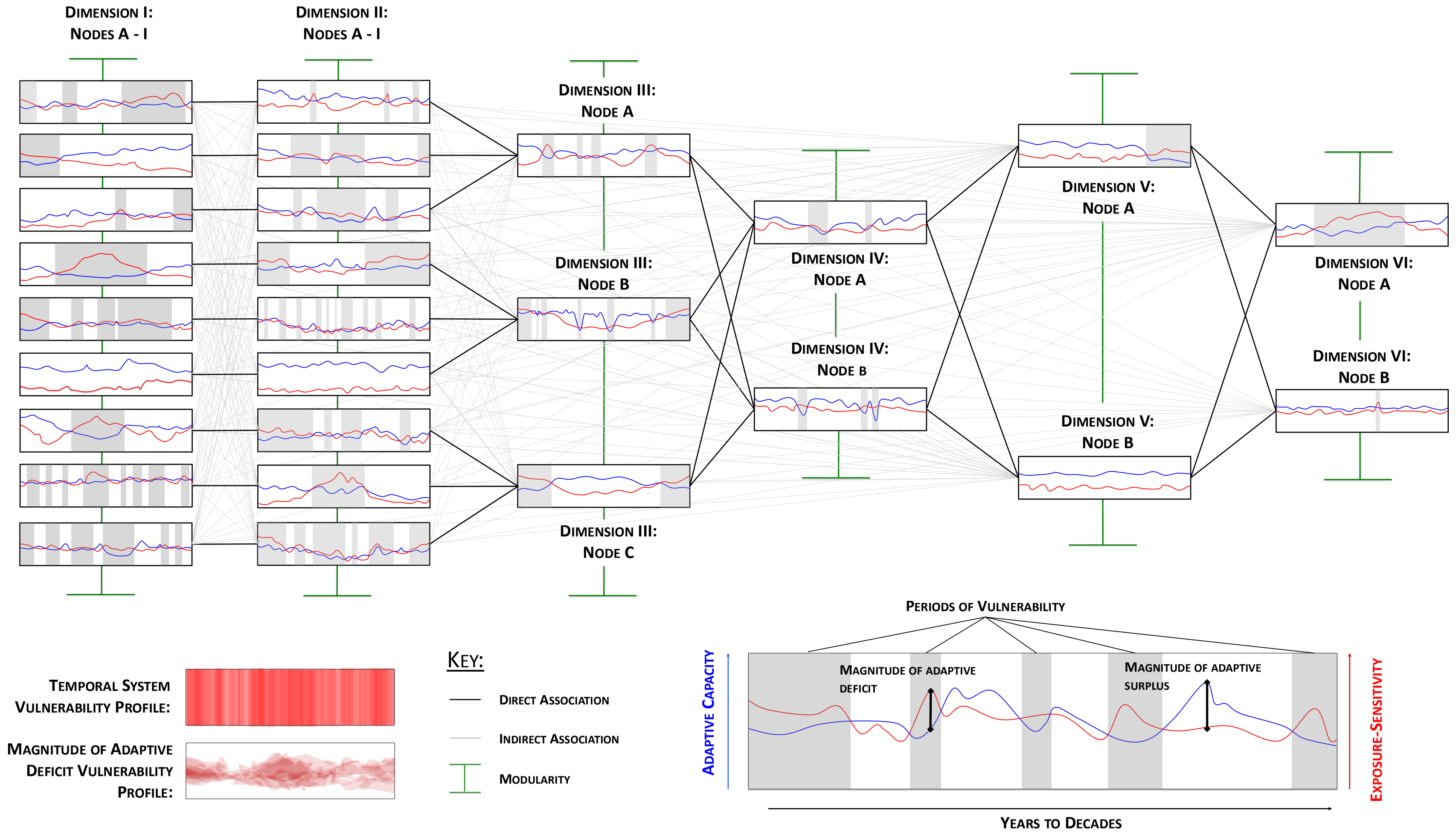

Figure 2.3: Composite vulnerability profile of an idealised human-environment system:

Here, the system is seen to comprise a CAS of multiple dimensions and nodes, which relate to areas where vulnerability has the potential to manifest. Through assessing the vulnerability of specific dimensions and nodes and accounting for their interlinkages and associations through time, it is possible to develop a whole-system vulnerability profile. This composite profile can highlight both the vulnerability of the overall system in time and the relative magnitude of its adaptive deficit or surplus in this time. The vulnerability of the system is further influenced by the redundancy potential of components that perform similar functions (e.g., dimensions V:A and V:B, whose linkages are demonstrated with green lines) and the degree to which components can be separated or disconnected from other vulnerable components within the system.

Box 2.1: Inuit traditional food system, Arctic Canada:

Indigenous traditional food systems describe networks of agents, actors, and stakeholders within a specific area who are involved in the production, distribution, processing, preparation, and exchange of foods that derive from short, localized supply chains, and a have cultural and spiritual importance beyond simply their nutritional value (Ericksen, 2008; Kuhnlein *et al*., 2009). In the context of the Canadian Arctic – a region warming at more than twice the global annual average (IPCC, 2001) - climate change has come to represent a significant threat to Inuit traditional food systems (Ford *et al*., 2006, 2013; Prno *et al*., 2011). However, the challenge of an altered climate extends far beyond simply its physical effects, with research highlighting the compound and pluralistic nature of how climate change interacts with social, political, cultural and economic stresses to affect individuals, households, and communities (Ford, 2009; Ford *et al*., 2013; Statham *et al*., 2015). To this end, we outline below a hypothetical Inuit traditional food system, representing a CAS of coupled human-environment interactions. Using examples from Figure 2.3, and working left to right, the below table sub-divides the system into dimensions that are commonly considered key to its function, and outlines potential exposure-sensitivities, adaptive capacities and interactions that might otherwise affect the vulnerability of nodes/exposure-units. Conceptualization in this way would track current and future threats to system stability, and by extension threats to potential food security. Moreover, through focusing on the causal factors underlying vulnerability within the system, and understanding their interactions, such an approach would have the potential to improve the success of targeted adaptations and interventions.

Dimension (e 3)		I	II	III	IV	V	VI
Indigenous food system dimension		*Quality and health of subsistence species*	*Availability of subsistence species*	*Access to hunting/fishing /harvesting grounds*	*Traditional/non-traditional methods of food preparation*	*Traditional/non-traditional methods of food storage*	*Methods of food distribution*
Nodes (figure 3)		A - I	A - I	A - C	A - B	A - B	A - B
Indigenous food system nodes		Specific subsistence species (e.g. B = caribou)	Specific subsistence species (e.g. B = caribou)	Specific land access types (e.g. A = sea-ice, B = open water, C = land)	A = Traditional B = Non-traditional	A = Traditional B = Non-traditional	A = Inter-community B = Intra-community
Possible exposure-sensitivities	Fast	Seasonal variation in edibility (e.g. caribou rutting season); human-induced environmental changes/contaminants; anomalous land/sea/ice conditions;	Possible over-hunting; knock-on effect of decline in species health/food quality from dimension I; predation from invasive species;	Affordability of, and cash-flow for, equipment required for access (e.g. purchasing and maintaining machinery, ammunition, gasoline); inter-annual and inter-seasonal land conditions (e.g. early ice break-up); time constraints of engaging in waged-employment/full-time education	Conditions becoming too warm to use drying racks or ferment foods;	Cost of purchasing personal freezer; power cuts; access to community freezers dependent on social networks	Ability to distribute foods between communities based on weather conditions;
	Slow	Increase in climate/temperature-sensitive zoonotic diseases/parasites;	Changes to seasonal migration routes as a result of climatic changes;	Attrition of Indigenous knowledge (IK) of the land; centralization and sedentarization of semi-nomadic population	Attrition of IK of food preparation; architecture of housing results in lack of space to butcher meats	Melting of permafrost insulating ice-cellars;	Changing ethos and culture surrounding sharing
Possible adaptive capacities	Fast	Harvesting at different types of year; selective harvesting of specific animals;	Travelling increased distances to access hunting grounds;	Creation of new routes/trails; sharing equipment/resources; uptake of technology to navigate in poor conditions	Country food preparation programs and nutrition education	Community freezers;	Purchasing of traditional foods, development of country food markets;
	Slow	Environmental controls/regulation	Harvest quotas;	Harvester's assistance programs	Transition to store-bought alternatives	Transition to store-bought alternatives	Transition to store-bought alternatives
Redundancy potential		High (able to substitute which species are hunted)	High (able to substitute which species are hunted)	Moderate (lack of access to ice, overcome by access to open water, dependent on break-up).	Moderate (system can operate with only one node, but may have implications for food preference)	High (system can still operate with traditional or non-traditional storage).	Moderate (some relationship between sharing and monetization of country food)

4. Conclusion

This Perspective outlines an innovative conceptual approach for assessing climate change vulnerability. Our approach builds upon previous scholarship that has conceptualised vulnerability as a function of relative exposure sensitivities and adaptive capacities and incorporates wider perspectives that vulnerability is dynamic and contextual rather than outcome based to emphasise that vulnerability is a process rather than a static or binary state. Vulnerability is therefore seen to be determined by the continuous interaction of multiple exogenous and endogenous stressors, in addition to the interconnectedness of components that interact with them.

To this end, we emphasise the need for climate vulnerability assessments to recognise systems as complex, adaptive, and comprising multiple dimensions and nodes. Each node is considered interrelated to a greater or lesser degree and has interoperability that facilitates overall system function. It is within nodes that potential manifestations of excess vulnerability arise, and these are tempered by their potential modularity and redundancy and have an effect on the net vulnerability potential of the system as a whole (Norberg & Cumming, 2008; Cairney, 2012). The dynamic state of vulnerability within the CAS, along with its exposure sensitivities and adaptive capacities, means that it is capable of migrating across nodes to alter system structure, status quo, or dynamic function. Vulnerability is understood in this manner with the objective of highlighting, among other factors, deficits in adaptive capacity and priority areas for adaptation. More specifically, an understanding of the role of modulation and redundancy between components with time, underpinned by knowledge of why certain areas are vulnerable, also allows the pinpointing of areas that are priorities for adaptive learning, potentially maladaptive trajectories, or other areas, which could be potentially susceptible to positive and negative feedback.

The CAS vulnerability approach is an attempt to overcome critiques leveled at past vulnerability approaches. Not only does the framing address the issue of how exogenous and endogenous drivers in adaptive capacity and exposure sensitivity drive local manifestations of vulnerability, but its focus on vulnerability as a process also departs from previous constructions and framings of vulnerability as a static and constant state. The utility of our approach comes from its ability to be generalised. If the components and relative bounds of a system are known, it would be possible to reconstruct and reorder nodes within our approach to assess vulnerability for any system across any given timescale, so long as it is conceptualised as complex and adaptive. Although the approach is not explicitly tied to a set of methods, it has been designed with the application of a longitudinal methodology in mind. Longitudinal application of our typology would facilitate an improved understanding of the magnitudes of deficit and surplus relating to both adaptive capacity and exposure sensitivity with time. Such work is rare at present but is urgently needed if we are to better understand how societal systems will be affected by future climate change.

5. Acknowledgments

We are grateful for the continued funding and support received from the UKRI Economic and Social Research Council (reference no. 1948646) and Crown-Indigenous Relations and Northern Affairs Canada Climate Change Preparedness in the North program. We would also like to thank both reviewers of this article for their constructive input and critical insight, in addition to Anuszka Mosurska and Jake Fletcher for their assistance in proofreading the final pre-submission copy of the manuscript.

6. Author contributions

A.N. and J.F. conceived and developed the approach with additional input from T.P. and J.V.A. A.N. produced original draft and diagrams. All authors edited and approved the manuscript.

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CHAPTER III

MONITORING THE DYNAMIC VULNERABILITY OF AN ARCTIC SUBSISTENCE FOOD SYSTEM TO CLIMATE CHANGE: THE CASE OF ULUKHAKTOK, NT

'Original Research' article, published as:

Naylor, A.W., Ford, J.D., Pearce, T., Fawcett, D., Clark, D, and van Alstine, J. 2021. Monitoring the dynamic vulnerability of an Arctic subsistence food system to climate change: the case of Ulukhaktok, NT. *Plos One*, **16**(9), e025848.

Introduction to the manuscript

Published in 2021 in Plos One, this manuscript accomplishes the second objective of this doctorate through combining the conceptual approach to complex adaptive systems, outlined in the previous chapter, with a participatory, real-time land-use monitoring methodology to understand the vulnerability of the *Ulukhatokmiut* food system to climate change in the context of multiple socially constructed stressors, and to characterise how this affects hunting participation and foodshed stability. It comprises one of the two major empirical and methodological contributions of this thesis. It should be noted that the conceptual approach applied in this paper is considered a heuristic. Therefore, while it informs the theories and basis for the thesis' understanding of vulnerability, its purpose is not provide a workable framework that prescribes methods of data collection or analysis, or the reporting or format of results.

Abstract

Vulnerability to climate change is highly dynamic, varying between and within communities over different timescales. This paper draws upon complex adaptive systems thinking to develop an approach for capturing, understanding, and monitoring climate vulnerability in a case study from northern Canada, focusing on Inuit food systems. In the community of Ulukhaktok, Northwest Territories, we followed 10 hunters over a 2-year period, asking them to document their harvesting activities and discuss their lived experience of harvesting under changing environmental and societal conditions. GPS monitoring and participatory mapping sessions were used to document 23,996km of trails (n = 409), with conversational bi-weekly semi-structured interviews and secondary instrumental weather data used to contextualise climate change within a nexus of other

socioeconomic, cultural, and political stressors that also affect harvesting. Our results demonstrate that climate change has considerable potential to affect harvesting activities, particularly when its impacts manifest as anomalous/extreme events. However, climate change impacts are not necessarily the most salient issues affecting harvesting on a day-to-day basis. Instead, factors relating to economics (particularly financial capital and the wage-based economy), social networks, and institutions are found to have a greater influence, either as standalone factors with cascading effects or when acting synchronously to augment the impacts of environmental change.

1. Introduction

The impacts of climate change have been observable in the Arctic for over four decades (Hinzman *et al.*, 2005; Ford, 2009a). Yet with current rates of warming in the circumpolar north at two to three times the global annual average, the incidence and severity of these adverse impacts is projected to increase (Meredith *et al.*, 2019). Climate-induced environmental change holds especially severe implications for Inuit in Northern Canada, whose subsistence-focused livelihoods are closely linked to environmental conditions (ICC, 2010; Ford *et al.*, 2018a). It is for these reasons that many Inuit organisations and communities have identified climate change as a fundamental challenge to both their ways of life and human rights (ICC, 2010; ITK, 2005; Jodoin *et al.*, 2020).

The challenges Inuit presently face when practicing subsistence extend beyond the simple biophysical impacts of climate change, however. Changing land, ice, and ocean environments are intersecting with a diversity of socially-constructed stressors – both dynamic and multiscale – that can affect food systems, food security, and circumpolar health (Ford, 2009b; Wenzel, 2009; Beaumier & Ford, 2015; Archer *et al.*, 2017; Huntington *et al.*, 2019). For instance, previous studies have documented the role and importance of Inuit ecological knowledge in adaptation to climate change, finding that it underpins competency in harvesting and adaptation to changing conditions (Pearce *et al.*, 2015; Waugh *et al.*, 2018). Other research has examined the influence that top-down wildlife management practices, introduced in response to changing animal migration patterns, can have on harvesting, mental health, and wellbeing (Snook *et al.*, 2020; Middleton *et al.*, 2020). A broad body of scholarship has also assessed how food systems altered by climate change are changing from a post-harvest perspective, in particular examining how cultural change, demography, and altering social norms are affecting sharing networks (Collings, 2011; Harder & Wenzel, 2012; Collings *et al.*, 2016).

Despite an improved understanding that the impacts of climate change in the Arctic are dependent upon multiple socioeconomic, political, and cultural factors, little research has captured the interaction of these dynamics across space and time (Naylor *et al.*, 2020). Much past research has been structured around the organising concept of 'vulnerability', which was developed within the disaster studies and natural hazards fields during the late 1970s through a focus on the 'un-naturalness' of disasters (O'Keefe *et al.*, 1976; Lewis, 1977; Hewitt, 1983), and was subsequently incorporated into human dimensions of climate change scholarship (Lewis, 1990; Watts & Bohle, 1993; Smit & Wandel, 2006; O'Brien *et al.*, 2007; Kelman *et al.*, 2018). Vulnerability research seeks to identify and understand the factors that put people and places at risk or reduce their ability to respond to threats. It is important to note that vulnerability approaches are designed to understand dynamics and drivers of change, and do not establish populations a priori as vulnerable; a common theme in much vulnerability research is instead an emphasis on adaptation, adaptive capacity, resilience, and agency (Ford *et al.*, 2018b; Ribot, 2011).

Past vulnerability research—in the Arctic and globally—has been critiqued for producing a temporally "static" account of vulnerability, despite conceptual thinking and approaches that highlight that the experience of vulnerability is highly a dynamic and transient process (e.g. Naylor *et al.*, 2020; Lewis, 1999). Other researchers have also criticised vulnerability approaches for privileging biophysical drivers over social phenomenon in their analyses (Huntington *et al.*, 2019; Hinkel, 2011), for bringing a deficit framing to the study of climate change (Cameron, 2012; Haalboom & Natcher, 2012), or for their propensity to produce an incomplete picture of vulnerability through a poor accounting of endogenous and exogenous drivers of differential risk (McDowell *et al.*, 2016; Barnett, 2020). More recent critiques have also suggested that while vulnerability research is effective at signposting which stressors are present, such work infrequently discusses how they interact or their relative precedence (Singh *et al.*, 2019). Addressing these methodological and epistemological shortcomings represents a 'grand challenge' for vulnerability research, where new approaches are critically needed (Ford *et al.*, 2018b).

This paper examines how climatic and wider sociocultural, political and economic factors affect climate change vulnerability, focusing on Inuit hunters from Ulukhaktok, NT. The paper attempts to capture how these various factors interact over time, to develop an in-depth understanding of how climate change is being understood, experienced, and responded to. In doing so, our research aims to reconcile some of the aforementioned conceptual-methodological disconnects relating to past vulnerability assessments in the Arctic. We advance a new conceptualisation of the Inuit subsistence food system, or 'foodshed', as a dynamic, complex adaptive system, and integrate this approach with the real-time monitoring of risk. We first outline the conceptual basis for our research approach. This is followed by an overview of the study area and documentation of the methods used. Our results and subsequent discussion highlight the spatial context of the subsistence-based foodshed, the relationships between place and the manifestations of vulnerability and adaptive capacity over time, and the role of climate versus other socially constructed factors affecting foodshed stability. While our approach is developed and operationalised in an Arctic context, it has global relevance for similar studies working with people whose lives and livelihoods are associated with diverse food environments.

2. Methodology

2.1. *Conceptual approach*

We draw upon, and advance, the heuristic approach for conceptualising climate vulnerability outlined in Naylor *et al.* (2020) and apply it to a complex adaptive system: the subsistence foodshed of Ulukhaktok, NT. Derived from the principle of a 'watershed', a 'foodshed' refers to the social and physical landscape of a food system, within which foods are sourced, prepared, distributed or otherwise exchanged (Kloppenburg *et al.*, 1996; Peters *et al.*, 2009; Ford *et al.*, 2011). In the context of Ulukhaktok, the subsistence foodshed describes the physical extent of hunting, fishing, and foraging grounds on the lands, sea, and ice proximal to the community and the relationships and norms that govern how these foods are harvested and shared between its residents (see Study Area).

Studies addressing social-ecological phenomena are increasingly adopting complex adaptive systems theory (Levin *et al.*, 2013; Levin, 1998; Preiser *et al.*, 2018; Greenlees & Cornelius, 2021). A complex adaptive system (CAS) describes a set of components – self-organised and grouped relationally according to function – whose micro-interactions and non-linear interdependencies develop emergent, dynamic behaviours that can dictate whole-system characteristics (Naylor *et al.*, 2020; Levin, 1998). Crucially, CAS approaches place specific emphasis on the dimension of time within linked human-environment systems, and the ways through which time and the structure of a system can interact to develop emergent process-based phenomena (Naylor *et al.*, 2020). Specifically, CAS theory argues that a system exists in a non-equilibrium state; that its components have the potential to disaggregate, develop webs of causality, and exhibit feedbacks, redundancy and adaptive learning; and that these can create hierarchical interactions that may be both endogenous and exogenous to the CAS in question (Levin *et al.*, 2013; Preiser *et al.*, 2018; Rammel *et al.*, 2007; Coetzee *et al.*, 2016a). Framing system interactions as constantly changing and more than simple linear 'cause and effect' in this manner provides a particularly useful frame of reference for appraising and understanding the dynamic manifestations of vulnerability and risk that often emerge from climate-society interactions (Naylor *et al.*, 2020; Coetzee *et al.*, 2016b).

However, in order to better understand the ways through which vulnerability might manifest or be ameliorated within a specific complex adaptive system, location-specific, geography of place research approaches are also essential (Ford *et al.*, 2010; Richmond *et al.*, 2020). By compartmentalising the subsistence foodshed of Ulukhaktok, NT into components that can be appraised for their relative vulnerability in time and space, it is possible to identify transient or persistently at-risk dimensions within the system (e.g. access to hunting grounds, food storage capacity), and subsequently highlight these areas as priorities for adaptation (Figure 3.1). Moreover, by compartmentalising but not detaching components from their broader context in the system as a whole, a vulnerability approach based upon CASs theory allows for a stronger understanding of the influence of vulnerable components on total-system stability. In particular, the ways through which vulnerabilities might otherwise migrate or be contained as a result of stocks and flows between components and the development of emergent adaptive or maladaptive responses (Coetzee *et al.*, 2016a; Schipper *et al.*, 2020).

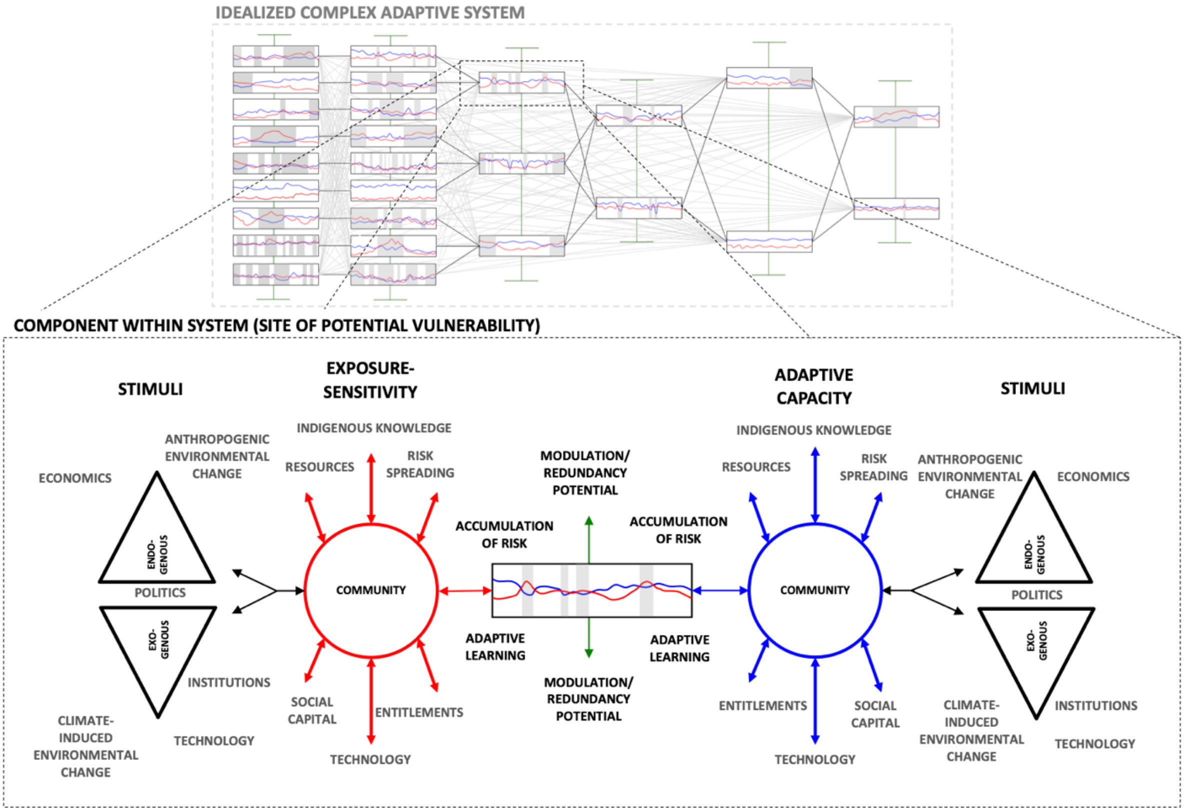

FIGURE 3.1. IDEALISED COMPLEX ADAPTIVE SYSTEM, DISAGGREGATED INTO COMPONENTS ACCORDING TO THEIR FUNCTION.

Here, potential vulnerability in each component of the food system (e.g. the availability of certain subsistence species, ability to access lands) - indicated by the box insert - is determined by the role of exogenous and endogenous stimuli and stressors, such as environmental change, the degree to which an individual has access to technology, or their access to entitlements. The ways in which these stimuli interact creates potential exposure-sensitivity (red) and adaptive capacity (blue) across time. The central 'barcode' illustrates this interaction and its dynamism, with the grey bars highlighting periods of adaptive deficit (vulnerability). Interconnectedness between components within the system allows vulnerability in a single component to affect or migrate to multiple other areas of the system through time, and to produce emergent/system wide changes (modified from Naylor *et al.*, 2020).

In the context of the CAS vulnerability framing posited here, the potential susceptibility of components within a system (and by extension the system as a whole) is understood to be a function of the relative occurrence, duration, and magnitude of 'exposure-sensitivity' and 'adaptive capacity' (Naylor *et al.*, 2020; Smit & Wandel, 2006). As outlined by Smit & Pilifosova (2003) (see also Ford & Smit, 2004), exposure-sensitivity describes the nature and rate at which stressors/stimuli (e.g. altered entitlements, climatic extremes, changes to social relationships) are applied, in addition to the pre-existing conditions that are present at their point of application. Adaptive capacity refers to the function of all relationships, expertise, and entitlements (and their ease of mobilisation and utilisation) that allow for the preparation, coping, or adjustment against stressors/stimuli throughout the duration of the latter's application (Smit & Wandel, 2006; Ford & Smit, 2004). A negative disparity between exposure-sensitivity and adaptive capacity creates an adaptive deficit (period of relative vulnerability), requiring either an increase in the strength of an adaptive response, or a change in the conditions developing exposure-sensitivity (Naylor *et al.*, 2020) (Figure 3.1).

While there have been attempts to empirically 'measure' or provide values for magnitudes of adaptive capacity, exposure-sensitivity, and, therefore, vulnerability through the use of indicators and indices (e.g. Debortoli *et al.*, 2018; Cold *et al.*, 2020), the efficacy of such approaches is contentious (Hinkel, 2011; Birkenholtz, 2012). This reflects the difficulties associated with measuring intangible socio-political and cultural drivers of vulnerability, which, if unaccounted for, can lead to an inadequate or even obfuscated understanding of root causes (Hinkel, 2011; Birkenholtz, 2012). Therefore, in order to place an emphasis on dynamism and cross-component interactions, while also retaining a focus on socioeconomic, cultural and political conditions, a mixed-methods vulnerability methodology is used (see Methods). The results section is structured around the ways through which multiple stressors combine and compound each other to affect exposure-sensitivity and adaptive capacity over time; numerical values are not applied when attempting to discuss magnitudes of exposure/sensitivity.

2.2. *Study area*

Ulukhaktok is a community of ~440 people located on the western coast of Victoria Island within the Inuvialuit Settlement Region (ISR) of Inuit Nunangat (western Arctic Canada) (NWT Bureau of Statistics, 2019a) (Figure 3.2). Established as a permanent settlement in the late 1930s with the construction of a Hudson's Bay Company trading post and a Roman Catholic mission, the construction of buildings at the site initiated a period of drastic livelihoods change and sedentarisation for Inuit living nearby (Condon, 1994; IRC, 2011). Prior to the 1930s, the *Kangiryuarmiut* and *Kangiryuatjagmiut* peoples of Victoria Island had practiced semi-nomadic livelihoods, predicated on temporary settlement in seasonal camps and patterns of movement in line with the migration of keystone subsistence species (Farquharson, 1976; Collignon, 1993). However, over the following decades a government-subsidised housing initiative in Ulukhaktok and pull factors related to education and opportunities for wage-based employment all factored into the sedentarisation of peoples into the community (Condon *et al.*, 1995; Damas, 2002).

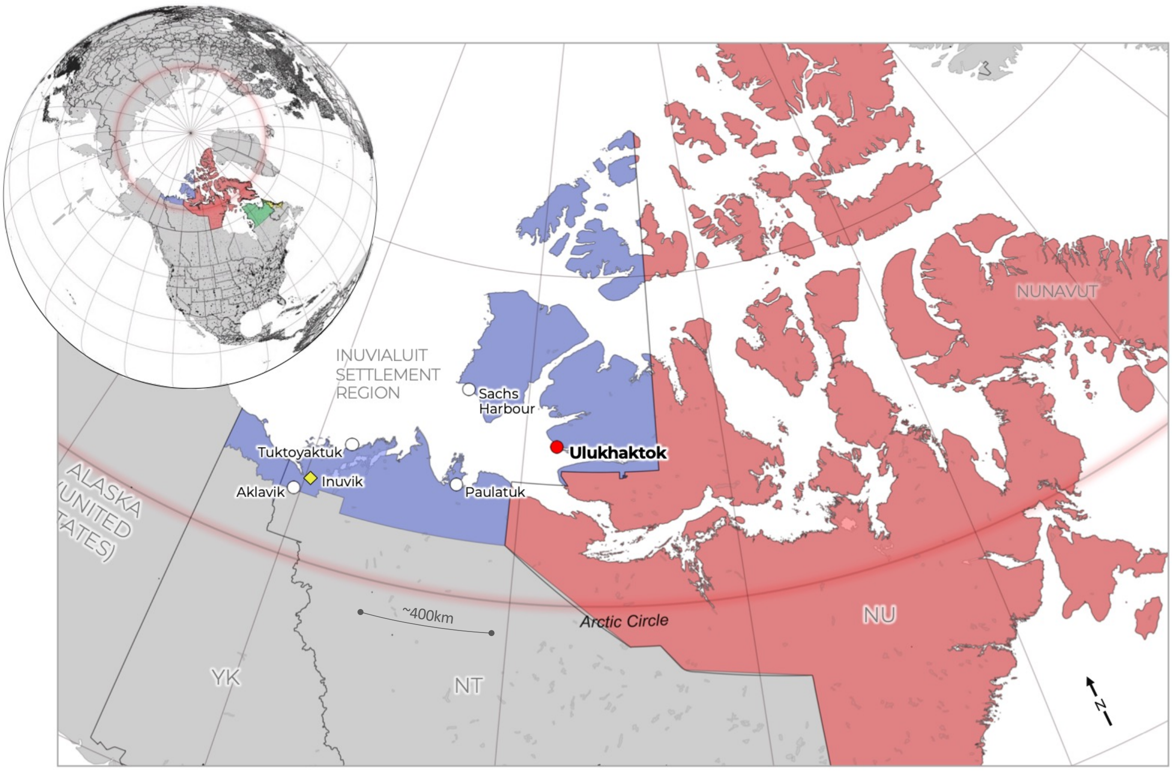

FIGURE 3.2. MAP OF ULUKHAKTOK AND THE OTHER FIVE COMMUNITIES WITHIN THE INUVIALUIT SETTLEMENT REGION OF *INUIT NUNANGAT* (ADAPTED FROM NAYLOR *ET AL.*, 2021).

By 1967, the last family had moved from the land into permanent housing (Condon, 1987). As a result, distal traditional hunting and trapping grounds were abandoned in favour of new or existing areas more proximal to the community, whilst a desire to maintain certain keystone species for economic, cultural and dietary purposes necessitated the uptake of mechanised transport in order to travel greater distances in shorter periods of time (Collignon, 1993; Condon, 1996). Mechanisation also enmeshed Inuit subsistence practices within the broader global and national economies of resource use and capital accumulation, and by extension, increased the community's reliance on waged labour, cash liquidity and the global fur market (Kemp, 1971; Smith & Wright, 1989; Wenzel, 2019).

Despite wide-ranging sociocultural and economic changes since the early-to-mid 20th century, and the difficulties now associated with accessing their traditional lands, many *Ulukhaktokmiut* (peoples from Ulukhaktok) still regularly engage in subsistence activities in the present day. The strong ethos and cultural basis that underpins subsistence remains celebrated in the community, and the year-round right to harvest is protected in treaty legislation through the Inuvialuit Final Agreement. As of 2018, 75.9% of the adult population in Ulukhaktok stated that they had either 'hunted or fished' in the previous calendar year, as compared with 45.4% across all communities within the Beaufort

Delta region as a whole (NWT Bureau of Statistics, 2019a). Species, considered integral to the stability of the community foodshed, include muskoxen, umingmak (*Ovibos moschatus*), caribou, tuktu (*Rangifer tarandus groenlandicus x pearyi* and *Rangifier tarandus*), ringed seal, nattiq (*Pusa hispida*), king eider ducks, qingalik (*Somateria spectabilis*), Arctic char, iqalukpik (*Salvelinus alpinus*), and lake trout, ihuuq (*Salvelinus namaycush*). In addition to the by-products of some of the above, polar bears, nanuq (*Ursus maritimus*), grizzly bears, akhak (*Ursus arctos horribilis*), wolves, amaruq (*Canis lupus*), and Arctic fox, tiriganniaq (*Vulpes lagopus*), also represent a potential economic resource through the sale of pelts, furs or horn.

Beyond their sociocultural importance, however, subsistence foods are also essential in light of the lack of alternatives available to *Ulukhaktokmiut*. Subsistence foods, typically comprising 50% or more of dietary meat intake (Collings *et al.*, 2016), are supplemented by store-bought foods in the community, which, while subsidised by the Nutrition North Canada (NNC) program, are often costly, relatively nutrient-poor, and can pose a challenge in terms of affordability (NNC 2016; Galloway, 2017). According to the 2019 Community Price Index, prices in Ulukhaktok are, on average, 80% more expensive than in Yellowknife, and 26.3% more expensive than Inuvik, the administrative centre of the of the Beaufort Delta Region (NWT Bureau of Statistics, 2019b). The excess cost of store-bought items in the community stems from the number of food miles they incur; long shelf-life foods are shipped to the community once per year on the NWT Marine Transportation Services (MTS) barge, whilst perishables and fresh foods are flown in each week via Inuvik.

Given the importance of subsistence foods for food security and nutrient intake in the community, changes to the foodshed arising from climate change have become an increasing concern in recent years. Current trends for the Northwest Territories indicate an observed increase in annual mean temperature of 3ºC or more between 1948-2016, with mean annual winter warming of between 4-6ºC across the same period (Zhang *et al.*, 2019). Forecasts of future annual mean temperature change across Northern Canada as a whole suggest that further alteration of the environment is inevitable, with projected increases of between 2.1ºC to 7.8ºC by 2100 relative to 1986-2005 values depending on emissions scenarios (Zhang *et al.*, 2019; Cohen *et al.*, 2019). Although previous research in Northern communities has developed baseline understandings of how an altering climate is affecting the vulnerability of food systems (e.g. Brubaker *et al.*, 2011; Wesche & Chan, 2010; Gilbert *et al.*, 2021), new methodologies focusing on longitudinal methods or real-time community-based monitoring show promise for identifying more nuanced dynamics and interactions between climate and other interacting stressors (McDowell *et al.*, 2016; Ford *et al.*, 2012). The use of longitudinal methods has seen increased application in recent years (e.g. Archer *et al.*, 2017; Fawcett *et al.*, 2018), however, the application of real-time approaches, which provide an opportunity for understanding the day-to-day and season-to-season interplay of climatological and broader socially-constructed dynamics, remain less widespread.

2.3. *Methods*

2.3.1. *Data collection*

This paper draws upon work conducted as part of the *Tooniktoyok* project, jointly developed and led by Inuit in Ulukhaktok in collaboration with researchers. An explicit focus within the project was placed on non-Inuit researchers holding a facilitatory – as opposed to directive – role in the research process, and researchers' actions were guided by best-practices relating to community collaborative research (Pearce *et al.*, 2009; Carter *et al.*, 2019), and guidelines produced by Inuit organisations (ITK and NRI, 2007; ITK, 2018). Data collection spanned a two-year period between June 2018 – June 2020. A cohort of 10 Inuit hunters, from a range of socio-economic backgrounds within the community and aged 26-82 years, were asked to take part in bi-weekly participatory mapping sessions and semi-structured interviews, conducted as a group and convened by a local project co-ordinator. The cohort were selected through consultation between researchers and the Hamlet of Ulukhaktok based upon purposive criterion sampling (Palinkas *et al.*, 2015). Criteria for selection included hunter experience (Creswell & Clark, 2011), inferred from the regularity with which participants engaged in land-based activities and their knowledge about the lands surrounding Ulukhaktok, and communication skills. Participants were required to have the time and ability to regularly discuss, in-depth, their experiences of hunting and practicing subsistence. The broad age range of hunters allowed for the incorporation of multiple perspectives beyond those of just elders and facilitated knowledge transfer and co-learning between participants and researchers in order to create a co-produced research agenda.

Each bi-weekly interview and mapping session commenced in an intentionally conversational format, with hunters asked to recount the stories of their hunting trips from the previous two weeks to the wider group. The interview protocol was outlined sequentially according to 5 stages documented in Table 1.

In rare instances where hunters felt less comfortable discussing their routes or experiences in a group setting, one-on-one sessions between members of the cohort and the project-coordinator were offered. All interviews were audio recorded, with the co-ordinator also taking written notes to assist in data analysis. To prevent the privileging of climate as a factor in exposure-sensitivity, and consistent with other work in this area (e.g. Ford *et al.*, 2006a, 2006b; Pearce *et al.*, 2011), the phrase 'climate change' was omitted from all questioning, and the theme of environmental change was only included in the prompt "did you experience anything unusual on the land whilst you were out". In line with the collaborative, community-led approach adopted by *Tooniktoyok*, the results section includes verbatim quotes so as to retain the narrative and granularity of participants' stories (further supporting quotes are also available in S1 Table) (Appendix G).

TABLE 3.1. SEMI-STRUCTURED INTERVIEW PROTOCOL USING CONVERSATIONAL FORMAT FOR ELICITATION.

STAGE 1
Commence session with high-level discussion of group activities for the week – each participant notes whether they travelled on the land that week and takes turns tracing and annotating their routes on a set of laminated 1:250,000-scale maps using whiteboard markers (Figure 3.3).
STAGE 2
Following annotation, each individual tells the story of their hunts to the rest of the group: recounting in their own words their experience of travelling on the land that week. This offers a chance for participants to highlight observations or feelings to the group that would not otherwise be covered by the more semi-structured nature of follow-up questions, or may not explicitly be addressed by an interviewer with a Western valence. Interviewer makes notes on topics not ordinarily covered by the interview guide where a subsequent line of questioning would add context or valuable information.
STAGE 3
Interviews develop into a more structured format, conducted between the interviewer and individual participants in the presence of the whole group. Prompts are organised thematically according to the conceptual framework (Figure 3.1) and according to the notes made on discussions in the previous stage. Routes of enquiry centre around the productivity of specific hunting trips (mass of edible weight returned); socioeconomic and other non-biophysical barriers to hunting success or access to hunting grounds; coping mechanisms and potential adaptive measures that have facilitated subsistence activities; and broader scale observations of change that have occurred in the community post-sedentarisation.
STAGE 4
Interview returns to a more discursive format involving all participants. Cohort are encouraged to ask any questions they might have about each other's trips or on any of the answers provided in Stage 3. They are also encouraged to offer anecdotes of similar experiences they might have had, with the objective of further developing narratives and contextualising earlier discussions.
STAGE 5
Interview session concludes with photographing of annotated routes, which can then later be digitised and combined with GPS tracking data using QGIS3.12 and ArcGIS 10.08.

Conversational interview formats in the manner outlined above, which have a purposeful direction and topic but can also digress or 'meander', are sometimes referred to as 'research topic yarning' in other Indigenous-focused research methods literatures (Bessarab & N'handu, 2010; Walker *et al.*, 2014). Conversational methods are a legitimate and culturally appropriate means of interviewing Inuit participants, aligning with oral traditions surrounding knowledge transmission, and allow for Inuit values and perspectives to be conveyed into the research process, creating relationality and accountability between interviewee and researcher (Kovach, 2010; Fredericks *et al.*, 2011). Due to COVID-19, interviews and participatory mapping sessions were stopped in April 2020, with data collected during this period through the remaining monitoring approaches outlined below only.

In addition to participatory mapping sessions and semi-structured interviews, the hunter cohort were also asked to track their harvesting activities across the project through the use of a GPS tracking system between June 2018-June 2020 (Figure 3.3). The GPS system was internet-linked, for use with low bandwidth, with hunters asked to upload their recorded routes as .gpx files to a secure cloud system, which both researchers and the cohort had access to. Hunters were given full control over the data they uploaded and were given the option of either hiding their routes from other hunters within the system or not having their routes included in the creation of final maps. For participants who did not have access to the internet at home, the Helen Kalvak School Wi-Fi system was made available for the uploading of data. From tracked trails, meta-data relating to distance travelled, seasonality, time and date, and location of harvests were extracted.

FIGURE 3.3: TYPES OF ELICITATION AND DATA ANALYSIS.

a): real-time GPS tracking, import of data into QGIS 3.12 and ArcGIS 10.08, b) participant observation, c) participatory mapping and bi-weekly semi-structured/conversational interview. Basemap: *Dark Grey Canvas* (Attribution: Esri, HERE, Garmin, INCREMENT P, © OpenStreetMap contributors, and the GIS user community).

Potential ethical issues relating to the provision of GPS systems (including possible increases in risk-taking behaviour (Clark *et al.*, 2016; Dahmani & Bohbot, 2020)) were reduced through the use of a passive system, which could track activities but could not be used for navigation. With regard to critiques over the potentially 'undemocratic' nature of past GIS research (Harris *et al.*, 1995; Dunn *et al.*, 2007), results and associated maps were regularly shared with participants. In relation to perceived incompatibilities between GIS and Indigenous value systems (see Rundstrom, 1995; Briggs *et al.*, 2020), the mixed-methods nature of this research meant that trails tracked using GPS were also hand-drawn by the cohort in participatory mapping sessions; therefore, a process of 'interviewing the map' was undertaken (see Chambers, 1997, 1996). Combining routes with an oral recounting of hunting trips allowed for trail data to be contextualised and facilitated the conveyance of Indigenous values and worldviews about the traversed environment that would not ordinarily be captured through conventional, more technocentric participatory GIS studies (Briggs *et al.*, 2020; Gadamus & Raymond-Yakoubian, 2015).

In addition to the above, more implicit methods of research were also adopted in order to triangulate data collection and analysis. These focused on participant observation, and included 'deep hanging out', whereby members of the research team—who spent a total of approximately 12 months in the community between June 2018-January 2020—lived with families in Ulukhaktok and took part in hunting trips. Participant observation through immersion represents a critical means of dispelling preconceptions or *a priori* assumptions that may have arisen from receiving second-hand information before the conduct of research, and was important for developing routes of inquiry in semi-structured interviews and discussions that were germane to the research question at hand (Collings, 2009, Madden, 2017).

Primary research data was supplemented by secondary weather and sea ice data relating to indicators of environmental change. These were extracted from two weather stations that had been established at the community airport, one running from 1987-2009, the other from 2010-present, in addition to daily ice charts published by the Canadian Ice Service (CIS). Dates for sea ice break-up and freeze-up were established according to the average day of the year on which concentrations at eight points in Amundsen Gulf and Prince Albert Sound dipped below 5/10 (50% surface cover) in the summer months, and above 5/10 in the winter months (see Archer *et al.*, 2017; Gough *et al.*, 2004).

2.3.2. *Data analysis*

GPS data were imported into QGIS and ArcGIS software to identify distances travelled and hunters' annual and seasonal land use patterns. Place names, the location and mass of harvests, and other features of interest that were annotated during mapping sessions relating to land conditions or events occurring on hunting trips were also added. GIS maps were shared on a quarterly basis with the cohort, and prior to the project's conclusion were printed out to allow for direct annotation of changes and amendments to place name spellings. Upon finalisation, routes and hunting areas were compared with historical maps of land use activity in the region (see Freeman, 1976), and copies were provided to major community organisations (Hamlet of Ulukhaktok, Ulukhaktok Community Corporation, Helen Kalvak Elementary School).

Interview data were transcribed by researchers involved in producing interview formats and interviewing participants. Once complete, transcripts along with research diary entries were uploaded to NVivo 12 and analysed through latent content analysis. Content analysis took the form of Provisional and Structural Coding, whereby a provisional list of themes identified as drivers underlying adaptative capacity, adaptation, and exposure-sensitivity, derived from this study's conceptual framework (Figure 3.1) and previous literatures on Arctic climate vulnerability research, were coded and indexed according to the driver in question, its influence on components of vulnerability, and its relative dynamism (e.g. "adaptation – slow: Indigenous knowledge relating to food preparation" or "exposure sensitivity – fast: environmental change relating to land access"). Particular emphasis was placed on situating narratives discussed in interviews within the broader context of data derived from weather stations, participant observation, and previous research on environmental change in the community (e.g. Pearce *et al.*, 2015; Smith & Wright, 1989; Fawcett *et al.*, 2018). Weather and climate data were graphed and, where granularity was sufficient, were subject to statistical analysis through least squares regression and the Mann-Kendall test, with $p = <0.05$ as the threshold of significance. Interview data were anonymised; in instances where names are used in quotes, this has been altered to a pseudonym. Due to the impact of COVID-19 on international travel in 2020, results were provisionally communicated to participants digitally and through the local project coordinator.

2.4. *Ethics*

Research was undertaken with consent of the Hamlet of Ulukhaktok and was overseen by a four-person volunteer Inuit Oversight Committee within the community. Study protocols were approved by Institutional review boards at the University of Guelph (REB 17-12-012) and the University of Leeds (AREA 18-117). The research was licensed by the Aurora Research Institute (No 16533), which oversees research in the Northwest Territories. Verbal and written consent for interviews and data storage was obtained from each participant.

3. Results

3.1. *Altering subsistence land use patterns in Ulukhaktok*

Between 1st June 2018 and 1st June 2020, 409 routes were recorded by the cohort, yielding an average of 0.56 routes per day of data collection. 376 of these were recorded directly through GPS monitoring – from which exact distance measurements could be extracted – and a further 33 routes were annotated onto maps during semi-structured interviews. Due to the large scale of the maps used for annotation (1:250,000), and due to some hunters opting to provide only summary sketches of their travels, exact distance measurements were not extracted from drawn routes. In total, 23,995.58km of routes were recorded in the GPS system (Figure 3.4), with snowmachines covering the greatest distance (12, 819.17km), followed by boats (6,248.89km), and ATVs (4,927.52km). Snowmachines were also used with the greatest frequency (in 215 (53%) of the 409 instances for which mode of transport was recorded by hunters). ATVs (n = 111 / 27%) were used more often than boats (n = 83 / 20%), with the latter involving, on average, travel over the greatest distances (Table 2).

The cohort's recorded and annotated trails covered a calculated land use area of approximately 27,940.857 km² (including land, sea and ice) between 2018-2020, and the maximum extent of distance travelled away from the community (annotated) was 250.22km as the crow flies, with the maximum recorded total trail distance recorded by GPS being 525.26km. These statistics provide a strong proxy measure of utilised contemporary foodshed extent. When compared with historical maps produced by Freeman (1976) and Collignon (1993) that examine hunting range on the lands surrounding Ulukhaktok for the harvesting periods '1930's-1965' (Period I (see Collignon, 1993) and '1965-late 1970s' (Period II (see Collignon, 1993), data on areal extent is indicative of a decrease of approximately 83,301km² (74.8%) and >26,733km² (48.9%) respectively. Also of note was an observed reduction in the relative diversity of routes used by the cohort compared with these periods (trails from historical periods inferred by location of traplines) (Freeman, 1976). Between 2018-2020, the majority of travel for harvesting activity was confined to three main trails. The Prince Albert Sound trail (Aug-Oct and Dec-Feb caribou and muskox hunting, Nov-March and Jun-Aug sealing) to the southeast; to the northeast, around and on the trail to Fish Lake (Tatiik) (Sept-Jul muskox hunting, Jul-Aug and Oct-Dec char runs, year-round lake fishing); and to the northwest on the coastal trail toward Kitekut (May-Jul duck and fowl hunting, Nov-March and Jun-Aug sealing) (Figure 3.4). (Dates represent approximate periods of hunting activity, for full seasonal calendar see Parker, 2016.)

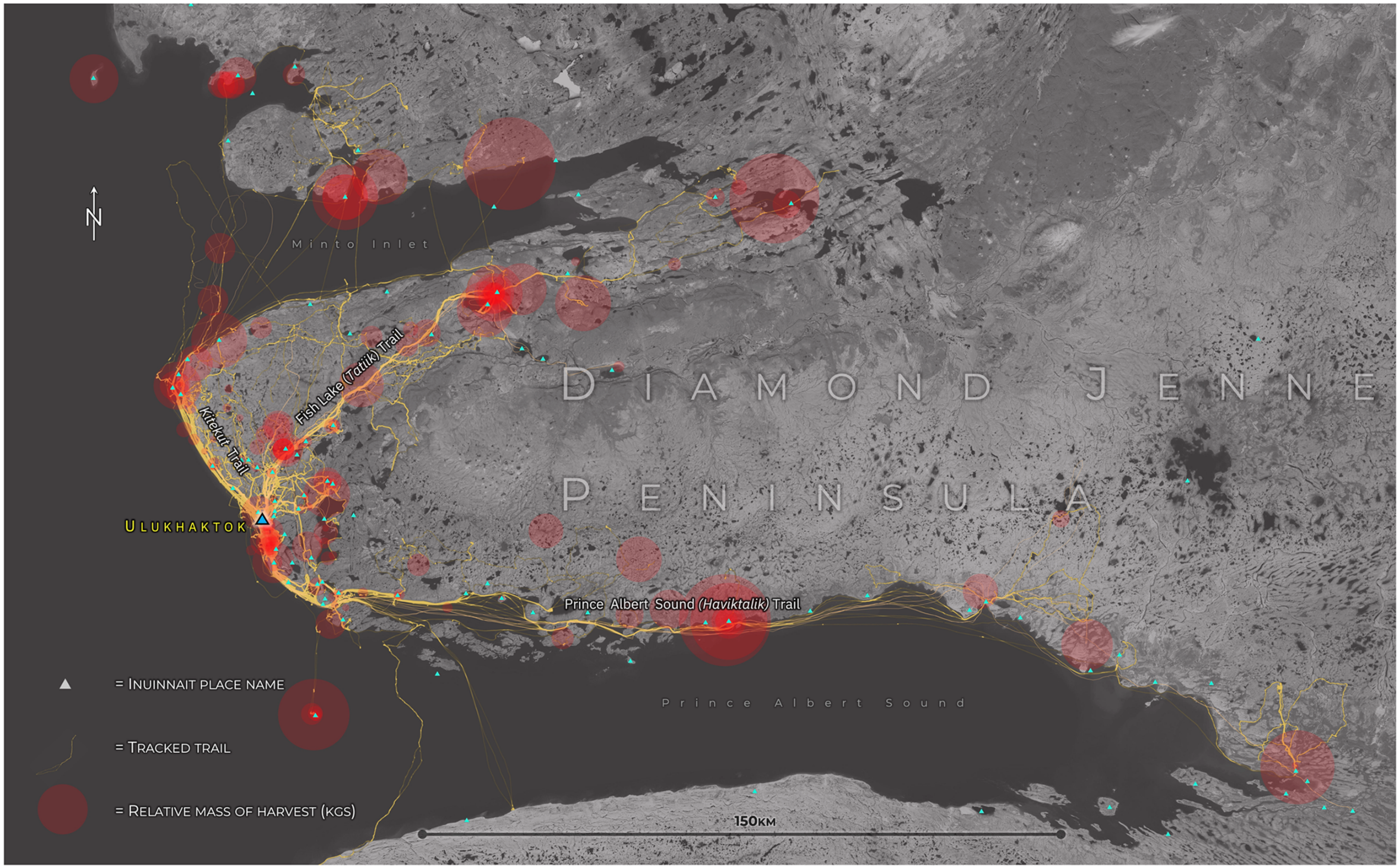

FIGURE 3.4: ANNOTATED AND TRACKED GPS TRAILS AROUND ULUKHAKTOK JUNE 2018 – JUNE 2020.

Includes locations of Inuinnait places visited and harvests and their relative mass of edible weight (kgs), recorded for the year 2019. Basemap: Esri World Imagery (Attribution: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

TABLE 3.2: DISTANCES TRAVELLED BY YEAR, MODE OF TRANSPORT AS PART OF THE *TOONIKTOYOK* PROJECT, JUNE 2018-JUNE 2020.

	GPS TRAILS (ADDITIONAL ANNOTATED)	**DISTANCE TRAVELLED (KILOMETRES)[c] (% OF TOTAL DISTANCE)**				**DATE OF BREAK-UP[d]**	**DATE OF FREEZE-UP[d]**
		ATV	**BOAT**	**SNOW-MACHINE**	**TOTAL**		
YEAR							
2018	178 (0)	3,528.11 (40%)	3,741.15 (42%)	1,617.17 (18%)	8,886.43	June 30th	Oct. 14th
2019[a]	162 (33)	1,399.41 (11%)	2,507.74 (19%)	9,054.98 (70%)	12,962.13	June 19th	Nov. 7th
2020	36 (0)	0 (0%)	0 (0%)	2,147.02 (100%)	2,147.02	-	-
2018 – 2020	**376 (33)**	**4,927.52 (21%)**	**6,248.89 (26%)**	**12,819.17 (53%)**	**23,995.58**	**-**	**-**
POST-BREAK-UP (SUMMER)							
June 30th 2018 – Oct. 13th 2018	131 (0)	3,150.19 (45%)	3,741.15 (54%)	46.96 (1%)	6,938.3	June 30th	Oct 14th
June 19th 2019 – Nov. 6th 2019	43 (14)	1,251.94 (29%)	2,384.54 (56%)	660.56 (15%)	4,297.04	June 19th	Nov. 7th
Summers 2018, 2019	**174 (14)**	**4,402.13 (39%)**	**6,125.69 (55%)**	**707.52 (6%)**	**11,235.34**	**-**	**-**
PRE-BREAK-UP (WINTER)							
31st Oct. 2017 – June 29th 2018[b]	4 (0)	131.65 (94%)	0	8.62 (6%	140.27	June 30th 2018	31st Oct 2017
Oct. 14th 2018 – June 18th 2019	136 (17)	393.74 (5%)	123.2 (1%)	7,820.11 (94%)	8,337.05	June 19th 2019	Oct. 14th 2019
Nov. 7th 2019 –[b]	62(2)			4,282.92 (100%)	4,282.92	-	Nov. 7th 2019
Winters 2018/2019, 2019/2020	**202 (19)**	**525.39**	**123.2**	**12,111.65**	**12,760.24**	**-**	**-**

[a] Denotes a full calendar year, as opposed to 2018, 2019, which denote June 1st – Dec. 31st.
[b] Data collection period does not span entire 'winter' period.
[c] Denotes GPS-tracked routes
[d] For process of deriving freeze-up and break-up dates, see Methodology.

3.2. *Current exposure-sensitivities and adaptive capacities affecting the foodshed*

3.2.1. *Climatic variability affecting land access*

In addition to a constriction of the foodshed over a longer timescale, a reduction in the areal extent of harvesting at an inter-annual scale was also evident within the study period itself, during the winter of 2018/19, when delayed and limited snowfall to the east of the community left rocky ground exposed or insufficiently covered. The cohort noted that this affected their ability to harvest caribou through creating land-use bottlenecks, with a number of traditional trail routes compromised and detours required, and also had implications for travel safety and the accumulative costs associated with the replacement of skirods, track wheels, and hyfax runners. Hunter observations of reduced snowfall broadly reconciled with descriptive historical weather data. In any given winter since 2004/05, the recorded ground snow thickness between 1st Oct – 1st May in 2018/19 was lower than in 12 of previous the 14 years, was the lowest on record since the 2010/11 season (11.15cm (n = 213) vs. 9.18cm (n = 181)), and was 39.8% lower than the average daily mean across all days between 1st Oct – 1st May between 2004-2018 (S2 Figure) (Appendix H).

> "It's good all the way up to here [down Prince Albert Sound], but then once you get on the land [there] was no snow. The [sea] ice was okay, but it doesn't take long to finish skirods over here." (20th June, 2019; #441-07)

Observations pertaining to changing snow conditions in winter of 2018/19 were accompanied by perceptions that wind and ice and land conditions were becoming less predictable in general, reducing the number of days available for travel and with implications for the applicability of previously established ecological knowledge. Participants noted that the shoulder portions of seasons were particularly severe, with freeze-up commonly cited as taking longer or, in the case of winter 2018/19, incompletely as a result of changing wind conditions, requiring some to take greater risks to harvest. Alternatively, there were perceptions that breakup could now occur rapidly due to increased wave strengths, but that in some cases winds would keep broken-up ice in bays and inlets, meaning that neither snowmachines nor boats could be used for travel. Changing melt season dynamics were also observed on the land, affecting permafrost dynamics and the amount of standing water and overflow, with implications for ATV and snowmachine trail access.

> "The biggest thing for the ice this year is how long it's taking to freeze up…. The ocean is taking so long to freeze, and the ice isn't staying when it does freeze. It opens up [again]. It's been opening up all winter...ice is not getting thick enough anymore I guess… It was like this last year too, but it didn't last as long; this time it's lasting longer." (20th March, 2019; #117-06).

Hunter observations were supported to a degree by available sea ice data, which indicates a trend toward later year-on-year ice freeze up (Figure 3.5). However, Mann-Kendall analysis of de-seasonalised max and mean annual temperatures between 1987-2010 and 2000-2010 from two weather stations in the area, and an analysis of maximum wind speed between 2003-2020 indicates no trends with statistical significance ($p = <0.05$). It is possible that average wind speed and direction has changed significantly in the community, however, limited data availability from either weather station precludes these from analysis.

In terms of adaptations, much of the cohort cited the use of alternate travel routes or travelling at a different time as primary means of overcoming land use access problems. Others suggested that they had purchased, or in the future intended to purchase, larger boats with four-stroke engines. Larger hulls permit travel in winder conditions, while four-stroke engines are typically more fuel efficient, thereby offsetting the increased costs associated with traveling through larger waves and swells. Notably, almost all of the adaptations cited for responding to changing climatic conditions required additional economic input (i.e. the purchase of new machinery, or the use of more supplies).

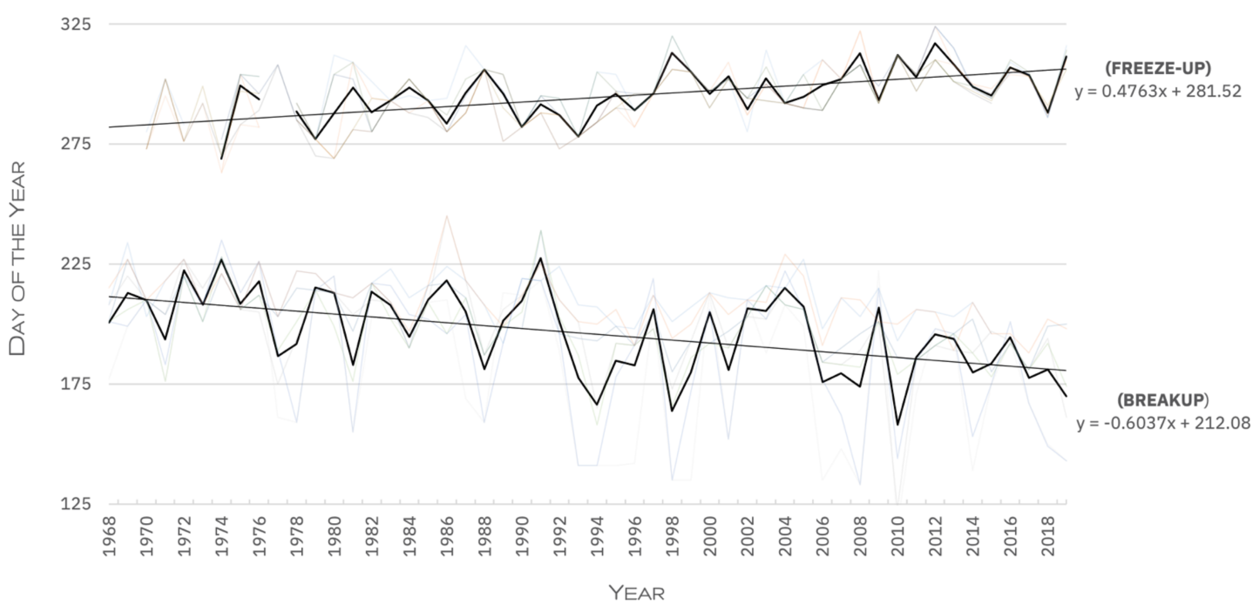

FIGURE 3.5: DAY OF THE YEAR ON WHICH BREAK-UP/FREEZEUP OCCURRED ON THE WATERS AROUND ULUKHAKTOK, 1968-2019 (ADAPTED FROM FAWCETT *ET AL.*, 2018).

3.2.2. *Mechanical issues, vehicle design, supplies used*

Mechanical reliability was recurrently noted as a factor affecting the day-to-day accessibility of the foodshed. In the 2019 calendar year, of 130 trips (out of a total of 132) where the question of reliability was raised, participants stated that they had experienced mechanical issues relating to either their snowmachines, ATVs, boats, sleds or other hunting equipment 18.4% of the time. This was notably higher than the incidence of issues experienced pertaining to the environment, which were recorded in 13.6% of cases across the same period. Mechanical issues rarely resulted in a trip being cancelled or ended, as often hunters were able fix machines or instead travel on the sleds or vehicles of those accompanying them. The majority of issues pertained to the breaking of snowmachine ski rods or hyfax runners due to insufficient snowfall in winter of 2018/19 (as above). However, seven instances of blown pistons in machines were noted, and in three cases hunters were forced to attempt to return to the community by foot, having left their machines on the land. In summer of 2020, for instance, a member the cohort was forced to walk approximately 25 kilometres back to the community, in rain and fading light, following the breakdown of their companion's ATV and due to their own vehicle becoming stuck in boggy ground.

Compounding the increased risk of damage to machines in poorer conditions, hunters remarked at the prohibitive cost of new parts and supplies (e.g. gasoline, heating fuel) as key factors affecting land access. From an intra-community perspective, differential sensitivity relating to the availability of gasoline, parts and back-up machinery was especially notable between different sharing networks. Members of the cohort with access to the most capital-rich networks often demonstrated the greatest adaptability, either through their ownership of, or access to, multiple modes of transport, or through an ability to borrow parts or gasoline from other members of their family in order to access the land when they themselves had run out. Conversely, a lack of parts, insufficient funds to purchase gasoline or other supplies, or the fact that the equipment needed to be shared across multiple members of a network simultaneously, limited access to the foodshed among members of the cohort with less financially robust networks – sometimes impacting harvesting for days at a time. Some participants felt an inability to access land in this manner held implications intergenerational knowledge transfer, with subsequent cascading effects for the availability of subsistence species (i.e. knowledge of how and where to hunt).

> "There's a lot of things we've got to teach our kids, and not all of us are going to teach them because some of us hasn't got the equipment to take our families out." (7th July 2018; #008-01).

A notable adaptation to offset the excess cost of gasoline among high-capital members of the cohort has been investment in more-fuel efficient four-stroke snowmachines, ATVs, and boats. Although there was also a perception that these new vehicles, particularly snowmachines, were less resilient to the changing environmental conditions due to the design of new machines catering more to sports and leisure markets. Spikes in exposure-sensitivity, derived from difficulties sourcing or paying for parts or the obstacles related to the operation or fixing machines on the land, often necessitated 'bricolage' adaptations – making do with what resources are at hand – in order to complete trips or access the land (see Abu & Reed, 2018). Over time this has resulted in adaptive learning and increased preparedness, whereby hunters frequently take a 'toolkit' of various items, such as rope, tyre plugs, duct tape, spark plugs, etc. that can often be used to conduct interim repairs. Examples of bricolage adaptation included one participant wrapping a towel around the handlebars of his machine when electrical wires short-circuited and heated the metal in them, the use of ropes to support broken vehicle suspension chassis, piling sea ice (*hiku*) on top of engine blocks in order to cool them when antifreeze did not work, and the creation of new machine parts (such as skirods) from scrap metal. Maladaptations were evident in some cases, when members of the cohort used bricolage adaptations beyond their optimal lifespan, resulting in more severe damage once poor conditions were once again encountered. In addition to bricolage toolkits, participants often discussed that they had taken additional supplies with them onto the land, or had stored supplies (e.g. gasoline, heating fuel) at caches. Increased preparedness in some cases also allowed for opportunism when harvesting, often allowing hunters to catch more than one species when travelling.

> "I tried to come back [to town] a couple of times when we were out. First time, past *Nuvuk*, the wind kept picking up…really started getting rough so we had to turn back. The repairs we did this summer [to the boat], they got wet… they were short repairs [in the hull], but [they're] really long cracks now. Really lots of water going in [to the boat]." (27th September 2018; #033-10).

3.2.3. *Inter-annual variations in species availability and quality, multiple exposures*

Hunters perceived that they were seeing an increase in the number of parasites or disease within certain species, particularly within muskoxen and char populations. In many cases this was attributed to environmental changes, and in some cases explicitly to climate change. An observed increase in the presence of parasites is consistent with recent brucellosis and lungworm research conducted on muskox populations across Victoria Island (Tomaselli *et al.*, 2019). Increased incidences of disease hold implications for species availability, as some parasites can leave animals more susceptible to predation, but also from a food quality perspective; brucella-infected meat can be particularly dangerous if consumed, for instance (Kutz *et al.*, 2013; Tomaselli *et al.*, 2014).

Observed changes in muskox health were also accompanied by suggestions that populations may be in decline, or less available through the migration of populations toward the more distal areas of the foodshed. Despite a relative constriction in foodshed extent since the 1970s and 1990s (see 'Altering subsistence land use patterns in Ulukhaktok'), a number of hunters suggested that they were travelling further in attempts to harvest muskox. Some hunters attributed decline in muskoxen availability to a return of limited caribou populations to areas more proximal to the community and suggested that the two populations were on an inverse cycle. These observations reconcile with research conducted by Fawcett *et al.* (2018), who in 2016 documented perspectives that muskox populations were found further from the community, and that, as a result, some hunters expected to subsequently see a rebound in the Peary caribou population (see also Wesche & Chan, 2010; Pearce *et al.*, 2010).

> "We have to go quite a ways… for what we're trying to get. The other day, like I said, me and my daughter went out to go and hunt muskox, and we went over 100 miles return [journey], and we haven't seen any muskox… this place is already hunted out." (31st July 2019; #505-06).

> "It's getting harder... but the caribou are coming back, so that's making up for the muskox disappearing…" (7th March, 2019; #163-11).

In 2016 the community was assessing the feasibility of expanding the number of Arctic char that could be commercially caught, with a proposed increase from 500 to 700 fish allocated for sale per annum (Fawcett *et al.*, 2018). Char numbers remained relatively high through 2017, whereafter in 2018 the community's Char Working Group made a decision to increase the commercial quota to 700 for the following year. However, a number of the cohort throughout the study period (2018-2020) perceived a decline or highlighted unpredictability with the fluctuation in char numbers - the root cause of which is not as yet fully known. As a result, the Char Working Group returned the tagged quota to 500 for the 2020 season, and subsequently placed a moratorium on commercial char fishing between 2020-2025.

Concerns over depressed char numbers were compounded in early-mid July of 2019, when the char run – during which char migrate from the ocean into lakes to spawn – coincided with an anomalous bloom of pelagic tunicates extending approximately 225km along the western coastline of Diamond Jenness Peninsula (Pettitt-Wade *et al.*, 2020). A type of small jellyfish, whose presence in the 2019 was attributed to altered ocean currents as a result of early sea-ice breakup, the effect of pelagic tunicates on the physiology of marine animals is poorly understood (Pettitt-Wade *et al.*, 2020). A number of the cohort in Ulukhaktok voiced concerns that fish and marine mammals may be avoiding the tunicates (and therefore the coastal fishing grounds proximal to the community), while others suggested that the accumulation of algae on nets was making them more visible to fish, and that this was affecting the viability of fishing. Not only did nets need to be cleaned more regularly – achieved by placing them on the beach and rubbing them with sand – they were also more difficult to physically pull from the ocean due to the added weight of the tunicates; a factor some participants felt was further exacerbated by increased strength of waves in recent years due to climate change (see Thomson *et al.*, 2016). The bloom in Amundsen Gulf is reflective of a similar trend of rapid biological change recorded in the Pacific Arctic between 2017-2019, instigated as a result of altered water column temperatures.

> "There's just so much [(tunicates)], all together. I think when animals dive in it goes on their face, that's why there's not much seals in the water. I brought the pilots to the airport, and they told me this [there are] thousands of seals on the ice, down Minto [Inlet]. My wife and I went down here yesterday [to the southeast]; lots of seals on the ice. They don't want to go in the water. Along the shore, in the shallow spots it's okay. You go a bit further out, there's millions of that stuff [(tunicate blooms)]." (4th July 2019; #448-12).

3.2.4. *Cultural change, broader impacts of globalisation*

Engagement in the wage-based economy – which has now almost become a prerequisite for purchasing adequate hunting equipment – and its associated time commitments were considered to compound less predictable weather conditions and the greater travel distances required to harvest some keystone species. In some cases, the effect of the wage-based economy was direct, whereby hunters could not travel on the land because they were working. For hunters that were part of either single-parent households, or households with children where the spouse was employed, childcare commitments were also a limiting factor. More experienced hunters within the cohort remarked that less time available for land-based activities was leading to some younger harvesters travelling in conditions that were considered dangerous, at unusual times, or without sufficient preparation. Reinforcing the notion of limited time available for hunting, single-day hunting trips accounted for 64.4% of trips (n = 85 / 132) for which interviews were conducted among the cohort in the 2019 calendar year. This may also explain to an extent the recorded constriction of the foodshed in terms of distances travelled from the community relative to studies from the 1990's and 1970s, and has significant implications in light of recent unpublished research establishing association between the number of days hunters spend on the land and the productivity of their hunting groups in the community (Naylor *et al.*, 2021).

Cultural change, in terms of the ways through which youth engaged with the subsistence economy, was voiced as a concern by a minority of the cohort when they were asked about the future of the food system. Opinions occasionally reflected past research conducted by Ford et al. (2006), among others (Pearce *et al.*, 2011; Prno *et al.*, 2011), across Inuit Nunangat whereby youth were perceived to be losing interest in harvesting, or now have diets that are primarily predicated on store-bought foods, with implications for knowledge transfer relating to food preparation. However, in many cases the cohort often reflected positively on youth engagement within the *Ulukhaktokmiut* foodshed. This may point to the success of more recent attempts to engage youth in subsistence practices across the Inuvialuit Settlement Region and the wider Arctic, which mainly come in the form of education programmes and increased on-the-land learning (Kenny *et al.*, 2018). In testament to the continued need for such initiatives in the region, participants suggested that rather than cultural change or a lack of desire to learn, the greatest barrier to youth engagement was the availability of equipment and supplies, or the ability of parents or mentors to take them out on the land (see also Andrachuk & Smit, 2012).

3.2.5. *Institutional drivers*

Hunters remarked on the fact that institutional support for hunting could be a critical factor in facilitating or constraining land access. In particular, federally funded, community-based initiatives, such as the Community Harvesters' Assistance Program were perceived positively; in part due to the generosity of grants, and a belief that resources were allocated with the greatest impartiality under such schemes. Conversely, concerns were more frequently raised as to the efficacy of federally and regionally administered programmes, particularly NNC and the Inuvialuit Harvesters' Assistance Program. Regarding NNC, hunters echoed concerns flagged in other Northern communities in suggesting that the focus of the Canadian Government on funding the provision and affordability of store-bought foods was diverting funds that could otherwise be spent funding harvesters directly, or through developing land-based learning initiatives (NNC, 2016; ITK, 2016; Ford *et al.*, 2019a).

> "IHAP [(Inuvialuit Harvesters' Assistance Program)], it's supposed to be for harvesters… There's people who get equipment but then don't hunt, they just use it around town…. the way I see it is that it should be for people that [actually] go for harvesting, not just around town… it should be more looked into for future generations. It needs to be fixed and dealt with." (30th June 2019; #504-07).

> "CHAP [(Community Harvesters' Assistance Program)] funding is the one that helps out people. Each household gets at least a barrel (45 gallons) of gas. It usually goes about four times [a year] I think - Spring, Summer, Winter and Fall." (31st July 2019; #503-06).

In addition to federally and regionally administered programs, the community also funded a number of on-the-land learning initiatives for youth through the Helen Kalvak Elementary School and the Ulukhaktok Community Corporation (UCC). These projects were seen as hugely successful by the hunters, and often provided opportunities for temporary employment, access to funds, and the creation of social networks that facilitated hunting and land access. In one instance, a hunter who worked closely with the school was also able to borrow one of their snowmachines in order to go trapping whilst his was being repaired. In another, the UCC purchased supplies (gasoline, food) for hunters to take youth on a four-day muskox hunt, with youth allowed to keep the meat and hides they harvested.

4. Discussion

This article documents and examines the spatiotemporal vulnerability of a complex adaptive system to climate change in the context of multiple interacting stressors. While complimenting a body of pre-existing scholarship relating to climate change impacts, adaptation and vulnerability in Arctic Canada, it is both conceptually and methodologically distinct. The spatial component of our research provides empirical evidence for the areal constriction of the Ulukhaktokmiut foodshed relative to its past extent documented in the mid-to-late 20th century. GPS tracking shows that hunters are travelling less far as compared with early periods of settlement (1930s-1965/1965-late 1970s) and indicates an overall decrease in the diversity of travel routes taken. Although changes in land use have been discussed in previous qualitative studies, this has not been previously quantified. Comparisons of harvest data from 1989 and 2019, population growth of 386% in the community between 1963 – 2019 (NWT Bureau of Statistics, 2019a; Usher, 1965), and the high rate of recorded hunting participation in Ulukhaktok relative to other Beaufort Delta communities (75.9% vs. an average of 45.4%), suggest that a reduction in harvesting range is not attributable to an overall reduction in the frequency or volume of harvesting by the community. Rather, these trends are indicative of contemporary hunting activities occurring with a similar if not greater intensity, but across a smaller, concentrated area. This is supported by previous research, which states that sedentarisation in the community had the effect of reducing the number of seasonal camps and resupply points in distal locations away from Ulukhaktok (Collignon, 1993; Damas, 2002), and brought about a number of sociocultural changes (e.g. wage-based employment) that fundamentally altered the nature of harvesting. Indeed, following sedentarisation in the 1960s, whole-system re-organisation became necessary in the community in order to allow subsistence practices to reprise their essential role in sustaining Inuit livelihoods and food sovereignty within the foodshed (Condon, 1996).

Multiple points of emergent change stemming from sedentarisation, and the associated adaptive responses and new exposure-sensitivities that developed across multiple dimensions of the foodshed as a result, are still extant and in evidence in many of our findings. Socioeconomic stressors relating to wage-based employment are but one pertinent example – representing a forced adaptation that funds the cost of contemporary hunting technologies and supplies, while also holding the maladaptive effect of limiting time on the land. The real-time monitoring nature of our work allowed us to draw specific conclusions relating to the frequency with which economic factors in particular are affecting the foodshed. Beyond the issue of simply purchasing gasoline to travel, in 2019 hunters recorded issues relating to mechanical problems 18.4% of the time when travelling on the land (26% more often than environmental issues were experienced), many of which necessitated the purchasing of replacement parts. This illustrates the financial capital individuals often require in order to adapt and the close links that now exist between harvesting and exogenous capital markets, and the subsequent potential for differential vulnerability between hunters, particularly between those engaged in wage-based labour and those hunting full-time. The prominence of economic stressors adds to a body of previous research conducted in the community that has pointed to pre-existing tensions between the subsistence economy, wage-based labour and Westernisation (Collings *et al.*, 2016; Fawcett *et al.*, 2018; Pearce *et al.*, 2010).

In the context of a changing climate, reduced time on the land stemming from engagement in the wage-based economy, the costs of hunting, and Westernisation - compounded by a reduction in both areal extent and diversity of trails used - makes an understanding of the ways through which the biophysical environment may be changing and affecting harvesting all the more important. Particularly as a reduction in the number of trails or overall hunting range used by hunters also holds implications for the diversity of areas that hunters are able to use and wild species that can be accessed. Such diversity and redundancy potential has been identified as a key factor historically underpinning adaptive capacity across Arctic communities, and alterations to land use intensity in tandem with climatic changes holds implications for placing subsistence species under strain from multiple stressors (Ford *et al.*, 2015). To this end, our study documented two types of climatic drivers that could act as landscape and ecosystem stressors: high-magnitude low-frequency events or more incremental, accretionary year-to-year changes. Previous research in Northern Canada has explored the notion of multiple stressors on food systems in the context of anomalous climatic extremes (e.g. Gilbert *et al.*, 2021; Statham *et al.*, 2015) and broader incremental changes (e.g. Wesche & Chan, 2010; Andrachuk & Smit, 2012; Nancarrow & Chan, 2010). However, the temporally constrained nature of data collection in past scholarship means that these have infrequently explored within the same study. Among the cohort here there was widespread recognition that changing climatic conditions, both incremental and anomalous, were developing new and unexpected challenges. This was seen to be particularly true for the biophysical extremes, which often produced considerable spikes in exposure-sensitivity, and in some cases exceeded the coping or adaptive capacities operationalised by individuals and social networks. One example was the anomalously low snowfall recorded to the east of the community during the winter season of 2018/19. This resulted in the creation of significant land use bottlenecks and drastically increased wear and tear on expensive machinery, with implications not only for the period over which an adequate land area could be accessed for hunting keystone species, but also the financial viability of harvesting for some families who were simultaneously experiencing compound economic stresses relating to cash liquidity. The longer-term implications of such 'spikes' is poorly understood and represents a priority for future research.

Incremental biophysical changes were most frequently discussed in conjunction with other socially constructed stressors. Indeed, notwithstanding the potential impact of incremental climatic changes as standalone stressors on the foodshed, rather than being cited as the most prominent or severe drivers of exposure-sensitivity, much discussion of gradual environmental change by the cohort was contextualised by its role in exacerbating pre-existing social drivers of vulnerability and creating cascading effects. Two prominent examples included: i) travelling in sub-optimal conditions, and ii) the alteration of animal distributions or populations. Regarding the former, travel in poorer conditions, be these adverse wind or weather or deteriorating trails, was most commonly discussed in conjunction with their effect on fuel efficiency (and subsequently the high fuel costs within the community), or the issue of available time when considering travel on an alternative day. The latter often left hunters with the choice of "risking it" if conditions were poor at weekends, or instead forced travel in evenings after the working day had concluded. The alteration of animal distributions or populations, on the other hand, was often contextualised by political factors relating to wildlife management policies and concerns over the provision of support to hunters by institutions if hunters have to travel further to access certain species. The latter was particularly in relation to the costs associated with equipment and consumables, in addition to the eligibility criteria of individuals for harvester support. These findings, in addition to a lack of statistical association to support some observations, give credence to arguments that stimuli deriving from the effects of climate change are not always the most salient issues affecting Arctic communities on a day-to-day basis (Huntington *et al.*, 2019; Ford *et al.*, 2006a, 2006b, 2019b; Ready & Collings, 2020). Indeed, discussions relating to exposure-sensitivities often, rather than mentioning climate or environmental change as a primary driver, centred around the economy and wider socio-political stressors relating to vulnerability.

In the absence of sufficient individual financial capital to repair machines or purchase fuels and other supplies to access the land, many hunters cited a reliance on either their social networks or institutional support; thereby demonstrating the crucial importance of strong social relationships to the continuing stability and redundancy potential of the foodshed. Many harvesters in Ulukhaktok, in addition to sharing country foods, also shared their equipment between familial groups. Therefore, particularly for younger hunters, the ability of older members of their networks to invest in equipment, or to have spare machines that might otherwise allow for redundancy across a sharing network, has become crucial. In addition to the differential strength on individual hunter's financial capital affecting their exposure-sensitivity, the relative wealth and strength of a harvester's social network also therefore creates differences in adaptive capacity. For instance, some hunters remarked at the relative ease they had in sourcing new parts from others, either purchasing or in some cases receiving them for free with expectations of reciprocity at some point in the future. Others, citing cultural change, and the increased likelihood that others' machines might also break, suggested that there was a lesser ethos of sharing or even selling on parts as compared with the near past, with hunters instead choosing to hold on to parts should they themselves encounter difficulties.

The points outlined above illustrate the multiscale and complex nature of potential exposure-sensitivities and adaptive capacities within the *Ulukhaktokmiut* foodshed. Critically, in order to sustain existing and develop new adaptive strategies there is a need to recognise the evident dynamism and inherent unpredictability that exists both within and between biophysical and social drivers of vulnerability. In particular, our research highlights that while a number of exogenous stressors can affect the viability of the foodshed, multiple intra-community factors – often rooted in the effects of sedentarisation – can also create significant differences in vulnerability and adaptability to climate change between community members in response to the same stimuli as a result of cascading effects. The majority of these exposure-sensitivities derive from socioeconomic factors within their familial group or social network relating to the affordability of or access to equipment and supplies. To this end, biophysical stressors, while still holding a degree of relative influence over the vulnerability of the foodshed, at present are often not the most significant determinants of foodshed vulnerability on a day-to-day basis; especially at the individual/household level. However, with the likelihood that presently infrequent anomalous extremes may become more frequent in the Arctic in coming years (Meredith *et al.*, 2019) there is the potential that new barriers to adaptation may develop in the community relating to biophysical stressors. This potential is symptomatic of a broader changing Arctic, which in an increasingly globalised world is seeing the emergence of new stressors that have not held a similar level of precedence for a number decades (e.g. infectious diseases), or are continuing as trends with ever-increasing influence (e.g. the costs of gasoline and other supplies). This highlights the need for adaptive strategies to address complex community and individual/family-level drivers of exposure-sensitivity, particularly within socially-constructed spheres, but to also understand the greater exogenous interaction of these stimuli at regional or even global scales.

5. Conclusion

This paper adopted a two-year real-time monitoring and participatory mapping methodology to examine the role of climate change as a determinant of dynamic vulnerability within a complex adaptive system: the foodshed of Ulukhaktok, NT. Our findings suggest that while environmental changes brought on by an altering climate are having a substantive impact on the stability of the *Ulukhaktokmiut* foodshed, these are often not the most salient stimuli affecting the vulnerability of the foodshed on a day-to-day basis. Instead, social drivers of vulnerability, rooted in the historical process of colonial sedentarisation (e.g. cash liquidity and access to gasoline, the time availability for hunting, and the mechanical reliability of machinery) are more immediate concerns when examining foodshed stability over the course of an entire year. In part, this may be due to the strong adaptability that *Ulukhaktokmiut* possess in the face of an incrementally changing environmental conditions, and the dual role that socioeconomic, cultural and political factors play in governing both sensitivity and adaptive capacity to climate change. However, it is of note that these stimuli can, and frequently do, manifest as barriers to foodshed stability almost entirely independent of climate change. Indeed, in many instances the impacts of climate change often represent an additional veneer of susceptibility that is overlain on top of a nexus of pre-existing temporally intransient stimuli in the short term. Further research in the context of climate change is necessary to develop more insights into the longer-term implications of anomalous extreme events, and how these might be shaped by further atmospheric interference. But beyond climate change, it is also evident that further exploration of the root causes of social components of vulnerability is necessary to develop more concrete understandings and to better inform adaptation that could bring about transformative change.

6. Acknowledgements

The authors would like to acknowledge the work of the Tooniktoyok Hunters: Adam Kudlak, David Kuptana, Isaac Inuktalik, Roy Inuktalik, Colin Okheena, Tony Alanak, Allen Joss, Ross (Napayok) Klengenberg, Kelly Nigiyok and Roland Notaina. In addition, Adam Kuptana and Koral Kudlak (project coordinators), Laverna Klengenberg (project lead), and the contribution of the Hamlet of Ulukhaktok and the wider community as a whole, for their support for, and administration of, the Tooniktoyok project. We would like to thank Scott Wiseman for his proofreading of the manuscript pre-submission. We are also grateful to representatives from Crown Indigenous Relations and Northern Affairs Canada's (CIRNAC) Climate Change Preparedness in the North program, particularly Yves Theriault and Marijo Cyr, without whose support the project would not have been possible.

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CHAPTER IV

(PAPER III)

UNDERSTANDING DETERMINANTS OF HUNTING TRIP PRODUCTIVITY IN AN ARCTIC COMMUNITY

'Original Research' article, published as:

Naylor, A.W., Pearce, T., Ford, J.D., Fawcett, D., Collings, P., and Harper, S.L. 2021. Understanding determinants of hunting trip productivity in an Arctic community. *Frontiers in Sustainable Food Systems*, article online, doi: 10.3389/fsufs.2021.688350.

Introduction to the manuscript

Published in 2021 in Frontiers in Sustainable Food Systems, this manuscript accomplishes the third objective in this thesis: "quantify social-ecological determinants of hunting trip productivity in the *Ulukhaktokmiut* food system". Along with chapter three, it comprises this doctorate's major empirical, methodological and practical contributions.

Keywords: *Arctic; fuel use; mixed economy; subsistence; Inuit; hunting success; country food; traditional food*

Abstract

We examine factors underlying hunting productivity among Inuit in Ulukhaktok, Northwest Territories, Canada. Specifically, we focus on the role of gasoline use as the main variable of interest – commonly cited as a crucial determinant of hunting participation. Over the course of 12 months, 10 hunters recorded their on-the-land activities using a GPS tracking system, participatory mapping sessions, and bi-weekly interviews. A multivariable linear regression model was applied to assess whether factors such as consumables used (i.e. heating fuel, gasoline, oil, food), distances travelled, or the number of companions on a trip were associated with the mass of edible foods returned to the community. Results indicate that, despite being positively associated with hunting trip

productivity when assessed through a univariable linear regression model, gasoline is not a statistically significant determinant of standalone trip yield when adjusting for other variables in a multivariable linear regression. Instead, factors relating to seasonality, number of companions, and days on the land emerged as more significant and substantive drivers of productivity while out on the land. The findings do not suggest that access to, or the availability of, gasoline does not affect whether a hunting trip commences or is planned, nor that an increase in the amount of gasoline available to a hunter might increase the frequency of trips (and therefore annual productivity). Rather, this work demonstrates that the volume of gasoline used by harvesters on standalone hunting trips represent a poor a priori predictor of the edible weight that harvesters are likely to return to the community.

1. Introduction

Subsistence practices and their ideological foundations have retained critical importance to Inuit in Arctic Canada, despite the profound social, ecological and economic changes of the past half century (Wenzel, 2019; Ready, 2019). Contemporary hunting and fishing in Northern communities reinforce Inuit worldviews and identity, represent platforms for the intergenerational transfer of knowledge, and produce culturally and nutritionally essential country foods (Condon *et al.*, 1995; ICC, 2012; Pearce *et al.*, 2011). The products derived from subsistence practices also remain indispensable to the function of "mixed cash-subsistence" economies that typify many Arctic communities and are crucial to Northern food security (Usher, 1976; Wolfe, 1984; Ready & Power, 2018).

Mixed cash-subsistence economies are located at the interface between two interdependent sectors relating to means of food production in the Arctic. One is rooted in Inuit principles underlying subsistence and governs the ways through which country foods should be produced, consumed, and distributed. The other is more closely centered around financial resources and cash liquidity, whose primary purpose is to offset the costs associated with contemporary hunting (Aslaksen *et al.*, 2008; Ready and Power, 2018; Wenzel, 2019). Previous research identifying determinants of hunting productivity in the Arctic in the context of mixed economies has focused on the characteristics of hunters as individuals and the ways these might influence hunting success and participation. Collings (2009), for instance, identified how the characteristics of individuals, such as age or birth order, affect their annual harvest yield. Natcher *et al.* (2016), on the other hand, assessed the ways that wage-based employment, or the cost of supplies (e.g. gasoline, naphtha) relative to an individual's income affected their ability to access the land (see also Brinkman *et al.*, 2014). Despite hunters infrequently travelling or hunting alone, little scholarship has assessed how the activities of harvesters as a collective group, and the specific characteristics of their hunting trips (e.g. number of hunters in a group, volume of supplies used), might affect their productivity.

To our knowledge, the most-recent research conducted on a hunting group's productivity is from the 1980s (see Smith, 1985, 1991), now far removed from the context of the contemporary mixed economy. As such, a number of crucial questions pertaining to subsistence and hunting productivity in the North remain unanswered. Indeed, once a hunting trip commences, how might the time of year at which it takes place, the amount of gasoline used by harvesters, the number of harvesters in a group, or the duration over which hunters are on the land affect trip success? Improving understandings of potential drivers underlying the productivity of hunting trips holds implications for informing the direction of hunter support programmes across the North, and wider initiatives relating to food subsidy programmes and those aimed at supporting country food security. This paper responds to the above research gap by presenting a statistical analysis of data collected during a one-year, community-led, real-time monitoring initiative to assess determinants of hunting trip productivity in Ulukhaktok, NT. Specifically, our research focuses on the role of gasoline use as the main variable of interest – commonly cited as a crucial determinant of hunting participation (e.g. Brinkman *et al.*, 2014; Schwoerer *et al.*, 2020) – and its possible association with the productivity of individual hunting trips, while also exploring other characteristics relating to hunting parties or the environment (e.g. size of party, seasonality etc.). As such, we do not explore how access to gasoline affects whether a hunting trip is planned or commences, nor whether gasoline access increases the frequency of trips; rather, we quantitatively examine whether the volume of gasoline used by harvesters on *standalone* hunting trips is associated with the edible weight that hunting parties harvest. Furthermore, our paper identifies drivers of hunting trip productivity from a single Inuit community; however, its findings hold implications more broadly for collaborative research of land-based activities across the Arctic and serves to illustrate the importance of the multiple tangible and intangible factors that can affect hunting and country foods procurement.

2. Methods

2.1. *Ulukhaktok, NT, Canada*

Ulukhaktok (pop ~440, 93% Inuit) is a small coastal community, located on the western edge of Victoria Island in the Inuvialuit Settlement Region of western Arctic Canada (Figure 4.1). A permanent settlement was established in the area during the late 1930s, with the contemporaneous siting of a Roman Catholic mission and the closure and relocation of the Fort Collinson Hudson's Bay Company trading post in 1939 (Condon, 1988, 1996; IRC, 2011). Prior to this, the lands surrounding the community had been the site of semi-nomadic activity and temporary settlement since at least the early twentieth century (Farquharson, 1976; IRC, 2011). During this time Inuit had traced the seasonal migration routes of keystone species, with winter hunting typified by on-ice sealing camps, and summer characterised by inland camps with locations dictated by proximity to important lakes and rivers, and caribou calving grounds (Farquharson, 1976; Collignon, 1993). It was not until the 1950s and 1960s that Inuit settled permanently in the community, incentivised by government-subsidised public housing, investment in social services, and an increasing availability of wage-based labour (Condon *et al.*, 1995; Condon, 1996; Damas, 2002).

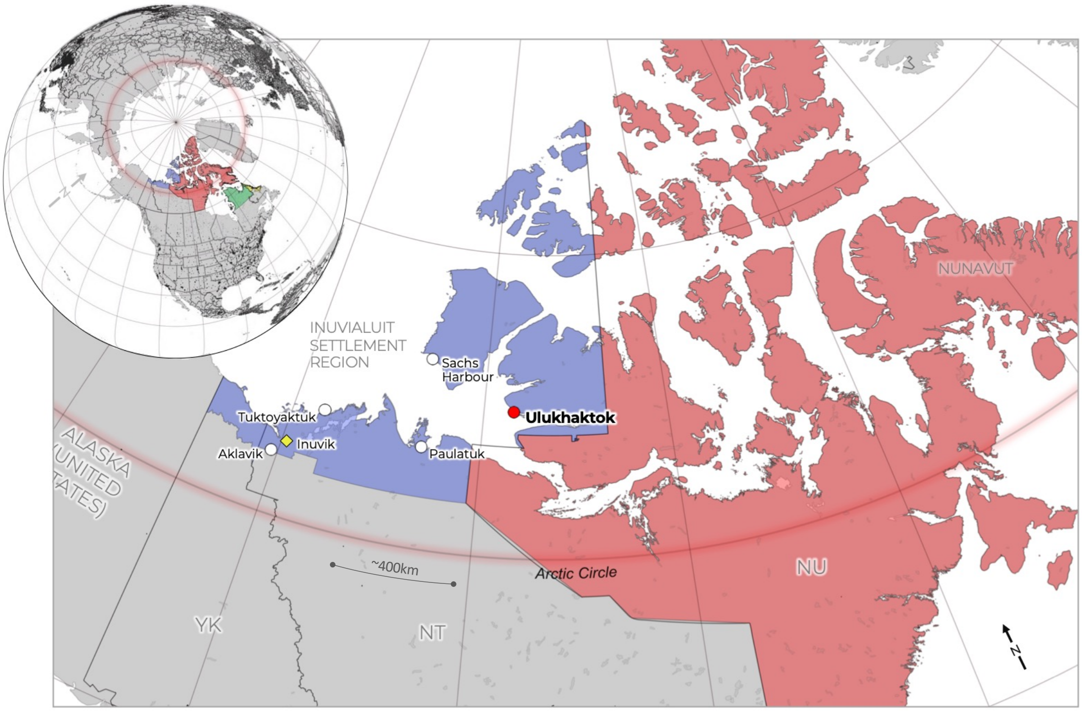

FIGURE 4.1: MAP OF INUIT NUNANGAT (COLOURED SECTIONS), SHOWING ULUKHAKTOK AND THE OTHER FIVE COMMUNITIES WITHIN THE INUVIALUIT SETTLEMENT REGION.

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Despite the above changes, and further government practices in the mid-to-late twentieth century aimed at acculturation—including residential schools system and continued pressure to engage in a formal wage-based economy (Condon *et al.*, 1995; TRC, 2015; Etter *et al.*, 2019)—Ulukhaktok has retained a number of year-round active hunters, whose efforts contribute to an important and enduring country food system comprising a wide variety of species. Country foods remain regularly shared within the community, with distribution according to a complex interplay of social structure and kinship, reciprocity, and financial capital (for a discussion on dynamics governing distribution, see Collings, 2011; Collings *et al.*, 1998, 2016), and their consumption remains crucial from both a food security, nutritional intake and cultural needs perspective. As of the most recent 2018 Traditional Activities survey, conducted by the Government of the Northwest Territories, 75.9% of the adult population in Ulukhaktok stated that they had either 'hunted or fished' in the previous calendar year (NWT Bureau of Statistics, 2019). *Ulukhaktokmiut*, meaning 'people from

Ulukhaktok', use the term 'hunting' to describe any activity, including fishing, hunting or gathering, from which foods might be derived from land, sea, and ice using all-terrain vehicles (ATVs), boats or snowmachines. (Hereafter, the term 'hunter' is applied to describe an individual who engages in hunting, fishing, or gathering).

A diversity of fish and wildlife (e.g. ringed and bearded seals, eider duck, geese, arctic char and arctic cod) can be accessed from hunting grounds relatively close (<5km) to Ulukhaktok; with some animals having almost year-round availability (Damas, 1972; Pearce *et al.*, 2010). However, the community's access to more prized, or high yield species (i.e. with more than 20kg of edible weight) remains mediated by the pathway and timing of more distal seasonal animal migrations (Farquharson, 1976; Pearce *et al.*, 2010). These distal 'keystone' species, particularly caribou, are hunted with intent through 'expedition hunts', and often require travel distances beyond 100-kilometres due to the siting of the community far away from traditional calving and grazing grounds. Other, less prized animals are harvested in a more opportunist manner. Hunters may take trips out on to the land, sea, or ice to see what animals are around, or temporarily divert their attention while on expedition hunts to harvest other species (e.g. waiting at seal holes (aglu) or lake fishing while also searching for larger animals (e.g. caribou, polar bears)). It is commonplace for a variety of species (e.g. seals, fowl, and marine fish on sea ice or open water, or muskox, fowl, and fish from lakes 'up land') to be harvested from a single trip using an ATV, boat, or snowmachine. Species considered crucial to the community food system include ringed seal, *natiq* (*Phoca hispida*); muskoxen, *umingmuk* (*Ovibos moschatus*); Peary and Dolphin and Union caribou, *tuktu* (*Rangifer tarandus pearyi/R.t. groenlandicus*); king eider ducks, *kingalik* (*Somateria spectabilis*); Arctic char, *iqalukpik* (*Salvelinus alpinus*) and lake trout, *ihuuhuk* (*Salvelinus namaycush*) (Pearce *et al.*, 2010). Other animals, such as Arctic wolves, *amaruq* (*Canis lupus arctos*) and polar bears, *nanuq* (*Ursus maritimus*) also represent an economic resource through the sale of their furs, or through Inuit acting as guides for sport hunters in the region.

The sedentarisation of *Ulukhaktokmiut* a significant distance from the traditional hunting grounds of larger keystone subsistence species (e.g. muskox, and caribou) lends credence to a hypothesis that hunting trips utilising a greater volume of gasoline are expected to yield of a greater mass of harvested edible weight. The relatively fixed nature of hunting camps and cabins often used as the foci for large mammal harvesting also attests to such a theory. However, these assertions make a number of assumptions relating to hunting trips that warrant further understanding and investigation. Notably, i). the premise that the harvesting of a reduced number of distal high-yield subsistence species outweighs the potential for the high frequency harvesting of more predictably distributed, lower-yield species (i.e. birds, fish) closer to the community, ii). that hunters who are successful in the early stages of a trip do not instead spend more time within the camp they travelled to, rather than being out on the land, and iii). that seasonal and real-time land conditions, and choice of differing trails to the same locations do not have a substantial impact on fuel use or economy.

The remoteness of Ulukhaktok makes country foods and understanding possible drivers of productivity stemming from their harvest all the more important from the perspectives of food security and nutrition. Access to store-bought foods remain limited in the community: the tariff for air freight and the costs incurred by retailers associated with long-term storage, in addition to the limited efficacy of the Nutrition North Canada program, has resulted in inequitable pricing for many of the products available in Ulukhaktok's stores (NNC, 2016; Galloway, 2017). Even then, there are concerns as to whether the nutritional value of store-bought foods can ever come close to those harvested from the land (Rosol *et al.*, 2016).

The limited affordability of store-bought foods in the community is compounded by a body of research dating back to the 1960s that highlights dwindling economic returns and increasing consumables and equipment costs associated with subsistence hunting, altered intergenerational transfer of Inuit knowledge about the environment, and unequal access to country foods and sharing networks as a result of changing household structure (e.g. Usher, 1965; Smith & Wright, 1989; Condon *et al.*, 1995; Pearce *et al.*, 2011; Collings *et al.*, 2016; Fawcett *et al.*, 2018). In general, there are few concerns in the community over the stability or sustainability of hunting from an over-harvesting or over-fishing perspective. However, in recent years the role that current and future climate change may be having on subsistence species' health, population or distribution has become a far more prominent issue, and community members have also voiced concern as to how these factors may interact with socioeconomic, political and cultural drivers of food systems in the future (see Pearce *et al.*, 2010; Fawcett *et al.*, 2018). However, much of this scholarship has focused on intra-community dynamics and issues of food distribution, or adopted a longer-term, climate-focused approach to its analysis. Little research has as yet examined the dynamics of subsistence from a more systematised assessment of hunting trips and on-the-land activities, nor looked at these factors from a real-time monitoring perspective.

2.2. *Data collection*

Between January 2019 and December 2019, a cohort of 10 male hunters—with ages 26-82 years old—undertook a community-led real-time monitoring initiative as part of the *Tooniktoyok* Project (see Appendix I). Data were collected to assess the potential impact of trip-specific variables on the per-kilo productivity of hunting activities (expressed as mass of harvest derived per trip) undertaken on the land, ice, and sea (hereafter collectively referred to as 'land' or 'lands') surrounding

Ulukhaktok. The cohort of 10 hunters were purposively selected, with participants being chosen based upon recommendations from the Hamlet Council in partnership with the research team. Criteria for selection included: i) the regularity with which participants were considered to engage in land-based activities (preference given to those who were most active and would likely hunt a minimum of twice per week across the data collection period), ii) their knowledge about the lands surrounding Ulukhaktok, and iii) their availability to regularly discuss, in-depth, their experiences of hunting and practicing subsistence. The cohort were from a range of socioeconomic backgrounds. Three engaged in full-time employment at the time of study, often hunting in their spare time on evenings or weekends. Five were engaged in seasonal employment, predominantly as wildlife monitors for the Department of Fisheries and Oceans (DFO), and one member of the cohort had retired and was in receipt of their state pension. Each had at least ten years' experience in hunting on the lands around Ulukhaktok at the commencement of the study.

Numerical data on productivity (harvest), consumables use, size of hunting party, number of days on the land etc. (see Table 4.1) were collected during bi-weekly group interviews, in addition to broader categorical data on trip characteristics such as mode of transport, or experiences of mechanical issues. During interviews, hunters were asked to recount all the hunting trips they were involved in the past two weeks: telling the narrative of where they went, who they went with, and the number and types of animals that were harvested by their hunting group. Interviews followed a conversational, semi-structured format, recorded using both audio recorders and notation, and were convened and conducted by an Inuit researcher, with non-Indigenous researchers also present when in the community. Conversational interviewing aligns with Indigenous research pedagogies and paradigms relating to storytelling and knowledge transfer and are a culturally appropriate means of establishing relationships and producing knowledge (Iseke, 2013). Interviews were primarily conducted in English; however, a number of participants offered real-time translation in instances where members of the cohort elected to speak Inuinnaqtun. For their participation, the hunters received a fixed rate of CAN$75 in compensation each week, recommended following consultation between the Hamlet Council and the research team.

A 'hunting group' was defined as all members of a party that attended a hunting trip (including instances where hunters travelled alone). A 'trip' was defined as any instance where a hunting group undertook any form of land, sea, or ice-based travel out of the community on ATVs, boats, or snowmachine with the intention of sourcing foods from the local environment. Whole group productivity (as opposed to individual productivity) was recorded due to the difficulties associated with keeping track of individuals' harvests when hunting as a group, in addition to the highly collaborative nature of group hunting and strong ethos of sharing between hunters and community members, which renders the productivity of specific individuals relatively less important. Individual consumables use was recorded due to the lesser ethos of sharing that relates to non-country food items in Inuit culture (e.g. gasoline), and the increased likelihood that hunters could accurately report these figures as a result. Interviews and GPS tracking during an initial 2018 scoping period suggested that hunters on the same hunting trip often followed similar routes, and would frequently camp for the same number of nights as other members of their party, meaning that an individual's consumables use was relatively representative of the rate of consumption used by other individuals within groups as a whole.

In addition to interviews, hunters also tracked the activities they would later discuss in interviews through the use of GPS receivers (for a discussion on Inuit wayfinding and use of GPS see Aporta & Higgs (2005)) and were involved in a number of participatory mapping sessions (n = 15) throughout the year to add a greater context to numerical data and collect further information relating to land use, locations visited, and distances travelled (Figure 4.2). Metadata relating to locations visited and time spent on the land were derived from GPS files that were imported into ArcMap 10.4 GIS software. Data were stored in the community and were subsequently shared electronically with the authors and the statistician working for the Inuvialuit Regional Corporation through the use of a secure cloud storage platform. Both the cohort of hunters and the Inuit researcher were compensated with honoraria.

In total, 23 variables, previously identified within the literature as potential determinants of hunter productivity (e.g. Smith, 1985; Smith & Wright, 1989; Ford *et al.*, 2013, 2019; Brinkman *et al.*, 2014; Fawcett *et al.*, 2018), were extracted from semi-structured interview and spatial data for 132 hunting trips (Table 4.1). These data were used to conduct statistical analyses.

The dependent variable, hunter productivity, measured in terms of mass of edible meat harvested per trip, was calculated from interviews by asking hunters how many animals, and of which species, had been harvested by all members of a hunting party, and by combining these data with values from Usher's (2000) standard edible weight yield calculations for species commonly harvested in the Inuvialuit Settlement Region (see also Ashley, 2002). This method is established as a best-practice method for estimating hunter productivity where the weighing of individual samples is not possible (e.g. Usher, 2002; Collings, 2009; Wenzel *et al.*, 2016). In instances where the standard edible weight yield values provided a range, the median value was used.

In some instances, rather than providing an individual break down of each trip undertaken in a week, hunters provided a sum total of resource use and productivity across multiple trips where they took the same routes in similar conditions or had very similar productivity across all trips. In order to retain analytical granularity, these data points were retained within the analysis, and from these an average was taken. In instances where two or more hunters within the cohort were a part of the same hunting trip, only one record, validated by all hunters on the trip, was retained for inclusion in the statistical analysis. As an important confounder, frequency of type of animal harvested was also retained and controlled for. While it could be expected that some larger animals (e.g. caribou) might have association with productivity on individual trips, the frequency with which these animals are harvested relative to smaller animals (e.g. fish or fowl) on a trip could still have a crucial effect on possible relationships with edible weight; therefore, it was important to consider this in our analysis.

2.3. *Statistical analysis*

A multivariable linear regression model (MvLRM) was constructed to assess the association between hunting trip productivity and a number of possible explanatory socio-economic and biophysical independent variables. A MvLRM is a statistical method for examining associations between a single, continuous dependent/outcome variable (in this case hunting productivity per trip), and multiple categorical, ordinal, and/or continuous independent/explanatory variables. More specifically, MvLRMs are able to better account for variability that occurs within the dependent variable by incorporating and assessing the influence of numerous explanatory factors simultaneously. A statistician was consulted to ensure the validity and rigor of our analysis.

Prior to model construction, Loess smoothing was used to assess linearity between the dependent outcome variable (hunting trip productivity) and each continuous independent variable extracted from interviews and GPS data (Table 4.1). Continuous independent variables were categorised if they had a non-linear relationship with the dependent variable. Spearman's rho was run for all independent variables to identify possible collinearity. Any two independent variables exhibiting strong correlation coefficients ($>|0.70|$) were further examined, and the most "plausible" variable (i.e. the variable deemed to hold the greatest likelihood of cause-effect relationship), or the variable with a considerably greater number of observations, was retained for model building. Additionally, variance inflation factor (VIF) was used to assess multicollinearity between explanatory variables within the final model, with a VIF value exceeding 10.0 indicating multicollinearity.

The main explanatory independent variable of interest was gasoline use, reflecting the objective of our study and given previous research identifying it as a crucial resource within the subsistence economy (e.g. Brinkman *et al.*, 2014; Schwoerer *et al.*, 2020). As such, a purposive model building approach was used; that is, we explored the effect of gasoline use on hunting trip productivity adjusting for the effects of other explanatory variables. First, a series of univariable linear regressions were conducted to assess the unconditional association between the dependent outcome variable (i.e. hunting trip productivity) and each explanatory independent variable. Then, all variables with $p < 0.20$ from the unconditional univariable linear regressions were explored in a MvLRM. As the main independent variable of interest, gasoline use was forced into the MvLRM regardless of its statistical significance, as was the mode of transport used on specific trips, which was included as a possible confounding factor given the possibility that transport mediums may influence fuel economy. Other independent variables ($n = 10$) were iteratively removed if $p > 0.05$ and were excluded from the model if the Bayesian Information Criteria (BIC) statistic decreased upon their removal. Global significance tests were used to examine the overall significance of categorical variables. BIC was used to assess the model fit (i.e. full vs reduced models), which takes into account the potential for over-parameterisation. The model with the lowest BIC was retained as the final model.

The assumption of homoscedasticity within the model was assessed visually through standardised residual plots, and normality was assessed visually through a frequency distribution (histogram) and normal quantile (Q-Q) plots. Potential outliers were explored visually, and the leverage of individual observations and influence of observations on the model were assessed by visually examining Cook's distance. To assess possible outliers identified visually, the MvLRM was re-run with these data points incrementally excluded to assess their effect on the model.

Since hunters frequently reported only the productivity of the total group that attended hunting trips (reflecting local culture and Inuit worldviews surrounding commons resources and sharing), the analysis of individual hunter characteristics (i.e. age, income, equipment owned) as variables were precluded from direct statistical analysis. Nonetheless, in order to explore possible clustering within individuals and/or groups (due to the diversity of socioeconomic backgrounds and age in the cohort), the model was re-run with a random effect to control for clustering effects of hunting groups. However, this random effect was not found to be significant and therefore was not included in the final model. All statistics were conducted in SPSS (version 23.0.0.2), with the exception of VIF and random/mixed effects testing, which were calculated in Stata (version 15).

2.4. *Ethics and research license*

Research was undertaken in line with the 5 Priority Areas of the National Inuit Strategy on Research (2018) and was overseen by a four-person Inuit Oversight Committee within the community. Informed oral or written consent was obtained from all participants. Licensing by the Aurora Research Institute (No. 16533), study protocols approved by the University of Guelph (REB 17-12-012) and the University of Leeds (AREA 18-117).

3. Results

3.1. *Productivity and tracked trails*

Numerical data pertaining to trip characteristics, including routes taken, productivity, consumables used, and days on the land, were collected for up to 132 trips between 7th January 2019 and 4th December 2019 (Figure 4.2). Across all variable categories, mean response rate was 81.4% and increased to 92.6% for those variables included in the final MvLRM. Of the 10 hunters within the cohort, the number of trips recorded by each hunter ranged from between 6.1% (n = 8) to 15.2% (n = 20) of the overall dataset. A summary of all variables and their respective number of observations is included in Table 4.1.

Total productivity of the cohort across all trips with available data (n = 132) (n values hereafter represent the number of recorded observations within the sample) was 6,972.34kg of edible weight, derived from 1,868 animals (large mammals n = 91, fish n = 1,223, fowl n = 554) and 409 eggs. None of the mammals harvested by the cohort were beluga whales. In total 5,387.3km of trails (n = 80) were tracked. Across the dataset, an average productivity of 56.7kg/trip (n = 123) was calculated, with a productivity of 0.77kg/km travelled for data available via GPS-tracked trails (n = 73). 251 days (i.e. 24 hour periods within which at least one subsistence activity took place) were spent out on the land in total, yielding a mean productivity of 26.1kg/day of hunting (n = 114). Average trip length was 2.02 days. In total the cohort recorded individual gasoline consumption across all trips to be 5,607.83L, translating to a market value of CAN$10,384.03 in gasoline purchased, assuming the 2019 price of gasoline in Ulukhaktok. This bore a fuel use per trip (n = 119) average of 47.14 L per individual, and a productivity ratio of 1.15kg of standard edible weight per litre (n = 113). In 70.7% of cases (n = 92 of 130 observations), hunters went as part of a group of 2 or more, with the average number of members in a party being 2.57 people. On average, hunters travelled 67.34km per trip (n = 80). Table 4.2 provides a further summary of descriptive statistics derived from both the independent and dependent variables.

3.2. *Productivity and association with gasoline use and other variables*

As a standalone explanatory variable, there was a significant positive association between gasoline use and hunting group productivity (p = <0.001, unadjusted); for every unit increase in an individual's gasoline use (litres) there was a 0.689kg increase in group productivity (CI = 0.421-0.957kg). Gasoline use, however, was no longer significant when other variables were adjusted for in the MvLRM (Table 4.3). When adjusting for other socio-economic and bio-physical variables, the effect of gasoline use on productivity was reduced to have almost no effect (Beta = -0.003kg) and was no longer significantly associated with productivity (p = 0.979). The time of year (month), days spent on the land, the size of a hunting party, and the type of animals harvested (large edible

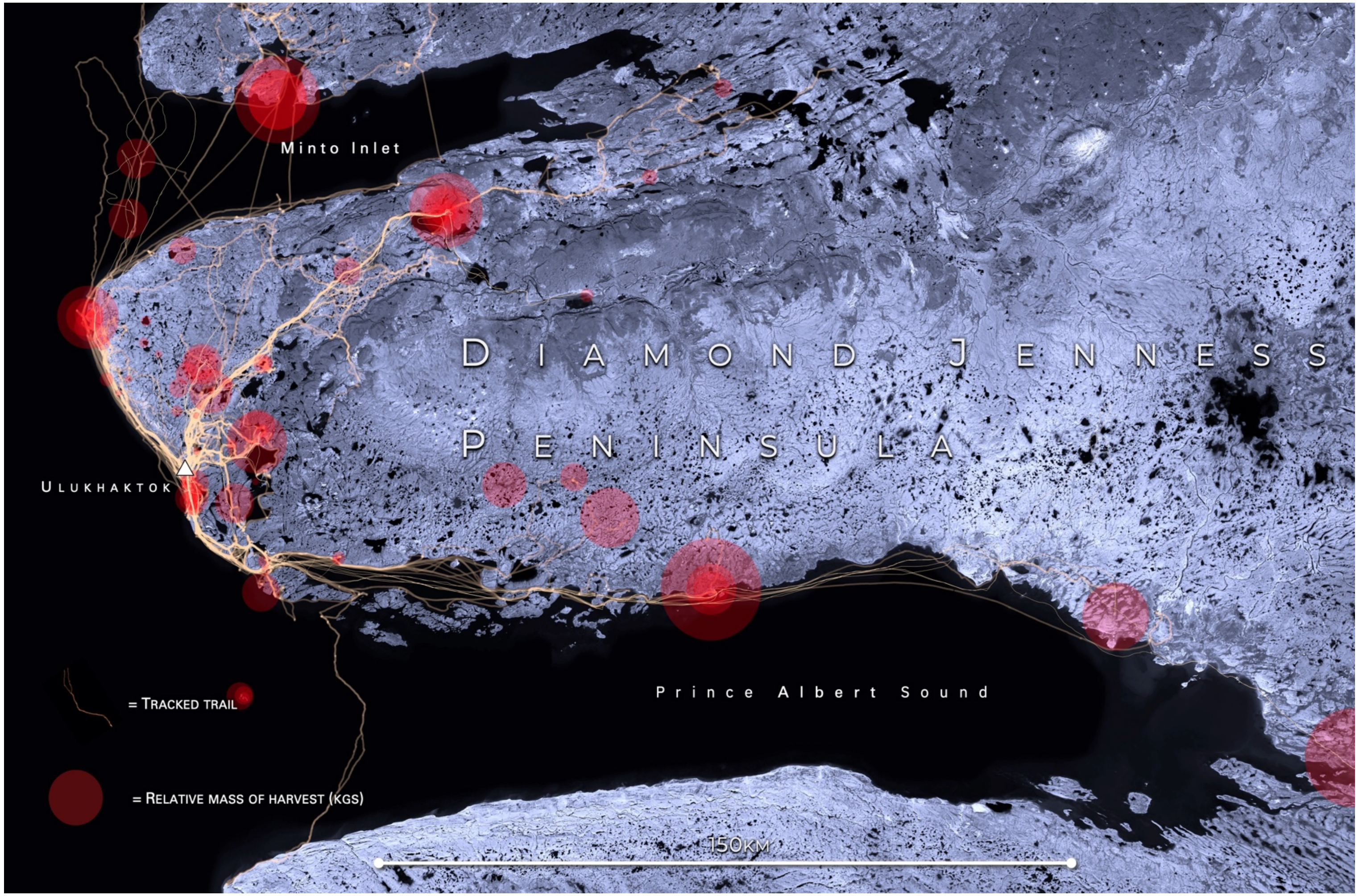

FIGURE 4.2: TRACKED GPS AND ANNOTATED ROUTES COLLECTED AS PART OF THE TOONIKTOYOK PROJECT, JAN 2019 – DEC 2019.

Thickness of lines corresponds to frequency of trail use. Red circles indicate approximate location of harvests, with size corresponding to relative mass of standard edible weight derived. Trails for unsuccessful harvests are also shown. Basemap: Esri World Imagery (Attribution: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

mammals/fish) was associated with group productivity ($p<0.05$). The random effect to control for clustering of individuals within hunting groups was not significant, and therefore was not included in the final model.

TABLE 4.1: SUMMARY OF VARIABLES EXPLORED IN STATISTICAL ANALYSIS

	n OBSERVATIONS	MEAN	STD. DEVIATION
Month	*132*	N/A	N/A
Season	*132*	N/A	N/A
Nº days on land	*123*	2.04	1.97
Borrowed machinery	*131*	N/A	N/A
Borrowed supplies	*114*	N/A	N/A
Gas taken (litres)	*67*	84.64	51.36
Gas used (litres)	*119*	47.12	47.02
Oil taken (litres)	*68*	1.27	2.13
Oil used (litres)	*114*	0.84	1.49
Naphtha taken (litres)	*77*	11.84	17.16
Naphtha use (litres)	*111*	2.76	5.55
Food taken (CAN$)	*50*	142.70	167.70
Food used (CAN$)	*61*	91.57	98.32
Cost est. of entire trip's consumables (CAN$)	*23*	403.91	272.73
Mode of transport	*132*	N/A	N/A
Distance travelled (kilometres)	*80*	108.37	115.18
Nº of companions	*129*	1.57	1.76
Mechanical issues	*130*	N/A	N/A
Environmental issues	*130*	N/A	N/A
Nº Group large edible mammals	*116*	0.78	1.54
Nº Group fish	*114*	10.73	22.06
Nº Group fowl	*115*	4.81	14.16
Group productivity (kilograms)	*123*	56.69	79.86

Note: 'Number of observations' here refers to the number of trips for which certain data were collected.

	Large mammals	Fowl	Fish	Eggs	Total
Number harvested	91	554	1,223	409	2,277
Standard edible weight (SEW) (kg)	4,561.35	688.125	1688.46	34.4	6,972.34

	Gasoline	Oil	Naphtha	Store-bought food
Total volume used (L)	5,607.83 (*n* = 119)	95.51 (*n* = 114)	67.30 (*n* = 111)	-
Total cost CAN$	$10,262.33 (*n* = 119)	$954.14 (*n* = 114)	$342.56 (*n* = 111)	$5,830.00 (*n* = 61)
kg of SEW/L	1.15 (*n* = 113)	58.21 (*n* = 107)	86.10 (*n* = 103)	-
CAN$/kg of SEW	$1.61 (*n* = 113)	$0.16 (*n* = 107)	$0.06 (*n* = 103)	$1.59 (*n* = 58)
Average L/trip	47.12 (*n* = 119)	0.84 (*n* = 114)	0.61 (*n* = 111)	-
Avg. CAN$ spend per recorded trip	$87.26 (*n* = 119)	$8.37 (*n* = 114)	$3.09 (*n* = 111)	95.57 (*n* = 61)

('*n* =' refers to the number of provided answers within a specific category (out of 132))

	ATV	Boat	Snowmachine	Boat & ATV	Total
Number of trips	23 (17.4%)	18 (13.6%)	89 (67.5%)	2 (1.5%)	132
Total SEW (kgs)	729.1 (*n* = 23)	530.1 (*n* = 15)	5,058.59 (*n* = 83)	654.55 (*n* = 2)	6,972.34 (*n* = 123)
Average SEW/trip	31.7 (*n* = 23)	35.34 (*n* = 15)	60.95 (*n* = 83)	327.25 (*n* = 2)	56.69 (*n* = 123)
Recorded distances (km)	672.61 (*n* = 16)	560.14 (*n* = 12)	3805.50 (*n* = 51)	349.00 (*n* = 1)	5,387.25 (*n* = 80)
Average distance/trip (km)	42.04 (*n* = 16)	46.68 (*n* = 12)	74.62 (*n* = 51)	349.00 (*n* = 1)	67.34 (*n* = 80)
Average gasoline use/trip (L)	22.67 (*n* = 22)	65.22 (*n* = 18)	47.24 (*n* = 78)	250.03 (*n* = 1)	47.12 (*n* = 119)

	Winter†	Summer†
Total SEW (kgs)	1,734.33 (*n* = 48)	3,873.50 (*n* = 71)
Recorded distances (km)	1614.75 (*n* = 36)	3,772.50 (*n* = 44)
Gasoline use (L)	1,734.33 (*n* = 48)	3,873.50 (*n* = 71)

† Seasons derived from dates for break-up and freeze-up as per the method used by Gagnon & Gough (2005)

	Freq. per hunting trip
Borrowed Equipment	30/131 (23%)
Borrowed Supplies	14/114 (12%)
Reported environmental issues	18/130 (14%)
Reported mechanical issues	24/130 (18%)
Average nº companions	2

TABLE 4.2: SUMMARY OF DESCRIPTIVE STATISTICS DERIVED FROM GPS TRACKING AND INTERVIEWS.

*

TABLE 4.3: RESULTS OF THE MULTIVARIABLE LINEAR REGRESSION INVESTIGATING ASSOCIATION BETWEEN SOCIO-ECONOMIC AND BIOPHYSICAL VARIABLES AND HUNTING PRODUCTIVITY IN ULUKHAKTOK, JAN 2019 – DEC 2019.

Final MvLRM BIC = 958.679†

VARIABLE	β-VALUE	95% CONFIDENCE INTERVAL		p
		LOWER	UPPER	
Gasoline use (litres)	-.003	- 0.228	0.222	0.979
Days on land				0.003*
1-2 days	ref**	-	-	-
3-4 days	39.550	16.339	62.761	0.001
5+ days	10.780	-17.893	39.399	0.460
Month				<0.001*
January	ref**	-	-	-
February	-91.493	-133.732	-49.225	0.130
March	-84.067	-127.028	-41.107	<0.001
April	-80.990	-128.349	-33.630	<0.001
May	-115.146	-158.875	-71.416	<0.001
June	-110.437	-151.538	-69.337	<0.001
July	-146.390	-191.235	-101.545	<0.001
August	-125.386	-170.947	-79.788	<0.001
September	-128.886	-174.992	-82.780	<0.001
October	-95.181	-138.349	-52.014	<0.001
November	-144.010	-189.556	-98.463	<0.001
December	-125.471	-177.023	-73.919	-
Number of companions	5.750	1.582	9.917	0.007
Number of large edible mammals harvested	29.389	23.008	35.770	<0.001
Number of fish harvested	1.048	0.632	1.465	<0.001
Transport				0.576*
ATV	-11.202	-37.297	14.892	.400
Snowmachine	-11.348	-33.581	10.886	.317
Boat	ref**	-	-	-

* Global p-value for variable (i.e. significance of category when aggregated as a whole)
**Referent category
†Other BIC values:
MvLRM BIC minus gasoline: 954.169
MvLRM BIC minus gasoline *and* transport: 946.364

4. Discussion

This study set out to assess possible associations between the productivity of Inuit hunting parties from Ulukhaktok and a range of other socioeconomic and biophysical variables. The number of companions on a harvesting trip was statistically associated with its productivity; our model suggested that for every additional hunter, a trip would yield an additional 5.750kg of standard edible weight. We posit that the size of a hunting party may be significant for a number of reasons. As per Smith (1985, 1991), in addition to increasing hunter safety a mutual advantage to travelling as a group may arise from i) certain individuals within that group being better placed to locate or spot prey, ii) from the ability of the group to use their collective knowledge of the land to hunt, or iii) through "the division of labour in capturing prey". Moreover, we postulate that larger hunting parties will also hold a greater capacity to return a high yield of food from the land, owing to the increased number of vehicles or sleds that are usually taken, in addition to being subject to a greater social expectation to gather more food. The latter arises from the notion that the larger a party the greater the number of direct (familial) social relations it will have linked to it, but also, due to the fact that with increased party size, the overall centrality and connectivity of its participants within extended sharing networks is set to be more substantive (see Collings *et al.*, 2016; Baggio *et al.*, 2016). It should be noted that optimal foraging theory (see Smith, 1985), suggests that there are limits to the expected increase in productivity with hunting party size, and that the optimal size of such varies by harvested species.

The harvesting of both high-yield, large edible mammals, but also certain lower-yield animals caught with greater frequency, namely fish, were both associated with greater trip productivity. These findings align with previous work by Usher (2002) on harvest patterns in six communities across the Inuvialuit Settlement Region between 1960-2000, where large edible mammals (i.e. muskoxen, caribou, ringed seals etc.) and fish (arctic char) were found to comprise nine of the ten most productive species. With regard to the fish, we suggest that an association with productivity likely results from a combination of char and lake trout being caught as accessory species on trips to harvest larger mammals, but also due to high seasonal catch rates during the spring and autumn 'char runs', wherein in excess of 100 fish can be caught on multi-day trips relatively close to the community. This was reflected in our data, where 8 of the 10 most productive hunting trips for fish saw them as the only type of animals harvested, and 7 of these occurred during the period in which the most char would typically be expected to migrate (the months of June and July). 'Char run' trips are typically to an area named *Tatiik*, or "Fish Lake" approximately 40km away from Ulukhaktok and involve the setting and leaving of nets in lakes close to a seasonal camp, which are periodically checked and emptied. Given the relatively static nature of this of activity, the lesser volume of fuel required to reach the cabins at the lake as compared with longer-distance expedition trips, and its relatively low-risk, high-reward nature in terms of consumables use, we suggest that the energy-efficient nature of char run fishing may also have had an effect on precluding a gasoline-productivity relationship within our model. Indeed, it might well be the case that rather than hunts travelling long distances (and therefore using a large amount of gasoline) to harvest large mammals not being productive, they are simply *proportionally less productive* than shorter trips harvesting smaller animals with a greater intensity. This assertion is supported in the data, where in the top 20 most gasoline-intense hunting trips there were only two instances where a zero mass of edible weight was returned to the community. This may also speak to the social context of large mammal hunting, whereby the prestige that comes from successful 'expedition hunts', in addition to the general preference that community members have for meats such as caribou over lake trout, might hold greater weighting as to how hunting is conducted as opposed to concerns surrounding energy efficiency.

The finding that days on the land holds association with trip productivity is unsurprising. Previous research has identified the importance of available time on the land in a subsistence context as crucial for the transmission of knowledge pertaining to hunting in Ulukhaktok (Condon *et al.*, 1995; Pearce *et al.*, 2011) and as prerequisite for hunting participation across the North American Arctic as a whole (Smith & Wright, 1989; Natcher *et al.*, 2016). Specifically, our model indicates that the most efficient method of harvesting was for hunting parties to spend more than 3 days away from the community. The exact reason underlying this trend is unclear. However, we postulate that, as per Smith (1983), differences in efficiency may result from trips of 3 or more days optimising the balance between travel times to hunting areas and within-hunting-area foraging time, in addition to the differences in animal species that are typically harvested on trips of different durations around the community. Previous research addressing differential productivity of harvesters in the community based upon hunted species supports this assertion. Collings (2011), in an analysis of annual hunting yield for 14 *Ulukhaktokmiut* hunters in 2007 found that, rather than being a harvester who partook in week-long 'expedition trips' for caribou, the most productive harvester was in fact one who concentrated his efforts on hunting muskoxen relatively close (<90km) to the community. Despite being a less preferred, and less prestigious keystone species, a trend toward muskoxen being more frequently harvested by the community than caribou (Pearce *et al.*, 2010), and the relatively high standard edible weight of muskoxen versus caribou (69kg vs. 33kg), may also explain why we see association between large edible mammals and productivity, but not gasoline use (expedition hunts for caribou are typically far more gasoline intensive (Condon *et al.*, 1995)).

Our results indicate that the month of the year was associated with hunting trip productivity. Variance in productivity by month could be accounted for by a range of factors, including the differing seasonal availability of certain animals and associated changes in the focus of harvest activities. During certain months around Ulukhaktok a number of high-mass species in terms of edible weight are available simultaneously; pertinent examples might be October, when muskox, caribou and char can all be harvested, or during the spring-summer months, where the eider duck migration may coincide with that of geese, the harvesting of young seals or muskox, or even beluga whales (Parker, 2016, p.31). Other drivers might include the timing and characteristics of break-up and freeze-up periods, which can promote or limit activities, or the uptake in seasonal or casual employment among some members of the cohort across different times of year (Pearce *et al*., 2011; Collings, 2011).

4.1. *Limitations and future research directions*

Our findings highlight a number of areas for future inquiry. Hunters included in the study were selected based upon the 'regularity with which they engaged in hunting' and 'their knowledge of the lands around Ulukhaktok'. This resulted in an all-male sample (Inuit divisions of labour often locate males as hunters) (Condon *et al*., 1995; Dowsley, 2015). It is unfortunate that selecting an all-male cohort contributes to what is already a heavily gendered dimension to hunting research across the North American Arctic. Although studies exist that have explored women's experiences of food security, climate change, and changing relationships with the land in the Arctic (e.g. Beaumier & Ford, 2010; Dowsley, 2015; Bunce *et al*., 2016) the dynamics governing the productivity of women's on-the-land harvesting remain poorly understood. Pertinent questions for future work here include: *How might women's involvement in on-the-land hunting in Ulukhaktok affect rates of productivity? In what ways do the actions of women outside of direct involvement in hunting (i.e. as wage earners providing or preparing supplies and equipment, or through their efforts in post-harvest food preparation) also affect productivity and overall harvest yield of hunting groups?*

Schwoerer *et al.* (2020) - when attempting to predict gasoline use among wild food harvesters in Alaska – suggest that "super-households are more likely to be energy [(fuel)] efficient than the community's average household" and suggest that "skill and local knowledge not only relate to larger harvest amounts, but also more efficient use of gasoline". In the context of our study, our decision to select a sample based upon their knowledge of the land, and by extension their skill at hunting, may have resulted in elite capture. Although it is important to understand the drivers that underlie the productivity of the most successful hunters in the community, given their importance for ensuring food system stability (Baggio *et al*., 2016), this leaves unanswered questions as to whether these same factors would affect productivity in the same way across a larger cross-section of less-experienced harvesters.

It is acknowledged that this research collected only one year's worth of real-time data on hunting group productivity. Although this should still be considered a substantive dataset, it best characterises the conditions that determine *present-day* hunting group productivity in the community. Therefore, this study is constrained in its ability to quantify how longer-term, less predictable changes to the food system, such as changing wildlife distributions as a result of climate change, or sociopolitical changes relating to wildlife management policies, might affect edible weight yields in the future. We also note that our study has a place-specific dimension, particularly as the harvest of specific animals of differing edible weights is found to be significant to hunting productivity, and that the distribution pattern of animal habitats is unique to the area around Ulukhaktok. To further increase the generalisability of these findings, it is evident that future research is needed to better identify and understand variables that affect harvest productivity across different food systems and local environments, and across longer timescales. Future studies might explore the potential for decadal re-analysis of patterns within harvest data, spatial analogues, multi-year longitudinal monitoring of harvesters, or more qualitative, ethnographic approaches to understanding long-term food systems change (Ford *et al.,* 2010). Monitoring across multiple years may also account for the role of anomalous climatic extremes and weather variation in order to identify which months of the year specifically can be attributed to increased productivity, and to unpack why this might be the case. These data would be useful at informing decisions of how best to support a range of hunters of different abilities under changing societal, environmental and economic conditions.

5. Conclusion

This study examined factors underlying the productivity of hunting trips undertaken by Inuit in Ulukhaktok, Northwest Territories, Canada. Results indicate that despite being positively associated with hunting trip productivity when assessed through a univariable linear regression model, gasoline is not a statistically significant determinant of standalone trip yield when adjusting for other variables in a multivariable linear regression. Instead, trip characteristics relating to seasonality, number of companions, days on the land, and the types of animal harvested exhibit greater explanatory power when attempting to understand drivers of productivity. In taking a more quantitative approach, this research adds further depth to a scholarship studied primarily through qualitative approaches, which have been effective in contextualising and highlighting the importance of hunters to the mixed economy of Arctic social-ecological systems, but less so at developing insights on the relative importance or weighting of specific drivers within those systems that might otherwise impact hunters' productivity. Our findings do not to suggest that the fuel access, availability, or consumption might not affect whether a hunting trip actually begins or is planned (see Brinkman *et al.*, 2014; Fawcett *et al.*, 2018), nor that gasoline consumption might otherwise hold a different relationship with hunter productivity in other areas of the Arctic (see Schwoerer *et al.*, 2020). Instead, they serve to highlight the complexity of Arctic country food systems in the Arctic, which comprise a nexus of socioeconomic-, political- and cultural-environment linkages changing over daily, inter-seasonal and inter-annual scales (Council of Canadian Academies, 2014; Ready, 2019; Naylor *et al*., 2020).

6. Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

7. Author Contributions

Project construction and data collection by A.N., T.P., D.F. Data analysis and statistics by A.N. and S.L.H. First and subsequent drafts of paper produced by A.N.,T.P., J.F., D.F., P.C. and S.L.H. Editorial revisions and approval conducted and granted by all authors.

8. Funding

We are grateful for the continued funding received from Crown Indigenous Relations and Northern Affairs Canada's (CIRNAC) Climate Change Preparedness in the North program (Ref #: 1718-HQ-803 000538), the UKRI Economic and Social Research Council (Ref #: 1948646) (Naylor), and the Canada Research Chairs Program, University of Northern British Columbia, Canada (Pearce). Without the generous flexibility of the budget structure afforded to this research it would not have been possible to conduct real-time longitudinal monitoring of this nature.

9. Acknowledgements

The authors would like to acknowledge the work of the Tooniktoyok Hunters: Adam Kudlak, David Kuptana, Isaac Inuktalik, Roy Inuktalik, Colin Okheena, Tony Alanak, Allen Joss, Ross (Napayok) Klengenberg, Kelly Nigiyok and Roland Notaina. In addition to Adam Kuptana and Koral Kudlak (project coordinators), Laverna Klengenberg (project lead), and the wider contribution of the Hamlet of Ulukhaktok, for their support for, and administration of, the Tooniktoyok project.

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11. Data Availability Statement

Transcription data cannot be shared publicly because of the need to anonymise research participants. Data are available from the Hamlet of Ulukhaktok (contact via corresponding author) for researchers who meet the criteria for access to confidential data.

CHAPTER V

DISCUSSION & CONCLUSION

1. Introduction, contributions to scholarship

This thesis set out to examine and characterise the vulnerability and adaptive capacity of an Inuit subsistence food system to dynamic, contextual climate change in the community of Ulukhaktok, NT. It makes theoretical, empirical, methodological, and impact contributions to current scholarship concerning the characterisation of Inuit food systems; determinants of Inuit hunting group productivity; and the processual nature of climate change vulnerability in the context of multiple stressors. The following chapter is organised around the objectives that guided the thesis' research, and how these and their respective research outputs correspond to the above contributions. This is followed by a discussion on implications of the key findings, reflections on conducting a PhD within a community-governed research setting, limitations encountered as part of the doctorate, and directions for future research.

This thesis was guided by three overarching objectives:

1. Develop a generalisable approach to better characterise the dynamic, contextual and processual nature of vulnerability to climate change.

2. Combine the new conceptual approach with a participatory, real-time land-use monitoring methodology to understand the vulnerability of the *Ulukhatokmiut* food system to climate change in the context of multiple socially constructed stressors, and to characterise how this affects hunting participation and foodshed stability.

3. Quantify social-ecological determinants of hunting trip productivity in the *Ulukhaktokmiut* food system.

1.1. *Objective one: theoretical contribution*

Objective one was addressed in the first published paper of this thesis (chapter two). The manuscript develops a **theoretical** contribution by combing concepts relating to the temporal component of vulnerability with compatible ideas from complex adaptive systems thinking to develop a new generalisable framing for vulnerability assessment within linked human-environment systems. Specifically, it builds and expands upon past vulnerability research – primarily from the fields of sustainability, political ecology, and natural hazards and climate change (e.g. Hewitt, 1983; Ford & Smit, 2004; Füssel & Klein, 2006; O'Brien *et* al, 2007) – that has conceived vulnerability to be a function of relative exposure-sensitivities and adaptive capacities, and has placed an emphasis on the impact of biophysical stimuli being rooted in the context of social environments. It goes beyond past conceptualisations by building upon the principle that vulnerability is process-based, should be seen as continuously dynamic and in a disequilibrium state, and is governed by the complex interaction of multiple social and biophysical components in a system over time. Specifically, it focuses on the principles that interactions between components of social-ecological systems can develop webs of causality, exhibit feedbacks and alter system structure or function; that systems are capable of redundancy and adaptive learning; and that the application of stimuli creates hierarchical interactions that can be both endogenous and exogenous to the system in question (see Rammel *et al.*, 2007; Levin *et al.*, 2013; Coetzee *et al.*, 2016; Preiser *et al.*, 2018).

The generalisability and efficacy of the new approach is evidenced through the global scope and multi-disciplinary nature of its subsequent application and impact. Its concepts and/or definitions have been referenced and applied in the development of subsequent vulnerability and complex adaptive systems frameworks (see Thiault *et al.*, 2021 Li *et al.*, 2021; Greenlees & Cornelius, 2021). In addition to vulnerability assessments including investigations into farming risks from climate change in New Zealand and Java (see Cradock-Henry, 2021; Suciantini *et al.*, 2020); social vulnerability and livelihoods trajectories in coastal Vietnam (see Thanh *et al.*, 2021); and population change and its implications for environmental vulnerability in Tehran (see Rezaei Rad & Akbarian, 2020).

1.2. *Objective two: empirical and methodological contribution*

Objective two was addressed in the second paper of this thesis (chapter three). The manuscript develops and applies a two-year, community-led GIS monitoring initiative, underpinned by the complex adaptive systems framing described in chapter two, to assess the spatiotemporal vulnerability of the *Ulukhaktokmiut* subsistence sector to climate change in the context of multiple social, economic and political stressors. It reconciles with the fact that previous studies addressing subsistence hunting have often failed to account for the dynamic, processual nature of climate vulnerability, and have been ineffectual at determining the relative salience of climatic stimuli as compared with other concerns experienced by Inuit hunters on a day-to-day basis (e.g. poverty, impact of colonial legacies, etc.). Its findings make an **empirical** contribution by indicating that, although environmental changes brought on by a changing climate are having an impact on the stability of the *Ulukhaktokmiut* foodshed, events and processes attributable to climate change are often not the dominant stressors disrupting it. Instead, socially-constructed determinants of vulnerability and adaptive capacity in the Arctic – rooted in the historical process of colonialism and sedentarisation – such as time spent on the land, reciprocity between hunters, the reliability of machinery, and the spatial constriction of the foodshed over time appear to constitute more immediate pressures.

In addition to an empirical contribution, the completion of objective two also develops a **methodological** contribution. Although harvester studies of this type have been conducted in other, larger population centres in the Canadian Arctic, such as Iqaluit (e.g. Ford *et al.*, 2013), to the authors' knowledge this work is the first of its type to track and interview a cohort of this size in real-time (n = 10), over a continuous time period (2 years) in a community-governed research setting, and with an Indigenous project co-ordinator as a primary interviewer. Moreover, it is also the first to utilise a cloud-based passive tracking system to document Inuit land-use in the Inuvialuit Settlement Region, and to the author's knowledge constitutes one of the most comprehensive grassroots GPS tracking projects ever undertaken in a single community in the Arctic. Having tracked approximately 24,000km of trails, it is on a par with the scale of government-administered wildlife monitoring initiatives adopted further east, such as the Nunavut Wildlife Management Board's Community-Based Monitoring Network (see Ndeloh Etiendem *et al.* 2020).

1.3. *Objective three: empirical and methodological contribution*

Objective three was achieved in paper three (chapter four) of this doctorate through a statistical analysis of determinants of hunting group productivity in Ulukhaktok. In total, data from 23 variables collected during the 2019 calendar year were subject to statistical analysis, with the application of a multivariable linear regression model providing an **empirical** contribution by indicating that month of the year, number of companions, days on the land, and number of specific animal species harvested (large mammals and fish) are associated with the per-kilo productivity of hunting trips taken from the community. In addition, despite being positively associated with hunting trip productivity when assessed through a univariable linear regression model, gasoline was not a statistically significant determinant of standalone trip yield when adjusting for other variables in a multivariable linear regression. These findings improve our contemporary understanding of the *Ulukhaktokmiut* foodshed as a linked human-environment system. The latter relating to gasoline should be considered especially important, as it adds a key piece of evidence to work cautioning against assumed relationships between fossil fuel consumption and rates of productivity across all Arctic communities (Ready & IRC, 2021). Given the drastic sociocultural, economic, demographic and environmental changes the Arctic has experienced as a whole over the past 35 years, filling knowledge gaps that have emerged relating to what exactly drives and underpins Inuit hunting success is essential. This work also compliments the previous paper in this thesis by further elucidating possible drivers that might limit participation in hunting activities more generally. Moreover, it also points to the complexity of Arctic Indigenous food systems, and the importance of social and economic factors as drivers of both harvesting participation and success (Usher *et al,* 2003; Collings, 2009a, 2011).

To the authors' knowledge, this paper makes a substantial **methodological** contribution, as it represents the first published statistical analysis of determinants of per-kilo hunting group productivity in the Canadian Arctic (in terms of hunting parties and their specific hunting trips) since the mid-1980s (see Smith, 1985). It is also the first of its type do so for the Inuvialuit Settlement Region and, at the time of writing, constitutes "the best available fine-grained data on harvesting in the ISR" (Ready & IRC, 2021, p.33). Moreover, unlike other harvest studies conducted at the regional level across the ISR, such as the Inuvialuit Harvester's Survey, *Tooniktoyok* is the first dataset to extract data for *unsuccessful* trips and the first to collect data on the location of specific harvests (Ready & ISR, 2021).

1.4. *Thesis as a whole: impact contribution*

In addition to the contributions made by each individual paper, this thesis also developed **impact** contributions as a consolidated whole. In line with calls for greater Inuit self-determination in research, the aims and objectives of this doctorate responded to Inuit-identified research needs surrounding factors that influence participation and success in hunting. Moreover, the research design for *Tooniktoyok* was co-developed in order to facilitate the transfer and documentation of Inuit knowledge about the environment. This transfer and documentation of knowledge occurred not only from participant-to-researcher, but also from participant-to-participant. Both were made possible as a result of the conversational format of the multiple participatory mapping and interview sessions – conducted between 2018-2020 – which allowed for knowledge to be conveyed through narrative: the medium preferred and most commonly used by Inuit. The production of a 1:250,000-scale map of land use and place names collected across the project lifecycle (an anonymised version of which was included in papers two and three) further developed a contribution to knowledge documentation. Not only does developing a repository of knowledge in this manner hold the potential to educate youth about the location of specific places around the community, documenting place names and land use has also been used elsewhere in the Arctic as a mechanism for communities to better assert their claims of sovereignty over their respective regions (QIA, 2012; Bennett *et al.*, 2016).

In addition to the impact contribution related to knowledge transfer and documentation at the community level, the project also increased grass-roots research capacity within the community. This was achieved through the hiring of a local project co-ordinator and the centralisation of the *Tooniktoyok* project's major administrative components within the Hamlet of Ulukhaktok. Constructing the project in this manner has developed a foundation from which the community might independently apply for federal funds or develop and conduct research projects going into the future. The project co-ordinator hired and trained by *Tooniktoyok* has continued to administrate other projects run by the Hamlet, including the Emergency Preparedness in a Changing Climate project, and was employed in a full-time position at the time of writing.

The dataset produced from *Tooniktoyok* has also been used to inform policy development at the territorial level within Canada. Following consultation with the Hamlet of Ulukhaktok, the anonymised numerical dataset from *Tooniktoyok* was shared with the Inuvialuit Regional Corporation (IRC) – the organisation responsible for representing the collective interests of Inuvialuit and for administering governance over the ISR. In 2021, this data was used as a primary evidence base for a report examining the possible impact of carbon pricing legislation that is currently being implemented by the Government of the Northwest Territories. Specifically, the report assessed how the NWT Carbon Tax may affect the affordability of the hunting, trapping, and fishing economy of the ISR (GNWT, 2020a; Ready & IRC, 2021). Based on the *Tooniktoyok* data, which was used to calibrate aspects of the federally funded Inuvialuit Harvest Survey, the report calls for:

1. Slower implementation of carbon pricing initiatives within the ISR due to the uncertainty of how these will affect the subsistence economy.

2. The need for harvesters to not be penalised by carbon pricing legislation (due to the lack of availability of non-gasoline reliant technologies) and to instead be incentivised to transition to more fuel-efficient transport (i.e. four stroke engines).

3. The need for offset payments to account for the productivity of high-yield households, so as to ensure that 'super households' who share and travel regularly are not disproportionately affected.

(see Ready & IRC, 2021).

2. Discussion of key findings

2.1. *Climate change (for now) is infrequently a primary stressor; hunters are typically highly adaptable*

Alongside recent calls to 're-frame' dialogues away from a "singular focus on climate change" in Arctic HDCC research and beyond (see Huntington *et al.*, 2019, p.1217), this thesis adopted a holistic approach to the study of climate vulnerability in Northern subsistence foodsheds through the application of a generalisable complex adaptive systems framing. Applying such a framing has added to a body of recent research across Inuit Nunangat indicating that the impacts of climate change on subsistence food systems are highly nuanced, and spatially and temporally dynamic (Ford *et al.*, 2013; Fawcett *et al.*, 2018). Specifically, its findings suggest that climatic stimuli are highly variable in terms of their magnitude of impact and frequency in Ulukhaktok; particularly when these stimuli are viewed in relation to (and contextualised by) socially constructed stressors. Crucially, a key conclusion is that factors associated with climate change are infrequently the most salient stressors affecting the *Ulukhaktokmiut* food system in terms of the regularity with which they impact hunting participation and hunting success. Exceptions to this emerged in the immediacy and aftermath of extreme weather and ecological change events attributable to climate change. More commonly, non-biophysical factors – arising from systemic acculturation, long-term socioeconomic marginalisation, and colonialism – such as the availability of supplies, the time constraints imposed by the wage-based economy, or the longer-term implications of centralisation *vis-à-vis* the proximity of the community to animal species, held a greater influence over the foodshed on any given day. Specifically, socially-constructed factors were found to impact harvesting more frequently in terms of *i)* initiating hunting on any given day, *ii*) the general ability of individuals and youth to develop skills required to hunt, and *iii*) and the edible weight a hunting trip might return once it has commenced.

Presently, the infrequency with which the community foodshed becomes vulnerable to climatic stimuli is attributable to the fact that the majority of climate-related stressors on a given day are incremental and slow-onset. Typically, climatic stressors are manifesting as gradual changes to the environment, such as year-on-year changes in breakup/freeze up, altered trail conditions, and animal distributions and health that are in a state of flux. In a majority of cases, incremental changes to the environment such as these were depicted by participants as an additional 'veneer' of susceptibility that overlay more severe contemporary and aforementioned intra-community issues tied to colonialism, contemporary Westernisation, and economic marginalisation. This characterisation reconciles with recent trails access modelling, conducted by Ford *et al.* (2019a), who in a study of 16 communities across Inuit Nunangat, found that between 1985-2016, the impacts of climate-related stimuli arising from >2ºC of warming were minimal relative to "the knowledge, equipment and risk tolerance of trail users". Similarly, qualitative research by Sawatsky *et al.* (2021)

notes the importance of individual and collective experiences of hunting when out on the land as crucial to determining how hunters presently respond and adapt to incremental climatic changes.

The relatively low incidence of climate-related changes being the primary stressor, and their characterisation as a 'veneer', is also potentially attributable to the high adaptability of hunters and evidence of adaptive learning displayed in the face of incremental environmental alteration; a phenomenon that has become increasingly well documented across Inuit Nunangat in recent years (see Ford *et al.*, 2006a, 2020; Wenzel, 2009; Laidler *et al.*, 2009; Pearce *et al.*, 2015). A strong example of this recorded in the study was the 'bricolage' approach that was exhibited among a number of hunters. Here, an expectation of encountering adverse conditions (or *emergent* events – see chapter two) led to harvesters bringing an assortment of tools or 'bric-a-brac' that could be used to develop temporary fixes for sleds and machinery damaged by poor trail or sea ice conditions. This suggests, as per Kelman *et al.* (2015, p.22), that experiencing high-frequency, low-magnitude climate stimuli may have become 'normalised' within the community, and infrequently threatens the foodshed due to "response mechanisms [and adaptations] that [have become] fully embedded within… everyday life" (see also Anderson, 1968). The high adaptability displayed by many hunters, and the consistency with which they currently experience and overcome adverse conditions, was also evidenced in the multivariable linear regression component of this doctorate (chapter four). Despite experiencing environmental problems on more than 1 in 10 trips in 2019, observations of environmental change were not statistically associated with the edible weight yield hunters returned to the community within the multivariable linear regression that was produced.

Potential limits to hunter adaptability and adaptive leaning were observed across the study period in the case of anomalous, extreme events attributable to climate change, such as the drastically reduced winter 2018/19 ground-snow depth or the July 2019 tunicata bloom. Qualitative interview data found that in many cases adaptive response mechanisms that have been incorporated into the general practice of preparing for a hunting trip are often insufficient to deal with these events, and climatic extremes were found to sometimes preclude harvesting trips from taking place for days at a time or make them considerably more high-risk. This was often in part due to concerns over land access or safety, but, in the case of the tuncata bloom, was also attributable to fast-onset ecological changes. It should be noted that neither of these factors (changes in snowpack depth or ecological instability) were accounted for in the aforementioned quantitative study by Ford *et al.* (2019a) that suggested climatic changes in the Arctic presently have a minimal impact on trails access[1]. Given the complexity of climatic stimuli encountered and the range of differential adaptive capacity recorded between harvesters, in terms of both their socioeconomic background, their social

[1] Use of snow depth data in the study was precluded due to a lack of instrumental data across communities, while ecological changes were likely not accounted for in light of the paper's focus on trails *access* as opposed to the stability of the food system more generally (see Ford *et al.*, 2019a, supplementary materials).

relationships, and their ecological knowledge, establishing at what point stressors transitioned from requiring response mechanisms that were a part of everyday life (and therefore allowed trips to commence) to those requiring exceptional or insurmountable degrees of adaptive capacity was difficult to ascertain. Among wage-earning hunters and households with high financial capital, the ability to invest in larger boats, or to use back-up machines if others broke, often allowed travel in poorer conditions. In the case of older hunters with increased ecological knowledge, adaptability was dependent on the applicability of established knowledge, which in some cases was tested by conditions that had not been encountered previously in an individual's harvesting career.

Notwithstanding uncertainties as to the degree to which climate change is affecting trail access and hunting success in Arctic communities relative to other stressors, the presence of at least two anomalous climatic events over just a two-year period in Ulukhaktok should still constitute a point of concern. Especially as recent biological evidence indicates that ecosystems proximal to Ulukhaktok may be at an ecological tipping point (the Chukchi and Bering Sea) (see Huntington *et al.*, 2020). Projections from recent scientific literature also suggest that the severity and frequency of the extreme events recorded in Ulukhaktok between 2018-2020 may yet increase. The *Special Report on the Ocean and Cryosphere in a Changing Climate*, for instance, highlights projections of 5-10% reductions in Arctic autumn and spring snow extent by 2050 under stringent reductions in global CO_2 emissions, with projections of a 15-25% reduction by 2100 under a worst-case emissions scenario (IPCC, 2019; see also AMAP, 2017). Regarding ecological change, there is uncertainty as to how increased Arctic Ocean productivity might affect tunicata blooms (Pettit-Wade *et al.*, 2020). However, recent studies conducted in the Beaufort Sea have pointed toward increasing concentrations of the invertebrate, courtesy of increased periods of open water, changing wind speeds and coastal upwelling attributable to climate change (Pettit-Wade *et al.*, 2020; Lewis *et al.*, 2020).

Placing 'climate in context' has been crucial for developing critical approaches to understand what makes communities and linked human-environment systems vulnerable (Ford & Smit, 2004; O'Brien *et al.*, 2007; Huntington *et al.*, 2019). The findings of this research provide a rationale for the continued use of contextual climate-focused approaches. Specifically, the fact that climate change was infrequently found to be the principal stressor affecting the community foodshed suggests that there is little foundation to past critiques that HDCC research designs and methodologies *a priori* privilege the role of climatic stimuli as stressors (Ford *et al.*, 2018; Ready & Collings, 2020). This is reflected in other work conducted following the adoption of contextual HDCC vulnerability approaches: in a review of 125 such studies published since 1996, Räsänen *et al.* (2016) found that ***non-***climatic stressors are identified as the major stressor affecting vulnerability in a majority (53%) of studies. Similarly, in a review conducted by McDowell *et al.*

(2016) assessing 274 community-level climate vulnerability assessments, climatic stimuli were identified as the main driver of vulnerability in just 21% of studies. Combined with the likelihood that the magnitude and frequency with which climate change affects and interacts with other stressors experienced at the community-level in the Arctic is set to increase – and will therefore likely hold progressively stronger relevance as a stressor – calls to abandon critical HDCC approaches may therefore be somewhat premature (Cameron, 2012; Haalboom & Natcher, 2012; Ford *et al.*, 2018).

The utility in adopting a climate-focused approach is through the fact that issues associated with climate change cross-cut and interact with so many components of human-environment systems at the community level and beyond (Moser & Hart, 2015; Simpson *et al.*, 2021). Few other potential stressors identified were so pervasive across the community, with the exception of the impacts of colonisation. However, given the composition of the research team tasked with data analysis and writing of research outputs as predominantly White, Eurocentric, and non-Indigenous, exploring the food system from a paradigm centred primarily around the issue of colonisation could be considered inappropriate (Smith, 1999; Aveling, 2013). Although *Tooniktoyok* was guided by Inuit priorities for research (see ITK, 2018) and aimed to develop a community-governed research agenda through the decentralisation of research power, non-Indigenous members of the research team held no true comprehension of what it is like to be colonised, nor were they able to claim to hold an Indigenous worldview (Smith, 1999; Aveling, 2013; Naylor, 2021).

2.2. *Climate change adaptations and hunting productivity are interlinked, and are rooted in household and community-level socioeconomic factors arising from the effects of colonisation*

Individualised and household-level, socioeconomic factors emerged as some of the most substantial drivers underlying both adaptive capacity and exposure-sensitivity in the *Ulukhaktokmiut* food system; both in terms of susceptibility to climate change and the productivity of the hunting trips. This reflects wider subsistence-focused research conducted across almost two decades in Inuit Nunangat, which has repeatedly identified – across multiple communities – issues relating to systemically engendered poverty, wildlife management, and the strength of social relationships as crucial determinants of food security and climate change adaptation (e.g. Ford *et al.*, 2006b; Ford & Beaumier, 2011; Pearce *et al.*, 2015; Ready & Collings, 2020; Snook *et al.*, 2020; Gilbert *et al.*, 2021). The continued significance of economic factors rooted in an individual or household's financial capital, and social factors rooted in ecological knowledge transfer and the use of social networks to borrow supplies and machinery, raise a pertinent question: *have federal policy approaches been optimised to also promote sustainable food systems and self-determination in Inuit Nunangat, or have they instead worked to maintain a status quo of acculturation and economic marginalisation?*

Federally and regionally-administered policy approaches aimed at harvester support were seen by many hunters in Ulukhaktok to be 'quick fixes' to problems that ignored – or in some cases exacerbated – underlying root causes. It was evident that hunters felt that initiatives did not address *why* financial support was necessary in the first place, and that little was being done to tackle systemic issues that developed high rates of food insecurity and in-sovereignty across Inuit Nunangat in the first place (see Council of Canadian Academies, 2014; St Germain *et al.*, 2019). Regular critiques were provided for both the Nutrition North Canada (NNC) and the Inuvialuit Harvester's Assistance (IHAP) programmes in particular, which were identified as being archetypal of federally and regionally administered policy approaches in Arctic Canada.

With the example of Nutrition North Canada (NNC) in particular, hunters raised concerns over a lack of historic support for harvesting within budgets as compared with subsidies provided for store bought foods. Many also commented on the efficacy of the initiative's primary aim to make healthy and staple foods in Northern communities more affordable (see St Germain *et al.*, 2019; Ford *et al.*, 2019b; Naylor *et al.*, 2020a). A lack of support for harvesting enshrined in historic NNC policy was seen to hold knock-on effects for the dominance of southern foods in the diets of young people (see also Pearce *et al.*, 2010; Collings *et al.*, 2016) and the ease with which hunters could afford to take youth out on the land to learn. Although the recent federal budget for NNC has seen a new allocation of "$40 million over 5 years, and $8 million per year ongoing, to Indigenous governments and organisations" in support for country foods harvesting, it is notable that the majority of these funds will be sequestered within Nunavut Territory (see NNC, 2020). In addition, by providing funds for harvesting, rather than tackling the underlying the root causes of *why* additional funds are required in the first place, the initiative is still failing to address the aforementioned systemic factors that cause hunters to require federal support (St Germain *et al.*, 2019; Ford *et al.*, 2019b).

In light of ethoses regarding the sale of country foods within communities (Ford *et al.*, 2016; Searles, 2016), and the depression of prices in the fur trade in recent decades relative to the increasing cost of supplies and equipment (Wenzel, 1996, 2019), there is a situation where harvesting infrequently provides hunters with a return on their investments in equipment (Condon *et al.*, 1995; Hoover *et al.*, 2016; Fawcett *et al.*, 2018; Wenzel, 2019). Although harvester support programmes operating in Ulukhaktok prior to 2021 provided direct financial support toward the purchasing of machinery or supplies (e.g. IHAP or the Community Harvester's Assistance Programme), these often only covered overheads relating to a partial cost of harvesters' expenses (e.g. machinery, or parts), and receiving a subsidy for consumable supplies (e.g. fuel) was only covered by one initiative (CHAP)[2]. This means that hunting households in the community are increasingly under pressure to either make a profit from their harvest or to have wage-earners in order to pay for their hunting *and* their living expenses (see also Condon *et al.*, 1995; Fawcett *et al.*, 2018). In interviews, the *Tooniktoyok* cohort also questioned the equity and fairness with which funds were allocated to successful applicants under some programmes. One participant suggested that younger hunters were struggling to receive the correct or adequate allocations, with preference instead given to "people who get equipment but then… just use it around town": a factor that may have been attributable to one harvester having to frequently borrow machinery from elders within his social network.

The problems documented in this thesis *vis-à-vis* the profitability of harvesting, in addition to issues associated with the current provision of harvester support programmes in Ulukhaktok, add credence to arguments made recently by the Qiqiktani Inuit Association (QIA) (2019) and Inuit Tapiriit Kanatami (2019, 2021), who contend that some of the greatest impediments to hunting and sustainable food systems in Arctic communities stem from systemic socioeconomic inequality and the marginalisation of Inuit knowledge systems and values. The former argue that harvesting needs to become "a paid job" with harvesters' support and stewardship programmes funding wages for hunters. Doing so, it is reasoned, will support food sovereignty in the North by increasing production and reducing the amount community members spend on food costs[3], revitalise the hunting economy, and promote equitable sustainable development by reducing socioeconomic inequality (QIA, 2019). They also point to the reconciliatory and healing role of federal investment in hunting as a viable economy, which could "yield profits beyond… economic value" by improving rates of mental health and wellbeing that contribute to Inuit becoming '*Innumarik*' ('a person acting from a place of wisdom', or one seen to be a 'real' Inuk) (see also Collings, 2009).

ITK's (2019, 2021) *Inuit Nunangat Food Security Strategy* and *National Inuit Climate Change Strategy* promotes a broader-scale vision for development in terms of policy and governance. The former makes the case for integrating food security and poverty reduction actions by increasing infrastructure development in Inuit Nunangat, particularly relating to harvesting, and suggests that Inuit self-determination needs to be a crucial component in any future poverty reduction initiative. Specifically, the document questions the current Canadian federal method for measuring poverty

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[2] As of April 2021, IHAP(2020) could cover the cost of 'major' harvesting equipment (e.g. snowmachines, ATVs) "up to 75% of the total cost of the item… with a minimal annual contribution of $5,000 per applicant", and 'minor' harvesting equipment up to 75% with "a maximum annual contribution of $1,000 per applicant".

[3] Available studies from Ulukhaktok suggest that harvesting country foods is substantially more affordable for households than purchasing store bought equivalents. In the 1980s, the cost of producing 1kg of country food was 20% less than purchasing in stores would be. In 2019, a policy brief produced by the *Tooniktoyok* hunters suggested that 1kg of store-bought meat was between 10-49% more expensive dependent on a harvester's rate of productivity (Appendix B; Smith & Wright, 1989, Wenzel, 2019).

(the Market Basket Measure (Statistics Canada, 2019)), and the current territorial-level implementation of federal policy (which does not disaggregate between majority-Indigenous and non-Indigenous jurisdictions in Canada). ITK argue for unconditional basic income payments for low-income families, in favour of current strings attached, 'poverty trap' social assistance mechanisms, which may facilitate increased spending on harvesting equipment. Moreover, they suggest that there is a need explore the development of commercial sales of country foods in the form of a Greenland-like model (ITK, 2021). Here, country foods are sold country-wide by retailers and in public markets, and can increase the profitability of hunting while reducing the costs of meat in stores and allowing for more culturally-relevant food choices (Searles, 2016; ITK, 2021).

The *National Inuit Climate Change Strategy* (2019) promotes the principle that adaptive capacity within food systems and beyond, at individual, household and community levels, would be improved by initiatives aimed at tackling the issues surrounding sustainable development, self-determination *and* climate change. Again, the document holds a strong focus on harvester support, with Priority Area three – 'Reduce the climate vulnerability of Inuit and market food systems' – advocating for support for Inuit households incurring damages or loss to harvesting infrastructure as a result of climatic changes, and for hunter support programmes to also cover search and rescue and marine services infrastructure (e.g. coastguard boats). Support is also outlined for the need to develop infrastructure, such as community freezers and processing plants that hold the potential for increased community-level food security and foodshed stability, but that can also develop economic opportunities from harvested products (see also Organ *et al.*, 2014). The example of the Inuvialuit Community Economic Development Organisation's investment in a 'Country Food Processing Methods' training course and country food processing facility in Inuvik is given (see IRC, 2016), whereby the programme attempts to promote economic benefits and accessibility of country foods in the ISR. The document contends that if the strategy is successful, there would be efficacy in the development of smaller-scale processing facilities and community freezers in each ISR community.

Both the QIA and ITK strategies highlight a need for programmes, research and policy aimed at reducing contextual climate change vulnerability to be embedded in initiatives that *primarily* combat socioeconomic inequality and the reversal of acculturation practices that have affected social determinants of hunting success and participation. Both organisations contend that transformative adaptations, aimed at systemic change and promoting adaptive learning, as opposed to those taken incrementally within the status quo are required. Most pertinently, through anticolonial and emancipatory approaches to Inuit self-governance and self-determination. This is reflective of recent trends in academic research in recent years, both in terms of how research is conducted in Inuit Nunangat, but also in their policy recommendations. There is increasing recognition that current initiatives aimed at promoting development or reducing socioeconomic inequality, such as

Nutrition North Canada, are consistently found to be falling short of their ultimate goals, and may be in need of more transformative, structural changes in terms of their administration and implementation (Galloway, 2017; St Germain *et al.*, 2019). Moreover, a transition toward fostering Inuit self-determination in research projects has produced not only more relevant, impactful results, but has also been cited as holding the potential to increase long-term community-based research capacity and for communities themselves to apply for funds to conduct research more independently of Western institutions (Pearce *et al.*, 2009; Pfeifer *et al.*, 2018; Carter *et al.*, 2019; Sawatzky *et al.*, 2020).

3. Reflections on working on a community-governed research project[4]

Community governed and stakeholder-led research projects are increasingly considered as a 'best-practice' and are becoming a prerequisite for successful federal- and research council-level funding in Inuit Nunangat (ITK, 2018; Pfeifer et al., 2018; FRQ, 2021; UKRI, 2021). The notion of a project being 'community governed' typically requires the devolution of power relating to decision-making, values, ethics, and knowledge production from Western academic and governance contexts into community-based Inuit-led organisations and institutions (Carter et al., 2019; Wilson et al., 2020). Such an approach is seen as an opportunity to redress some of the inherent imbalances relating to extractive means of data collection, lack of compliance with research protocols or capacity building at community levels, and the biasing of Western worldviews that have been characteristic of much past (and present) social, health, and natural sciences research involving Indigenous peoples (Koster *et al.*, 2012; Carter *et al.*, 2019; David-Chavez & Gavin, 2018).

However, community governed research and wider participatory research initiatives involving the Western academy in Indigenous contexts are not without unique challenges or contention (Pearce *et al.*, 2009; Carter *et al.*, 2019). Mosurska & Ford (2020), for instance, scrutinise the degree to which diverse communities can be adequately represented or defined in 'community-based' research, what constitutes an adequate or capacity-building level of 'participation', and what governs who 'participates' in such projects (see also Titz *et al.*, 2018). Others have questioned the prerequisite assumption that decentralising decision-making power and responsibility from researchers and the academy is always positive, and suggest that this may lead to the burdening of communities with research responsibilities as opposed to having an emancipatory effect – inadvertently opening them up to increased accountability to funders for mistakes that researchers may make (de Leeuw *et al.*, 2012). In the following paragraphs, I reflect on the issue of power in *Tooniktoyok*, and question whether devolution of power in some areas, but the retaining of Western research specialists (as is

[4] This section contains aspects of published work abridged from a book chapter produced by Naylor in *Research with Arctic Inuit Communities: Graduate Student Experiences, Lessons and Life Learnings* (see Naylor, 2021).

frequently the case in contemporary community-governed projects) reproduced inequalities and perpetuated a hierarchy of knowledge systems within the project.

In many ways, the project developed for *Tooniktoyok* was a substantive, and on-paper effective, attempt to develop and conduct efficacious community-governed research. To my knowledge – and those of the other researchers involved – it represents one of the first instances of a CIRNAC-funded research project in the ISR where a community organisation held more *de jure* control over research processes, timescales and budgets than the university researchers with whom they were collaborating. It made considerable efforts to devolve power across all parts of ITK's '5 Priority Areas' for the conduct of "respectful and beneficial research for all Inuit" (see ITK, 2018). *Tooniktoyok* was a three-year joint research initiative, funded by Indigenous and Northern Affairs Canada's (INAC) *Climate Change Preparedness in the North* program and led by the Hamlet of Ulukhaktok, with additional research support provided by researchers from the University of Guelph, the University of Northern British Columbia (UNBC), and the University of Leeds. In contrast to previous participatory projects conducted in the community, which had often been collaborative but with researchers maintaining a majority stake (e.g. Pearce *et al.*, 2010, 2015; Fawcett *et al.*, 2018), *Tooniktoyok* was community led *and* community administered. This meant that the primary community stakeholder, the Hamlet of Ulukhaktok (hereafter referred to as 'the Hamlet'), retained oversight over a majority project activities, including the setting and reviewing of aims and objectives, the hiring of project coordinators and research participants, the types of methods used for data collection, aspects of data collection when researchers were absent from the community, and the storage and relaying of data. The Hamlet were the primary point of contact with the funding body, Crown Indigenous Relations and Northern Affairs Canada (CIRNAC), with whom the deliverables of the project were agreed, and with whom financial and wider project activities reporting were required on a bi-annual basis.

Over the course of my tenure as a doctoral researcher working on *Tooniktoyok*, however, it became evident that there is a difference between *de facto* (on paper) and *de jure* (in practice) control in community governed research. Although I feel that the community-governed and capacity building aspects of the project genuinely developed a positive impact, reflecting on how the areas where the project did not develop true emancipatory potential in terms of promoting Inuit self-determination in research is worthy of attention. Firstly, the degree to which the project was able to 'devolve' power from researchers to the community is contentious in light of the privileging of knowledge systems within the funding agreement. Despite the project being 'community-led', in the sense that it was administered and conducted by the community through a local project co-ordinator, the fact that final deliverables were developed and largely geared toward compliance with a funding contract that was agreed with the federal government placed constraints on the ways through which research outputs could be Indigenist. Notably, the funding agreement dictated that the project develop a Western cartographic representation of knowledge and a statistical analysis of factors affecting hunting productivity (a method predicated on acceptance of a positivist knowledge system). Although this is something the community-members desired, in light of discussions that 'numbers talk' when attempting to inform government policy, this also meant that the ultimate power relating to the research – the generation of outputs – was still governed by factors external to the community. This was a direct consequence of the fact that technocratic knowledge and skills required for creating maps and producing statistical analyses were areas where only the Western researchers on the project held expertise. Indeed, while *Tooniktoyok* was designed to ensure that the local project co-ordinator was deeply involved in the data collection component of the research and the interpretation of participant interviews – with the primary aim of increasing the community's future research capacity – it was not possible to develop a system of training that would allow them to conduct the statistical and GIS analysis of the research. This was in part due to the sheer difficulty of training an individual in relatively complex statistics and GIS skills in such a short space of time, but also due to the limits of how academic institutions themselves currently licence and make software available (which in this case was to the researchers but not the project participants or co-ordinator). Despite the fact that the community had *de jure* power to select what data was collected, and indeed *how* the data was collected, the need to produce outputs that were 'usable' by the Government had the effect of epistemologically assimilating and constraining participants' and other stakeholders' power. The result was that the 'most impactful' outputs of the research were still processed through, and converted into deliverables with, a Western valence due to the epistemological bottleneck that we as researchers from the academy had created. Although some increased capacity for research was developed, the ability of the community to conduct research projects without the need for external specialists remains limited (see Bielawski, 2003; Kovach, 2010) (see also chapter five, section 4.4).

Alternative outputs and methods of analysis may have been more appropriate to communicate the narrative of Tooniktoyok, as opposed to the production of cartographic maps and statistical analyses. The degree to which this was achievable in the current climate of academic research, however, is questionable. Many academic institutions, for instance, as mine does, still expect outputs in PhD projects to have a dominant Western valence (e.g. journal articles, theses, monographs), with their legitimacy often judged from this same paradigm, predicated on the idea of usability, impact and 'scientific rigour'. Moreover, funders, if they are positioned within this paradigm (as the Canadian federal government is) often also expect deliverables that are similarly situated. To have 'impact' in Western administrations, Western outputs are still very much seen as the gold standard.

So, what can be done? The easiest answer to this is that the academy and funders need to not only recognise the legitimacy, but encourage the production, of outputs with non-Western valence by Indigenous peoples when research is conducted in Indigenous contexts. This goes beyond simply paying lip service, which appears to more often than not be the primary approach. Moreover, beyond recognising its legitimacy, Indigenous research also needs to be applied in policy development. Elevating Indigenist outputs in this manner will negate the need for, or at least reduce the privileging of, Western specialists, and by extension will remove the epistemological bottleneck that is so common in CBPR and community-led research involving academics.

Reducing the perceived need for Western specialists, may also help address the undercurrent of power that so many southern researchers hold when assisting in community-governed research. Working on a community governed project as an external 'specialist' diminished my explicit research power: I could not select participants, or set times for interviews or participatory mapping sessions without approval. However, simply through association with the Hamlet my status in the community felt different to that of independent researchers; I was implicitly empowered. I went from the common trope of an ephemeral graduate student who drifts into town for two months and is then never seen or heard from again into the 'one working with the Hamlet on the CIRNAC project', 'the one who will make the maps', or, in one case, 'the one who will make the maps for the Government'! Before I knew it, or had really considered the ethical implications of the mantle I adopted, I had been allocated office space, offered the keys if I wanted to work 'out of hours', given access to satellite internet to complete the GIS data uploads, invited to make use of the coffee facilities, and was finding myself privy to information that, in retrospect, I should never have heard. During my first stint in the community myself and the other 'specialists' were even offered the currently vacant unit of the community's Senior Administrative Officer when no other accommodation was available.

None of these things would have been available had we not accepted the niche of power for ourselves when co-developing the project. Although it could be argued that my participation and activity with the project (and subsequently the Hamlet's facilities) was a space into which I was invited - and indeed, some of the resources I was offered were necessary for the conduct of the research - I wonder how much of this 'inviting' came from the privileging of my knowledge system in the construction of the research project, and, by extension, my replicating of pre-existing colonial power relationships through participatory research (see Cooke, 2003; Haklay, 2013). Given the past context in which our funders CIRNAC, formerly Indigenous and Northern Affairs Canada (INAC), had historically operated in the North I now, in retrospect, find the latter a particularly troubling prospect. In co-designing the project to remove ourselves from many areas that are considered crucial for promoting self-determination, yet still designating ourselves as the sole members of a research team with the ability to create a set of deliverables, myself and the other academics 'researched ourselves (and the federal government's stipulated required outputs) into the research', as opposed to 'researching ourselves out' (Caine et al., 2007). The decision to have a map and set of statistical analyses, and the fact that I was the sole member of the project tasked with creating them meant that I had become the vector through which all data needed to pass through and be catered for. I had assumed the "mantle of expertise" and held the "power to shape the nature of truth" (see Reid & Sieber, 2020, p.7).

3.1. *Concluding thoughts*

While there appears to have been some progress in this area in recent years from a funding perspective, with regulations necessitating the inclusion of Inuit ecological knowledge in wildlife research and management in the North, the academy seems much further behind. Doctorates still require the production of peer-reviewed journal articles, theses etc., and are therefore still entrenched within Western worldviews. Beyond non-Indigenous PhD researchers extracting themselves from the process altogether (Aveling, 2013), this can often lead to ethical quandaries and conundrums. These are things that should rightfully make any academic, PhD researcher or otherwise, uncomfortable.

This section has only been able to communicate my experiences and opinions on Northern research as a non-Indigenous researcher. But from these experiences, it has become more apparent to me that, despite the frequent self-aggrandisement that can happen in Western academia – something that I myself am undoubtedly guilty of – "look at how Indigenist or community-centric our research is!", there is still a very long way to go. I will end this section with reflections from an Indigenous voice on the current state of Arctic research: Pitseolak Pfeifer, in issue 49 of the 2020 *Northern Review*:

> "Arctic warming is certainly a hot topic. For Inuit, though, it is burning: it is about our homelands, and yet we are left out in the national and global climate change conversation... The capacity is there, but it is a distinct, Inuit-specific capacity; the evidence is there, but it has been gathered and documented in a way that has not traditionally sat well with the exclusive understanding of science that drives evidence-based policy-making. If we, as a society, are to understand and design pragmatic solutions to climate change, Inuit need to be at the forefront of the research *and* decision-making process." (my italics).

4. Limitations

4.1. *Reflections on the conceptual framing*

It is acknowledged that no conceptual approach can account for all of the dynamics of the social world or its interaction across ecological systems. Although the framing of complex adaptive systems and vulnerability adopted by this doctorate was developed as a heuristic – and therefore is intended to allow for an understanding of reality through a simplified rendering of it – the approach has a number of limitations that are worthy of recognition and discussion. The approach outlines the notion of systems with definable (albeit loose) boundaries. However, in much of the social world, and through the conduct of this doctorate, defining boundaries within dimensions of the foodshed or food system of Ulukhaktok, and whether processes are exogenous or endogenous, remains an inherently subjective endeavour.

In addition, the specific framework for 'Indigenous traditional food systems' (Box one, paper one) conceptualised dimensions of the CAS as components within a supply chain of traditional foods (quality, access, availability, preparation, storage, distribution), with each component represented as having equal importance. However, when it came to the application of the approach in chapter three, it became evident that challenges relating to the food system in Ulukhaktok may in fact be more closely aligned with components of ICC-Alaska's *Alaskan Inuit Food Security Conceptual Framework* (2015) (i.e. access, availability, utilisation, stability, decision-making power and management, health and wellness etc.) and that certain components (i.e. access, availability) are often a far greater influence on the stability of the food system. Developing a new food security conceptual framework for the ISR was beyond the scope of this thesis, and the use of the Western concept of 'food security' as both a standalone concept and when applied in Indigenous contexts remains contentious (Barrett, 2010; Ready, 2016; FAO, 2021). As such, the term was intentionally avoided where possible in this thesis. It should be noted that the recent Inuit Tapiriit Kanatami (2021) *Inuit Nunangat Food Security Strategy* has since adopted the FAO (1996) Rome definition; though the degree to which this was done to facilitate the strategy to influence policy working within the constraints of the Canadian federal model, or whether the FAO definition was indeed considered the most reflective of Inuit conceptions of food systems, remains unclear. Future application of chapter two's approach to Arctic food systems may consider the development of a new framework, in line with Inuvialuit worldviews about the environment, similar to ICC-Alaska's (2015) report, to better incorporate Inuit worldviews surrounding food security into the research, and to promote a greater focus on food preference and the notion of food sovereignty on research taking place in the North.

4.2. *Practicalities of research design and stakeholder engagement*

Long-term and real-time community-based research projects necessitate significant time commitments from researchers, project administrators and participants (Thomson & Holland, 2003; Fawcett *et al.*, 2017). Both establishing and maintaining stakeholder engagement across the life course of the project was a challenge, particularly for the months of the year when researchers were not present in the community, and when the project timeline was affected by the novel coronavirus pandemic. In some instances, researching and liaising with the local project co-ordinator across time zones (Ulukhaktok being GMT-6) posed a challenge, as did the fact that some participants did not have permanent year-round access to the internet or a SIM card. In addition, the turnover of staff members administrating the project at the Hamlet offices; the fact that COVID-19 regulations in NWT prevented in-person and group meetings; and the desire for the project to not interrupt or place undue pressure on hunters in a way that would affect participation in harvesting activities could also be considered limiting factors. For these reasons, the statistical portion of the thesis was run across 2019 as this was the year with the most complete data collection for every season. With regards to the qualitative aspects of the thesis, although some sessions did not always have full participation from all hunters, and hunters were not always able to draw the routes that they had been on for a particular week due to COVID-19 regulations, the differing composition and size of interview groups had an unanticipated bonus where younger hunters within the cohort – who would typically defer to elders at meetings with stronger attendance – were better able to convey their thoughts undeterred, and a diversity of more in-depth perspectives across a range of issues was collected as a result.

4.3. *Use of standard edible weight calculations*

Although considered best practice for harvest studies, the application of the standard edible weight method used in chapter three for calculating the yield of hunting trips in Ulukhaktok has possible limitations (see Usher, 1976, 2000; Wenzel et al., 2016; Kenny & Chan, 2017). There is likely to be inherent variability in the edible weight of species based upon their sex, age and the season during which they are harvested, which may lead to variance either in the accuracy of the standard during certain times of year, or depending on individual hunter's harvesting preferences (e.g. male vs. female animals, age of animals) (Usher, 1976; Kenny & Chan, 2017). In addition, under changing environmental conditions the general quality and health of some animals in areas surrounding Ulukhaktok have declined over the last two decades (see Pearce et al., 2010; Kutz et al., 2013; Tomaselli et al., 2019). This holds implications for the accuracy of standard edible weights, as they assume that animals are in good health, and by extension that the entire 'edible weight' of harvested animals can in fact be consumed (Usher, 1976, 2000). The standard also does not account for variation in the butchering, preservation, and post-harvest use of country foods (Usher, 1976, 2000). The weight difference between fresh versus dried char (*piffi*) or caribou (*mikpu*) meats can be appreciable, the level of knowledge individuals hold in terms of how to butcher animals may also affect the final weight of edible meat extracted, and the meat from some species, such as cod, are used by some families in the Inuvialuit Settlement Region as food for dogs.

4.4. *Composition of the research team, epistemological bottleneck*

In addition to certain aspects relating to the research design, the composition of the research team in Ulukhaktok is also an important consideration. As an all-male research team, it was decided that it would be inappropriate for researchers to interview women within the community about their experiences. This was due to a common understanding that a gender-match between interviewer and interviewee is best, the fact that hunting and harvesting are in of themselves typically gendered activities, and due to a perception that male-female interviewing may have raised safeguarding concerns among community members. The fact that women were not a part of the cohort in this thesis' research represents a limitation, but also a direction for future research (ch. V, section 5).

Although the *Tooniktoyok* project was co-designed and developed so as to better incorporate Indigenous values and valence with regard to issues affecting climate change vulnerability and hunting in Ulukhaktok, it should be recognised that much of the data analysis and production of research outputs was conducted by the doctoral candidate, and many of the research outputs produced were items such as academic papers, policy briefs or maps. Although this was primarily due to practical considerations relating to both the skills of the research team (much of the data analysis required university-level knowledge of statistics, GIS or thematic content analysis), a desire from the community themselves for the research to have impact, and the requirements for attaining a doctoral degree at a UK university, it could be argued that this also created an 'epistemological bottleneck' within the study (see ch. V, section 3). In my position as a White, non-Indigenous, academy-educated Briton, the situatedness of my knowledge means that I can never have true comprehension of what it means, nor how it feels, to be colonised. Therefore, the fact that I was in some cases the sole individual responsible for producing outputs, no matter how Indigenist or culturally relevant the methods of data collection were, it is inevitable that research outputs and data have been produced from a predominantly Western valence. In order for community led projects to reach their true emancipatory (and anticolonial) potential, it is critical to relinquish and deconstruct decision-making 'power' structures – as was achieved in *Tooniktoyok* – but also the epistemological and ontological implicit power structures that can so often accompany participatory research (Pfeifer, 2018).

5. Future research directions

From the findings of this thesis and its potential limitations, a foundation and rationale for areas of future research emerge:

i). Incrementally applied climatic stimuli versus rapid onset climatic stimuli, and the notion of 'spikes' in exposure sensitivity. This thesis highlighted that the biophysical impacts of climate change can be rapid-onset or incremental, often with drastically different effects on day-to-day hunting activities. However, the vast majority of methodologies currently applied in the Arctic still examine climate-society interactions using either parachute studies (collecting data across a very short period) or rely on participant recall of past climatic events (and are therefore subject to recall bias) (Fawcett *et al.*, 2017; Naylor *et al.*, 2020b). Both of these methodologies fail to properly characterise the nuance and differential vulnerability that can arise as a result incremental versus extreme changes, particularly in social contexts, and the results of this thesis highlight the need for research methodologies, such as real-time and longitudinal methods of monitoring, that can capture both phenomena first-hand. Although this thesis has provided a baseline to better examine extreme and incremental environmental changes attributable to climate, and adds to a body of nascent scholarship with similar goals (e.g. Ford *et al.*, 2013; Fawcett *et al.*, 2018; Archer *et al.*, 2017; Lede *et al.*, 2021), a greater number of studies, particularly conducted outside of the Arctic regions, could provide greater generalisability and opportunities for further conceptual and methodological advancement.

ii). The involvement and experience of women in on-the-land hunting and harvesting in the Arctic. Chapters three and four note that this research used an all-male cohort. The all-male cohort of this doctorate contributes to what is an already gendered dimension within Arctic hunter-gatherer and climate change research (Beaumier & Ford, 2010; Bunce & Ford, 2015; De Olivera Menezes, 2019). In order to fully comprehend the impacts of a changing climate, society and culture on food systems in the Arctic over the past forty years, future research needs to better incorporate and assess the emerging role of women in harvesting and hunting. This could be through exploring the increasingly direct participation of women in the practice of hunting itself, or their more established roles as the primary wage-earners and the part they frequently play preparing, preserving, and distributing subsistence foods within communities.

iii). The costs of hunting: Although the volume of gasoline and other consumables (naphtha, oil, store-bought food) tracked in chapter four of this thesis were not found to be associated with the productivity of hunting groups, the availability of (and access to) adequate supplies to be used on hunting trips emerged in chapter three as a crucial prerequisite to hunting participation. Despite a 'golden era' of economics research into the outfitting costs involved in the Inuit subsistence economy in the 1970s and 1980s, research specifically addressing how much it now costs to harvest in the modern Arctic has been lacking in recent decades. The last study conducted in Ulukhaktok that attempted to produce a costings along these lines was conducted in the mid-1980s (see Smith & Wright, 1989), and compared to other regions of Arctic Canada this could be considered a relatively recent example (e.g. Müller-Wille, 1978; Wenzel, 1983, 1987). Research quantifying the costs of hunting, for instance assessing the cost-per-kilo of harvesting subsistence foods versus store-bought alternatives, holds the potential to inform existing federal government initiatives such as Nutrition North Canada and should be of a particular priority given the level of socioeconomic marginalisation experienced by subsistence-focused communities in Arctic Canada. Despite the creation of a new 'Harvester Support Grant' clause in 2020, NNC remains largely focused on shipping southern food into the North, and questions have been raised as to its efficacy in supporting food security or promoting self-sufficiency and food sovereignty due to the fact that it does relatively little to promote on-the-land harvesting (Galloway, 2017, St-Germain *et al.*, 2019; Ford *et al.*, 2019b).

iv). Implications of concentrated land-use activities across smaller areas: Chapter three identified a possible reduction in the areal extent of hunting range in Ulukhaktok since the early-mid 20th century, and a potential increase in the intensity with which hunting has occurred within the bounds of the foodshed as a result. The implications of concentrating hunting activities in a smaller spatial area remains poorly understood. Future research might ask how land use changes could affect the diversity of species harvested by hunters, the sustainability of harvesting when specific populations are hunted with an increased frequency, and the effects of a decreased harvesting range on adaptation and susceptibility to incremental and extreme changes in the environment.

v). Continued use of culturally appropriate methods to extract quantitative statistics data. This research made use of culturally appropriate semi-structured, or conversational interview formats to extract both qualitative *and* quantitative data; the latter of which was of sufficient quality for use in statistical analysis. This is arguably a proof-of-concept method for collecting empirical data in Indigenous communities in a more equitable and socially responsible way as opposed to simply the use of standardised questionnaires (albeit it requires on a far greater workload and resource provision on the part of researchers). Exploring the efficacy of this approach in other areas (e.g. health sciences, sociological studies) could represent an area for future methodological development.

vi). Understanding direct and indirect impacts of COVID-19 on subsistence economy. Restrictions imposed by GNWT following the onset of the COVID-19 pandemic, in terms of both travel to-and-from the community, in addition to regulations surrounding travel on the land, are likely to have affected subsistence activities at the tail end of the project lifecycle. For example, limits on shipping into the Inuvialuit Settlement Region meant that no cruise ships visited Ulukhaktok in 2020, with implications for the sale of crafts and furs by community members. Moreover, GNWT regulations early in the pandemic meant that hunters could only travel with members of their own household (GNWT, 2020b). Given the importance of hunting group composition on rates of productivity, this may have had a substantive impact on food availability in the community. Due to concerns over the safety and wellbeing of harvesters (limited technology required many interviews to be face-to-face), and concerns as to whether questions covering COVID were covered by the ethics applications of either Leeds or the Aurora Research Institute, it was not possible to explore in-detail the impacts that the novel coronavirus had on subsistence activities as part of *Tooniktoyok*. Given the likely long-term implications of COVID-19 on the global economy and the limits still imposed on travel to Inuit Nunangat going into 2022, this represents a research gap that is worthy of further investigation.

6. Concluding remarks

This thesis sought to examine and characterise the vulnerability and adaptive capacity of an Inuit subsistence food system to dynamic, contextual climate change in the community of Ulukhaktok, NT. A generalisable approach to conceptualising climate vulnerability, situated in a complex adaptive systems and human dimensions of climate change paradigm, was developed and combined with a community-led participatory research approach. The findings presented highlight that climate change is but one stressor affecting Inuit hunting practices, and therefore the vulnerability of the *Ulukhaktokmiut* subsistence food system as a whole. It is evident that (*at present*) climate change impacts are infrequently the most salient driver determining either hunting group productivity or participation in the food system. Instead, complex and interlinked factors relating to economic marginalisation, colonialism and social relationships are considered stronger determinants of food system vulnerability on a day-to-day basis. Moreover, these stressors are also in of themselves – whilst developing significant sensitivities independent of climatic stimuli – often affecting how hunters are adapting to changing climatic and environmental conditions. Although the pertinence of impacts attributable to climate may change in the future, present conditions call into question the current focus of federal initiatives aimed at sustaining the hunting economy and encouraging climate adaptation, which consistently work to maintain a status quo of socioeconomic issues (e.g. systemic poverty, acculturation, marginalisation of Indigenous economies). Recent Inuit-led initiatives, although presently in their infancy in terms of development, provide possible future directions for policy. There are calls for food systems and climate change adaptation programmes applied within Inuit Nunangat to focus on dealing with the root causes of *why* communities are experiencing threats to the stability of their subsistence livelihoods, particularly from a socioeconomic and political perspective. Taking a more transformative approach to how factors affecting the susceptibility of subsistence food systems are tackled and governed would have considerable implications for fostering Inuit self-determination and promoting sustainable development in Inuit Nunangat.

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CHAPTER VI

APPENDICES

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1. **Appendix A:** Ethics approval (AREA 18-117)
2. **Appendix B:** Policy brief produced for CIRNAC
3. **Appendix C:** 1:250,000-scale map with traditional place names.
4. **Appendix D:** Semi-structured/conversational interview guide.
5. **Appendix E:** Leverage, cook's distance, Q-Q plots, predicted value of mean response, loess smoothing scatterplots.
6. **Appendix F:** Raw model outputs, global significance, BIC, and descriptives.
7. **Appendix G:** (S1 Table): S1 Table. Supplementary quotes relating to current exposure-sensitivity and adaptive capacity in Ulukhaktok, 2018-2020.
8. **Appendix H:** S1 Fig. Historic average daily ground snow thickness in Ulukhaktok as a percentage of 2018/19 values.
9. **Appendix I:** Research approach summary.

Appendix A: Ethics approval (AREA 18-117)

The Secretariat
University of Leeds
Leeds, LS2 9JT
Tel: 0113 343 4873
Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

Angus Naylor
School of Earth and Environment
University of Leeds
Leeds, LS2 9JT

**Social Sciences, Environment and LUBS (AREA) Faculty Research Ethics Committee
University of Leeds**

15 April 2019

Dear Angus

Title of study:	**A Longitudinal Approach to Community Vulnerability and Adaptation to Climate Change**
Ethics reference:	**AREA 18-117**

The above project has been reviewed by the Chair of the AREA Faculty Research Ethics Committee. The following documentation was considered:

Document	Version	Date
AREA 18-117 UoL_TPearce_LVA_Ulukhaktok_rebapp_Dec 15, 2017	1	20/02/19
AREA 18-117 Ethics Certificate 20190111 Tooniktoyak Project 2019-2020	1	20/02/19
AREA 18-117 certificate_20180124	1	20/02/19
AREA 18-117 AWN_Consent Form_REB_June 2018	1	25/02/19
AREA 18-117 AWN_Tooniktoyok Final Interview Guide 07_01_18	1	25/02/19

On the basis of the information provided, the Committee Chair requested further information/ clarification of the following matters before a favourable opinion can be given:

1. The Chair would like you to change the information letter. There is a sentence that says any child at risk of abuse will be reported, or something of that nature. The Chair suggests taking this out completely. Raising the question of disclosure of child abuse in the information sheet is inappropriate. Instead in interview the interviewee should be told that if they disclose anything that suggests that they are at risk of harming themselves or others that this will have to be reported. In interviews, the language the Chair suggests you use is that of ‘harms to yourself or others’.

I am in full agreement with this suggested change. I have removed the sentence in question and replaced it with the following:

“If in an interview anything is disclosed that suggests you are at risk of harming yourself or others the researcher must report this to the relevant authorities.”

2. Also, the language used in the information letter is too complex a language; please simplify this and refer to the guidelines at http://ris.leeds.ac.uk/involvingresearchparticipants.

I have made significant changes to the wording of the letter. I have removed words that could be considered 'jargon' (e.g. encrypted/ personal identifiers) and replaced them with more easily understood synonyms (e.g. password-protected/ personal information). The section that discussed the use of a codebook has been simplified to better explain the process of anonymisation. I have also removed (with the exception of the project title) any words that could be considered to have a specific or different academic meaning/definition that is not widely used in a non-academy context (e.g. vulnerability, adaptation). This will reduce the possibility of participants misunderstanding the stated project objectives.

Sentence structure has been changes to reduce the use multiple clauses, and a number of compound sentences have been removed. Comma and more complex punctuation use have been kept to a minimum/significantly reduced.

All changes that have been made to the letter have been viewed through the 'Track changes' function on Microsoft Word.

3. The layout of the information letter is rather busy, and could be simplified. However, this isn't an ethical objection but more guidance for consideration – a different layout could facilitate reading of the information and enhance respondent recruitment.

Where possible I have removed content that was repetitive, and have also shortened or split paragraphs in many of the sections to make the letter easier to read.

In addition, I have included the most important aspects of privacy/participation as bullet points in order to highlight the most important information. I have considered putting sections/sentences in bold, however, I think this may encourage participants to skim-read.

4. One thing that needs to be clear in any guidance on the camera use is that you must not take any photographs that would identify others. This doesn't need to be in the information letter, but must be part of the participant-facing materials.

The following has now been included in the interview guide that is to be used by the local project co-ordinator:

"Note: If any photos are taken during this interview (e.g. of the annotated map), please ensure that these do not show participants themselves, or any identifying materials that may identify them."

I have also produced a confidentiality agreement that is to be signed by research team members (I have attached this as a supplement to my email).

5. Finally, in the interview materials and with the camera methodology, there are high risks to confidentiality and anonymity. The researcher must make extra efforts to mitigate against these.

In order to combat these issues, I have firstly produced a confidentiality agreement that is to be signed by researchers involved in the project (please see attached as above). This addresses the issue of both photography and the confidentiality of interview data.

Secondly, I have also included further guidance in the information letter on the possible use of photography.

"If any photos of the routes that you draw on the maps provided are taken, you will not be in these photos. In addition, any materials that could otherwise identify you will also be removed prior to a photo being taken. As with the other information in this study, only the research team members will have access to photos of maps, or any other photos that may be taken during the conduct of this research. If at any point a photo is found to have been taken that may allow you or another participant or individual to be identified, this photo will be cropped to remove the identifiable portion of the image in question. If cropping is not possible this photo will be deleted and will not form a part of the final project dataset. The project co-ordinator has been provided with guidance on how to take photos of the maps to protect your privacy."

A response should be sent to the Committee which addresses each of these points, and further consideration will be given to your response. Please highlight or use a different colour font to indicate the changes to your application form and supporting documents and provide a summary showing how each point has been addressed. Students are strongly advised to discuss their response with their supervisor before it is submitted.

The Committee is not able to approve your application at this stage so you are unable to begin your research. Please do not hesitate to contact us if you have any questions. Advice can also be sought from the Research Ethics Senior Training & Development Officer: http://ris.leeds.ac.uk/EthicsTraining.

Yours sincerely

Jennifer Blaikie
Senior Research Ethics Administrator, the Secretariat
On behalf of Dr Kahryn Hughes, Chair, AREA Faculty Research Ethics Committee

University of Guelph
Research Ethics Board (REB)
Application to Involve Human Participants in Research (REBApp)

DIRECTIONS

Email the completed form with all accompanying documentation (**each document** should be submitted as **an individual file** – do not merge documents into one long file) to reb@uoguelph.ca

You will find, as you proceed through this form, that some questions do not seem to apply to your research. Please be aware that there is a wide range of disciplines which use this form to apply for ethics clearance. If something does not apply – please feel free to choose the n/a option, or explain in a text box.

Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans, 2nd Edition (TCPS2)

The questions asked in the REB-App are drawn from the TCPS2. There is an online tutorial – the CORE tutorial - discussing the TCPS2 which anyone can take. Create a new account using your University email address so completion can be tracked by the ethics office. This tutorial is highly recommended.

Filling out your REB-App:

As you fill out the REB-App you will see this symbol: ⓘ
It means that there is an information entry in the table below that corresponds to that question.
Find the entry using the section letter and question number.
The notes provide further information about the question, and the Tri-Council Policy Statement quotation (*in italics)* will provide a reference to the section of the TCPS2 which generated the question.

This form is 'unlocked' to allow the 'cut and paste' function and the 'track changes' function to be used. You can use Ctrl F to navigate the form.

SECTION A: ADMINISTRATIVE INFORMATION

A.1 Title of the research project: A Longitudinal Approach to Community Vulnerability and Adaptation to Climate Change

A.2 Investigator Information

Note that in the case of student research, the Principal Investigator is the faculty advisor for the purposes of this submission.

Name & position	Principal Investigator	Faculty Co-Investigator	Student Investigator	Other Investigator	Department	Phone No.	E-Mail
Dr. Tristan Pearce	Yes				Geography	+61 7 5456 5811	tpearce@uoguelph.ca
David Fawcett	n/a			X	Geography	604-850-4326	fawcettd@uoguelph.ca
Angus Naylor	n/a			X	Department of Earth and Environment, University of Leeds	n/a	eeawn@leeds.ac.uk
	n/a	☐	☐	☐			
	n/a	☐	☐	☐			
	n/a	☐	☐	☐			
	n/a	☐	☐	☐			
	n/a	☐	☐	☐			

A.3 Are there any issues or concerns regarding the timeline for approval that you would like to raise? ☐ N/A ⓘ

Research dissemination for the prior project (#16MR034) and the commencement of this project is aimed to begin in approximately mid-to-late January 2018 granted ethics approval prior to this date. This research builds on a history of research by the principal investigator in the community of Ulukhaktok.

A.4 Research Ethics Approval (other than University of Guelph)

A.4.1 Will any other Research Ethics Board be asked for approval? X Yes ☐ No ⓘ

If **YES**, please specify:

This is the primary application to a research ethics board and the outcome of this application will be included with an application for a research license to the Aurora Research Institute (ARI) [http://nwtresearch.com/]. ARI acts as a liaison between researchers and communities in the Inuvialuit Settlement Region (ISR). This provides an opportunity for community organizations to provide feedback on the research.

Copy of the clearance certificate or approval will be provided to the REB when available

X Yes

☐ Attached

A.4.2 If you are undertaking research in a country other than Canada, submit a copy of the clearance certificate/approval from the Research Ethics Board in that country. ⓘ

☐ Attached

OR discuss what alternative measures are being taken (see information guide):

A.5 Level of the Project: please check all that apply ⓘ

X	Faculty Research
☐	PhD Thesis
☐	Master's Thesis
☐	Masters Major Research Paper
☐	M.Sc by Coursework

☐	Undergraduate
☐	Honours Thesis
☐	Class Project Specify course:
☐	Internship
☐	Practicum
☐	Independent Study
☐	Administration
☐	Contract – for profit sponsor
☐	Other – please specify:

A.6 Funding of Project

A.6.1 Has funding been granted for this project? X Yes ☐ No

☐ Pending

A.6.2 Agency or Sponsor

Funder	Name of Program	Title of Grant	Grant Number
SSHRC	Insight	Vulnerability and resilience to climate change in the Arctic (VaRCCA)	
Aurora Research Institute	Research Fellowship Program	Research Fellowship Program	

Comments:/funder

A.6.3 Contract – will there be an agreement with a research partner/funder (i.e. data sharing agreements, research funding agreements, confidentiality agreements etc.)?

X N/A

Name of Research Partner/Sponsor:
Title of Research Project:
Has a copy of the contract been submitted to the Contracts Department of the Office of Research? ☐ Yes
Has the contract received final signatures? ☐ Yes
Comments:

A.7 Peer Review

A.7.1 Has this project undergone peer review for scholarly merit during the course of funding approval?	X Yes	☐ No
A.7.2 Has this project undergone peer review for scholarly merit by a graduate advisory committee?	☐ Yes	X No
A.7.3 Comments: The PI has worked closely with the community and other PIs on the same major funding program to develop the project.		

A.8 Disclosure of Conflict of Interest

A.8.1: Will the researcher(s), members of the research team, and/or their partners or immediate family members receive any personal benefits This might include a financial benefit such as remuneration/income, intellectual property rights, rights of employment, consultancies, board membership, share ownership, stock options etc. ☐ Yes X No

If YES, please describe the benefits below. Include details of all fees and/or honoraria directly related to this study, such as those for participant recruitment, advice on study design, presentation of results, or conference expenses.

A.8.2 Describe any restrictions regarding access to or disclosure of information (during or at the end of the study) placed on the investigator(s), including those related to the publication of results. Note the nature of these restrictions and who is applying these restrictions. X N/A

A.8.3 Describe the possibility of commercialization of the research findings. X N/A

A.8.4 Describe any personal or professional relationship between a member of the research team and any participants aside from the researcher/participant relationship. X N/A

A.8.5 Disclose any employment that research team members have outside the University of Guelph, if it is related in any way to the study (e.g. as the source of research participants.) X N/A

The PI is Adjunct Faculty in the Department of Geography at the University of Guelph. Dr. Tristan Pearce completed hi Ph.D. in Geography in 2011 under the supervision of Dr. Barry Smit and completed a Post-Doctoral Fellowship in the Department of Geography in 2012. Dr. Pearce has remained actively involved in the department through his Adjunct status including teaching three distant education courses and acting as a co-advisor for five Master's students. Dr. Pearce is currently employed full-time as an Assistant Professor in Geography at the University of the Sunshine Coast, Queensland, Australia.

The other two researchers have been or currently are graduate students working with Dr. Pearce. David Fawcett completed his MA in the Department of Geography at the University of Guelph in September 2017 and is currently working for Dr. Pearce through the University of Guelph as a Research Associate. Angus Naylor is an MA/PhD researcher at the University of Leeds collaborating with Dr. Pearce through the VaRCCA grant.

A.8.6 Describe any consultancy or other contractual agreements, financial, partnership, or business interests within the last two years that might be perceived as a conflict of interest pertaining to this study. X N/A

A.9 Experience and Licensed Qualifications

A.9.1 What experience does the principal investigator have with the kind of research undertaken in this project and in this context, including the nature of the participants, methods of data collection, etc.?

The PI, Dr. Tristan Pearce, has 13 years of experience conducting ethnographic research with Inuit in the case study location (Ulukhaktok, NWT, Canada). This project builds on past research and existing relationships in the community, and experience collecting data from human sources. Dr. Pearce has published extensively in peer-reviewed journals including a well-cited publication on 'negotiating community-researcher relationships' (Pearce et al. 2009). This project is an exceptional opportunity to build on past studies in Ulukhaktok, and similar projects in other locations (Ford et al. 2013 – Iqaluit GPS monitoring project) that the PI has been a part of.

A.9.2 What is the role of each member of the research team?

Name	Role	Contact with Identified Data	Direct Participant Contact	CORE Tutorial Completed
Dr. Tristan Pearce	- Liaise with community research partners and integrate community feedback into the research design and execution - Conduct first round of interviews together with research team and community research partner/translator - Set up participants with GPS units; coordinate methods of data collection and storage by local research partner - Data analysis and results preparation - Dissemination of results: peer-reviewed literature and back to the community	X Yes	X Yes	X Yes
David Fawcett	- Liaise with community research partners and integrate community feedback into the research design and execution - Conduct first round of interviews together with research team and community research partner/translator - Set up participants with GPS units; coordinate methods of data collection and storage by local research partner - Data analysis and results preparation - Dissemination of results: peer-reviewed literature and back to the community	X Yes	X Yes	X Yes
Angus Naylor	- Liaise with community research partners and integrate community feedback into the research design and execution - Conduct first round of interviews together with research team and community research partner/translator - Set up participants with GPS units;	X Yes	X Yes	X Yes

	coordinate methods of data collection and storage by local research partner - Data analysis and results preparation - Dissemination of results: peer-reviewed literature and back to the community			
Local Inuit research partner/interpreter	- Conduct first round of interviews and GPS data collection with research team. This will involve training on the consent process and data collection and proper storage methods - Conduct bi-weekly data collection with hunting team/participants, store data safely and ethically for research team return	X Yes	X Yes	☐Yes

A.9.3 How will the faculty with principal responsibility ensure that each team member has the expertise and experience necessary to carry out the research? How will s/he ensure that all team members are familiar with the contents of the ethics protocol? **Discuss for each team member.**

Name	Review confidentiality requirements	Review recruitment process	Review consent process	Direct oversight of procedure/process	Review of debrief post deception	Completion of graduate level method's course	Other	Details:
Dr. Tristan Pearce	X	X	X	X		X	X	
David Fawcett	X	X	X	X		X	X	
Angus Naylor	X	X	X	X		X	X	
Local Inuit research partner/interpreter	X	X	X	X		☐	☐	

If more space is required, please add information here:

A.9.4 Does any specific procedure require professional expertise/recognized qualifications (e.g. performance of a controlled act)? ☐ Yes X No

If **YES**, describe, and specify which team members have this expertise:

SECTION B: SUMMARY

Provide a summary below, of the research to be undertaken. Please do not attach copies of detailed proposals submitted to a funding agency or sponsoring agency protocols; these will not be reviewed.

B.1 Describe the purpose and background rationale for the proposed project, as well as any hypotheses and/or research question to be examined.

Background Rationale: Inuit communities have been identified as particularly sensitive to climate change, largely due to the importance of subsistence hunting for their livelihoods and culture, and the sensitivity of subsistence activities to climate change (Condon et al. 1995; Furgal and Prowse 2008; Wenzel 2009). Even under the most aggressive mitigation regimes, the Earth is committed to some degree of change, making adaptation critical, especially in small, resource-dependent communities, such as those in the Arctic. Current understandings of the human dimensions of climate change in the Arctic is based on temporally static research and informant recall over relatively short time periods, limiting its utility (Ford and Pearce 2012). Adaptation is a dynamic process, interacting with complex community-specific variables, leading to an evolution of adaptation over time based on numerous interrelated factors, of which the environment is one (Smit and Wandel 2006; Pearce et al. 2010; Dilling et al. 2015). There has been an identified need to update current understandings of the human dimensions of climate change in the Arctic in order to better understand how exposures, sensitivities, risks, and adaptation strategies develop and interact, specifically in small Inuit communities, and how culturally-relevant policy can be shaped to better enable these communities to adapt to climate change (Ford and Pearce 2012).

Research Question: The proposed research aims to examine the processes and dynamism of climate change vulnerability in Ulukhaktok, NWT using community-based monitoring (similar to Ford et al. 2013) collected over one year beginning in Winter 2018. The objectives of this research are to: (1) monitor and record real-time land use data and hunter observations of the characteristics of and changes to climate-related risks encountered over the study period; (2) document land-based activity and experiences of key informants from the community; and (3) compare collected ethnographic and GPS data with biophysical data to understand and describe the processes and conditions that contribute to vulnerability and resilience to changing conditions.

B.2 Describe in clear and concise detail and sequentially each of the procedures in which the research participants will be involved. Use flow charts, diagrams, and/or point form.

Procedure 1 – Community Dissemination: The project will begin with the dissemination process for the research findings from a previous project completed in the community that is connected to this one (Guelph REB #16MR034). This will involve verifying interpretations and representations of information and to share the final results. The research team will work together with the local research partner and community partners to develop appropriate and effective methods for communicating results. This may include: a plain-language summary report in Inuinnaqtun and English with photos and key findings, household visits with previous participants who consented to be revisited to discuss results from the prior project, updates over local/regional radio broadcasts, and presentations within the community and school.

Procedure 2 – Community-Based Monitoring (CBM): CBM involves employing community members to collect data on a specific topic on a regular basis. This will involve four parts that feed into the same procedure:

- **a)** Organizing a community monitoring team/sample (6-8 participants) in Ulukhaktok consisting of hunters equipped with GPS units to record their land use from January/February 2018-January/February 2019. Route, distance, and speed data from the units will be downloaded onto an encrypted computer (provided by the research team) by a community research partner/interpreter biweekly.
- **b)** The community research partner will also ask a series of questions on each hunter's activities bi-weekly (~30 minutes), which will be recorded using a password protected audio recorder. GPS and interview data will be collected at the same time bi-weekly. Audio files will be uploaded to the encrypted computer at the end of each day and deleted from the recording device.
- **c)** Participants will also be recruited to keep diaries of their land-based activities.
- **d)** During several community visits throughout the year, the research team will debrief with the monitoring team and local research partner on the participants' land-based activities, providing context of the GPS data, interview data, and key informant recordings.

Procedure 3

Procedure 4

B.3 Indicate the location(s) where the research will be conducted (*check all that apply*):

☐	University of Guelph
☐	South Western Ontario
☐	Ontario
X	Canada: Ulukhaktok, Northwest Territories
	State Country:

X	Participant's home
☐	Participant's place of business or workplace
☐	School
☐	University or College
☐	Health Institution
☐	Correctional Institution
☐	Senior's Institution
☐	Other – please describe:

B.4 List and submit all documents used for data collection:

☐	Published scale/survey
☐	Researcher generated survey
☐	Focus group probing questions
☐	Screening questionnaire
X	Interview questions
	Health questionnaire
	Other – please describe:

Submit each applicable document as an individual attachment with your application– do not merge the documents into one long file.

B.5 If you are using a survey or questionnaire, please indicate if this survey or questionnaire is a published scale or has been created by the research team.

The questionnaire will be/has been created by the research team in collaboration with the community of Ulukhaktok and based on interview guide of another similar project completed in Iqaluit over a five year period (Ford et al. 2013).

SECTION C: METHOD

Answer each question below for each of the procedures/methods discussed in Part B.

C.1 Time required of participants

☐ N/A

For each type of interaction listed in B.2, describe the time required of participants. Also state the total time required over all interactions:

Procedure 1: Participants from the previous study (Guelph REB #16MR034) who consented to be re-contacted for research dissemination. This will involve informal visits at their homes for approximately 30-60 minutes.

Procedure 2:

a) This will involve participants taking small amounts of time during and after trips to record location data on GPS units.
b) GPS data collection and interviews should take approximately 30 minutes combined.
c) Time required will be up to participants.
d) This debrief meetings will take approximately 60 minutes.

C.1.1 Do you plan to re-contact participants for any purpose? If **YES**, this must be discussed here and in the consent form.

Participants will be re-contacted multiple times over the study period to collect bi-weekly GPS and interview data. They may also be re-contacted at other times during the data collection period to clarify responses, and after the data collection period, during a separate trip, to verify findings and interpretations of data.

C.2 Language

In what language(s) will the research be conducted?

X English

☐ French

X Other: Inuinnaqtun

☐ N/A

C.2.1 Is the participant sufficiently fluent in this language to understand the consent process? X Yes ☐ No

C.2.2 Is interpretation available? X Yes ☐ No

C.2.2.1 How will interpreter(s) be recruited? From what organization? From what region and cultural background?

An Inuinnaqtun and Inuvialuktun research partner/interpreter from the community will be identified by the Ulukhaktok Community Corporation (UCC). The PI has worked with the UCC for several years and has longstanding relationships with interpreters from the community.

C.2.2.2 Discuss the possible relationship between the interpreter(s) and the participants.

Ulukhaktok is a small community composed of ~400 Inuit. As a result, any interpreter will be related to many of the participants from which a sample will be drawn. The researchers will work with the interpreter prior to interviews to ensure that they are comfortable with selected participants. It will also be explained to the interpreter that the information shared during interviews may be confidential if requested by the respondent and thus the interpreter must keep that information confidential. The research team has developed a confidentiality agreement consistent with the University of Guelph's confidentiality protocol and this will be communicated with and signed by the interpreter who will be present at interviews and/or handling raw data.

C.2.2.3 Sample of Confidentiality Agreement or script for interpreter is:

X attached (submit as an individual attachment with your application)

☐ pending – will be provided to the REB.

C.2.2.4 Project documents (such as consent forms, information letters, surveys) should, where possible, should be made available to participants in translation. Will this occur for this project? X Yes ☐ No

If NO, explain:

C.2.3 Discuss any issues there may be with literacy in your participant population, and how you intend to address literacy issues ☐ N/A

Interviews will be conducted orally. Consent forms will be read to all participants as well as provided as a hard copy to sign. By reading the consent forms with participants, any literacy issues will be addressed. Also, any research information (posters, results summaries etc.) that is written will be provided in plain language English and Inuinnaqtun to make them as accessible as possible to all community members.

C.3 Participants

C.3.1 Estimate the number of participants you will be recruiting 6-8

C.3.2 Estimate the size of the pool from which you are drawing participants, if possible 400

C.3.3 Will you be recruiting either males only or females only? ☐ Yes X No ☐ N/A

If **YES**, please state the rationale:

C.3.4 What is the age range of the participants you will be recruiting? ☐ N/A

Lower Age Limit: 18

Upper Age Limit: 100

Justify both the upper and lower limit. Children and the elderly should not automatically be excluded from research based solely upon their age.

Lower: Community members (including those who have recently graduated from high school)

Upper: Elderly community members may be able to provide valuable insight, specifically those who contributed to the previous study in 2004/2005

C.3.5 Are participants University of Guelph students? ☐ Yes X No

Are participants affiliated with (formally or informally) a particular organization/institution (other than the University of Guelph? ☐ Yes X No

If **YES**, please name and provide details of the affiliation:

C.3.6 Participant **Inclusion and Exclusion Criteria**: List all inclusion/exclusion criteria. Indicate with an asterisk (*) those criteria which will be included in the Letter of Information.

Inclusion Criteria	**Exclusion Criteria**
Inclusive sample based on different ages, genders. Large focus on varying levels of engagement in subsistence activities for purposes of the research	Community members below 18

focus.	

C.4 Recruitment

C.4.1 What form will recruitment take: (*please check all that apply*): ☐ N/A

☐	Poster
☐	Advertisement
☐	Email
☐	Web page
☐	Letter of Invitation
☐	Telephone Call
☐	Social Media
☐	Verbal Script
☐	SONA - Psychology
☐	SONA – Marketing & Consumer Studies
☐	Office of Research Participant Recruitment Site
X	Other – describe below

Attach a copy of the above with your submission. **Submit each document as an individual attachment with your application – do not merge the documents into one long file.**

Note that the REB# should be quoted on all recruitment documents and consent forms.

Describe how/where you will use each of the instruments selected above:

The PI has extensive experience working in the community (most community members know who he is) and with the local Hunters and Trappers Committee and Community Corporation – recruiting participants and developing a sample will take place through conversations with these local organizations and contacting potential participants by telephone or in-person/at home.

C.4.2 Indicate the location of the participant at the time of recruitment. Is the physical location of the participant at the time of recruitment of importance? For example, could contacting the individual at their place of business increase risk of harm? ☐N/A

X	At home
☐	At work
X	Other – describe below

Discuss for each of the instruments selected in C.4.1, as appropriate:

Some opportunistic opportunities to recruit participants for the sample may arise, meaning participants may be recruited in the course of conversation while out in the community (e.g. if they inquire while the researcher is shopping at the Northern store). The researcher will not seek to recruit participants in public, but if someone inquires about the research they may be given the opportunity to be included in the sample.

C.4.3 If you are proposing to use **Mass Testing** as part of this project, provide the REB number under which the mass testing item was approved. Provide a copy of the Mass Testing questions.

X N/A

C.5 Incentives and Reimbursement

☐ N/A

C.5.1 What is the dollar value of incentive payments and other forms of reimbursement to participants?

☐	Participants will be reimbursed for costs incurred while participating
	Travel: Child Care: Parking: Other:
X	Participants will receive incentives to encourage participation
	Gift card: $20 gift cards to the Ulukhaktok Quick Stop (store and gas station) for each interview Cash: **Lottery or draw:** **If yes, describe in C.5.2.** Course Credit: Name of course: Other: GPS unit required for the study
☐	Participants will receive non-financial benefits
	Food and Drink: Other:
☐	Other – describe:

C.5.2 If you have indicated in C.5.1 that you will be using a **Lottery or Draw**, please provide the following information:

Estimated chances of winning

Number of prizes

Value of prizes

Give detailed description of how draw will be managed.

C.5.3 If you have indicated in C.5.1 that you will be providing payment to participants, how will you record dispersal of funds for audit purposes (i.e. reporting to Financial Services)? You may need to describe this in the consent form if you will be asking for a participant signature or initials.

The gift card number will be noted next to the participant's name on the consent form. This has been a common arrangement on past projects.

C.5.4 If you have indicated any incentives or reimbursement in C.5.1, detail how will you deal with incentives, reimbursements if participants choose to withdraw? (Cash payments should be prorated.)

Participants will keep the gift card even if they choose to withdraw from the research.

C.5.5 Are the participants likely to incur any expenses or inconveniences in addition to those described above as a result of their participation in this project? ☐ Yes X No

If **YES**, describe:

SECTION D: THE INFORMED CONSENT PROCESS

Are you planning on providing participants with a **hard copy consent** document, which they will sign? If so, fill out **D.2**.

Are you planning on obtaining **oral consent**? If so, fill out **D.3**.

Are you planning a survey, which will display the consent information at the front of the survey, and you will **assume participants consent** if they complete and return the survey? If so, please fill out **D.4**.

Will your participants be **unable to give consent** themselves, but must have a parent or guardian give consent on their behalf? These participants might be children, or an adult with a cognitive impairment, for example. If this is the case, fill out **D.5**.

Section **D.6** should only be filled out if your project involves **deception**. Please see Guideline 1-G-020 for information about deception.

Section **D.1** is seldom used, and is a **waiver of prior informed consent**. See the information guide for an explanation of when **D.1** applies.

You may fill out more than one type of consent section. You need not fill out ALL consent sections – only what you need.

Note that the REB# should be quoted on all recruitment documents and consent forms.

D.1.Alteration of Informed Consent:

If you are applying for a waiver of prior informed consent, see the information guide, and discuss Article 3.7 (a) to (e). X N/A

D.2 Written Consent:

Will you be obtaining **consent with a signature**? X Yes ☐ No

If **NO**, please explain why signed consent is not appropriate in this case then go to D.3.

If **YES** to consent with a signature, please answer the following:

D.2.1 What consent documents will be used to inform potential participants about the details of the project and to obtain consent for participation?

☐	Separate information letter, and consent form with signature section
X	Consent form with signature section
☐	Other – Specify

Discuss:

D.2.2 How will consent documents be delivered to participant?

The consent form will be distributed and read aloud to the participant (translated by the interpreter if necessary) prior to the beginning of the interview process.

D.2.3 How will consent documents be returned to researcher?

Returned after consent/signed, prior to the beginning of the interview process.

D.2.4 Which member of the research team will manage the consent process?

Dr. Tristan Pearce will lead the consent process at the beginning of the project, however all members of the research team may be involved in managing the consent process for different participants at different times.

D.2.5 Has this individual had the necessary training to administer consent? Describe the training received or planned.

Dr. Pearce has extensive experience and knowledge of the consent process and the other two members of the research team have undergone training on the delivery of consent and have experience managing the consent process from their own MA research projects.

D.2.6 Verify the following:

X Yes	☐ N/A	Copy of consent form is attached to this application	Comment
X Yes	☐ N/A	Copy of consent form will be given to participant	Comment
☐ Yes	X N/A	Script for introducing consent process is attached to this application	Comment
☐ Yes	X N/A	Letter of information is attached to this application	Comment
X Yes	☐ N/A	Copy of information letter and/or consent form shows University of Guelph letterhead or logo	Comment

Submit each applicable document as an individual attachment with your application – do not merge the documents into one long file.

D.2.7 Will the participant have an opportunity to have questions about the project and their role as a participant answered? How will this opportunity be communicated to them?

☐ N/A ⓘ

Questions and concerns will be addressed prior to the participation. This opportunity will be communicated and explained to them orally.

If this **written consent is from a parent or guardian**, please fill out section **D.5** as well.

D.3 Oral Consent: Will you be obtaining **oral consent**? ☐ Yes X No ⓘ

If **NO**, please go to D.4

If **YES**, to oral consent please answer the following**:**

D.3.1 What documents will be used to provide participants with information about the project to supplement the oral consent? ⓘ

☐	Information letter
☐	Consent script
☐	Other – Specify

Discuss:

D.3.2 How will the written information be delivered to participant? ⓘ

D.3.3 How will oral consent be documented by the researcher? ⓘ

D.3.4 Which member of the research team will administer consent? ⓘ

D.3.5 Has this individual had the necessary training to administer consent? Describe the training received or planned. ⓘ

D.3.6 Verify the following:

☐ Yes	☐ N/A	Copy of consent script is attached to this application	Comment
☐ Yes	☐ N/A	Copy of information letter will be given to participant	Comment
☐ Yes	☐ N/A	Copy of information letter shows University of Guelph letterhead or logo	Comment
☐ Yes	☐ N/A	Copy of information letter is attached to this application	Comment

Submit each applicable document as an individual attachment with your application – do not merge the documents into one long file.

D.3.7 Will the participant have an opportunity to have questions about the project and their role as a participant answered? How will this opportunity be communicated to them?

☐ N/A

D.4 Assumed Consent: Will consent be **assumed or implied**?

☐Yes X No

If **NO**, please go to D.5

If **YES** to assumed or implied consent, please answer the following:

D.4.1 What consent documents will be used to provide potential participants written information about the details of the project to supplement the assumed or implied consent?

☐	Information letter
☐	Consent form
☐	Other – Specify

Discuss:

D.4.2 How will the written information be delivered to participant? For online surveys, invite the participant to print the consent information.

D.4.3 How will consent be documented by the researcher (for example, by return of the completed questionnaire)?

D.4.4 Which member of the research team will administer consent? ☐ N/A

D.4.5 Has this individual had the necessary training to administer consent? Describe the training received or planned. ☐ Yes ☐ No ☐ N/A

D.4.6 Verify the following:

☐ Yes	☐ N/A	Copy of information letter will be available to participant (provide PRINT button for online survey)	Comment
☐ Yes	☐ N/A	Copy of information letter shows University of Guelph letterhead or logo	Comment

D.4.7 Will the participant have an opportunity to have questions about the project and their role as a participant answered? How will this opportunity be communicated to them? ☐ N/A

D.5 Proxy Consent: Will you be obtaining proxy consent (e.g. of parent/guardian)? ☐ Yes X NO

If **NO**, please go to D.6

If **YES** to proxy consent please answer the following**:**

D.5.1 Why is proxy consent necessary?

D.5.2 How will competence of the participant be established, and who will determine this?

☐ N/A

D.5.3 Will you be obtaining informed assent from the participant? ☐ Yes ☐ No

If **NO**, explain why not:

D.5.4 How will oral assent, if used, be documented? ☐ N/A

D.5.5 Verify the following:

☐ Yes	☐ N/A	Copy of written assent form attached to this application	Comment
☐ Yes	☐ N/A	Written assent form printed on University of Guelph letterhead	Comment
☐ Yes	☐ N/A	Copy of written assent form will be given to participant	Comment
☐ Yes	☐ N/A	Copy of oral assent script attached to this application	Comment
☐ Yes	☐ N/A	Copy of written information for participant providing oral assent attached to this application	Comment

Submit each applicable document as an individual attachment with your application – do not merge the documents into one long file.

D.5.6 Attestation regarding Proxy Consent: Article 3.9 TCPS2

☐ Yes	☐ N/A	the researcher will involve participants who lack the capacity to consent on their own behalf to the greatest extent possible in the decision-making process
☐ Yes	☐ N/A	the researcher will seek and maintain consent from authorized third parties in accordance with the best interests of the persons concerned
☐ Yes	☐ N/A	the authorized third party is not the researcher or any other member of the research team
☐ Yes	☐ N/A	the research is being carried out for the participant's direct benefit, or for the benefit of other persons in the same category. If the latter, the researcher has demonstrated that the research will expose the participant to only a minimal risk and minimal burden, and that the participant's welfare will be protected

		throughout the participation in research
☐ Yes	☐ N/A	when authorization for participation was granted by an authorized third party, and a participant acquires or regains capacity during the course of the research, the researcher shall promptly seek the participant's consent as a condition of continuing participation

D.5.7 Are provisions planned for participants, or those consenting on a participant's behalf, to have special assistance, if needed, during the consent process ☐ Yes ☐ No ⓘ

If **YES**, discuss:

D.6 Deception: Are you using **partial disclosure or deception** (i.e. the participant may not know that they are part of a project until it is over or is not informed of the true purpose of the research in advance)? ☐ Yes X No ⓘ

If **NO** go to question D.7

If **YES** to deception or partial disclosure, please answer the following:

D.6.1 Describe the deception(s) or partial disclosure(s) being used and why they are necessary.

D.6.2 Describe how and when the deception or partial disclosure will be revealed.

D.6.3 State who will debrief the participants regarding the nature of the deception or partial disclosure, and describe how they have been trained. ⓘ

D.6.4 Verify the following:

☐ Yes	☐ N/A	A second consent form will be used.	Comment
☐ Yes	☐ N/A	Second consent form will be printed on University of Guelph letterhead	Comment
☐ Yes	☐ N/A	Copy of second consent	Comment

		form will be given to participant	
☐ Yes	☐ N/A	If participant declines to sign the second consent form, data will be removed from the study without penalty. Participant will still receive any incentives or reimbursement due.	Comment
☐ Yes	☐ N/A	Copy of second consent form attached to this application	Comment
☐ Yes	☐ N/A	University of Guelph guideline on deception has been followed	Comment

Submit each applicable document as an individual attachment with your application – do not merge the documents into one long file.

D.7 Is **community or institutional consent** required for your project? X Yes ☐ No ☐ N/A ⓘ

Please discuss why this is required, how it will be managed.

This research will be performed through community collaboration. Local participation will be encouraged through community-based partnerships. The project requires a scientific research license administered by the Aurora Research Institute in Inuvik. Community organizations must also be consulted during this licensing process, including the Ulukhaktok Community Corporation and the Ulukhaktok municipal government.

D.8 Will the participant be free to give consent, or refuse, without any undue influence or coercion? X Yes ☐ No ⓘ

Explain any details you feel are relevant.

If participant is uncomfortable with the aim of the study or the nature of the questions the right to resign consent will be afforded at any time during the study period.

D.9 How will you ensure that **consent is ongoing** throughout the project? How will you ensure that necessary information is provided to participants on an ongoing basis? ☐ N/A ⓘ

Researchers will review consent prior to the first interview to ensure that the participant is fully aware of ongoing consent and their right to resign consent at any juncture.

D. 10 Discuss the likelihood that the **confidentiality** offered to participants may be **limited** by the legal obligation to "report information to authorities to protect the health, life or safety of a participant or third party" or that "a third party may seek access to information obtained and/or created in confidence in a research context" through either "voluntary disclosure" or "force of law".[TCPS2, Article 5.1] ☐ N/A ⓘ

Although the likelihood is minimal, participants will be informed through the letter of consent that the information provided will only be available to the researchers to the extent allowed by law. Researchers will communicate with participants that they have a duty to report to authorities any information about a child at risk of abuse and that the researcher may be required by subpoena to release information gathered during the course of this project. Participants will also be made aware that they do not waive any of their legal rights by signing the consent form.

D.11 Participant withdrawal ⓘ

D.11.1 Participants must have the right to withdraw from the project at any time. Describe how the participants will be informed of their right to withdraw and outline the procedures that will be followed to allow the participants to exercise this right.

Participants will be informed during the process of obtaining informed consent that they can choose to withdraw from the project at any time without any repercussions.

D.11.2 Indicate what will be done with the participants' data and any consequences for the participant of withdrawing from the study. Participants must have the right to withdraw their data from the project. Exceptions include anonymous data and collectively recorded data (such as focus group recordings).

Information retrieved from participants who wish to withdraw will be shredded and/or erased from technological devises.

D.11.3 If the participants will not have the right to withdraw from the project, please explain.

N/A

SECTION E: DESCRIPTION OF THE RISKS AND BENEFITS

E.1 Risks: Itemize your response by each method/procedure employed during this research.

Risk (check all that apply)

☐ N/A	
☐ Yes	Physical (including bodily contact or administration of any substance)
X Yes	Psychological (including feeling demeaned, embarrassed, worried, or upset)
☐ Yes	Social (possible loss of status or reputation)
☐ Yes	Economic (risk to livelihood or income)

E.1.1 If you indicated **YES** to any of the above, are any of the risks indicated greater than the participant would encounter in their everyday life? ☐ Yes X No

E.1.2 For each risk identified above describe how the risk will be managed and include an explanation as to why alternative approaches could not be used. ☐ N/A

Psychological risks will be managed through gentle communication, to ensure that the participant does not feel pressured, embarrassed, or upset in any way. Participants will be reminded during the interview that they can withdraw from the research at any time without repercussion.

E.2 Possible Benefits Describe any benefits to the participants/discipline/ society that would justify to participants why they should be involved in this study. ☐ N/A

Benefits to Participant	Indirect: opportunity to share their experiences, knowledge, and strategies related to how they experience and adapt to climate change, and how other non-climate factors influence this. Direct: There will be no direct benefits to participants outside of the $20 gift certificate they receive for each interview as well as the GPS units they will receive as a part of the project.
Benefits to Discipline	This research will advance knowledge on the human dimension of climate change in the Arctic, particularly how adaptation is taking place and adaptation decisions are being made in response to environmental changes and community conditions. It will also provide valuable insights on real-time risk, with potential practical applications that reduce risk related to climate change. Finally, it will have methodological contributions, advancing how the applied methodology attempts to predict future exposure-sensitivities and adaptation opportunities.

Benefits to Society	The research findings could inform the development of culturally relevant adaptation policies that reduce risk while travelling and hunting in the Arctic, for Inuit communities in particular.

E.2.1 Research results should be provided to participants where possible.

Will aggregate research results be provided to participants? X Yes ☐ No

If **YES,** explain what information will be provided to the participants upon completion of the project, and how will they receive this.

Research findings will be communicated in Ulukhaktok and elsewhere in the NWT. The researcher and PI will work with Inuit researchers to develop appropriate methods for communicating results. This will include a research summary booklet (highly visual and descriptive), household visits to discuss results, and potentially posters to be displayed in the community in plain language English and Inuinnaqtun, broadcasts on local radio, and posts on the community Facebook page. Each research participant will receive a research summary booklet and have the opportunity to communicate feedback to the research team in person and/or via phone or E-mail.

If **NO**, explain why this is not feasible or desirable.

E.2.2 Will an individual's research results be provided to participants? ☐ Yes X No

If **YES,** explain what information will be provided to the participants upon completion of the project, and how will they receive this.

SECTION F: CONFIDENTIALITY AND DATA SECURITY

F. 1 Indicate what type of information will be collected

X Yes	☐ No	Directly Identifying Information
X Yes	☐ No	Indirectly Identifying Information
X Yes	☐ No	Coded Information
X Yes	☐ No	Anonymized Information
☐ Yes	X No	Anonymous Information

Directly identifying if consent is given and anonymized if desired by the participant.

F.2 Describe any **personal identifiers** – both direct and indirect - that will be collected during the course of the research and justify the need to collect them. Researchers should reduce the number of identifiers to a minimum. ☐ N/A

All information, including participant age, gender, name, occupation and/or subsistence activity level and GPS routes, will be recorded and stored on a secured password computer using the University of Guelph's encryption service during the course of the research and on a password protected external hard drive in the long-term, also protected using the University of Guelph's encryption service.

F.3 Under some circumstances, **identified data** must be made available **to authorities**. This may occur at the request of auditors (e.g. Health Canada, Tri-Council), or under subpoena (see D.10). Describe the likelihood of this applying to this research project, and how or if you plan to communicate this possibility to participants.
☐ N/A

The letter of consent informs the participants that the researcher may be required by subpoena to release information gathered during the course of this project. They do not waive any of the legal rights by signing the consent form.

F.4 Describe any action that should be taken by the Principal Investigator prior to beginning the project, or any information which should be communicated to participants in the consent process, which deals with potential **incidental findings**. ☐ N/A ⓘ

The letter of consent informs the participants that the researcher may be required by subpoena to release information gathered during the course of this project. They do not waive any of the legal rights by signing the consent form.

F.5 If any personal identifiers will be retained once data collection is complete, provide a comprehensive rationale explaining why it is necessary to retain this information – including the retention of master lists that link participant identifiers with unique study codes and de-identified data ☐ N/A ⓘ

Personal identifiers will be collected in the research process and stored only on encrypted, password-protected computers and hard drives only to be shared between the research team and interpreter/Inuit researcher. Personal identifiers will be connected to data through the use of codes to be designed by the research team. These identifiers will be required for the analysis of data to understand trends in the results. Unidentified results will be communicated to participants. For those who wish to remain confidential, personal identifiers will be stored separately and then deleted at the end of this project. For those who give permission for their name to remain connected to their data, this will be stored with the data for the standard 5-year length, as well as with the data that is stored in the community.

F.6 If existing records (e.g. health records, other records/databases) are to be used, describe how permission was obtained. X N/A ⓘ

Submit Supplement III – **Secondary use of Data**

F.7 What would the impact be on the participant should **privacy** be **breached**? ⓘ

If privacy is breached and personal or indirect identifiers are released, there is potential for personal or social impacts to participants. This could include age, name, occupation, subsistence activity, thoughts on changes to the land, travel and hunting patterns, or personal concerns/thoughts related to climate and non-climate conditions. This could lead to social embarrassment, loss of social status, alienation and personal conflicts. The likelihood of impact is minimal though, and would very likely be restricted to impacts on pride (positive or negative) related to subsistence activities. The consent form has clearly informed participants to not disclose any information that they would disclose in a public setting to prevent social or personal impacts. To reduce any risk of this, data will be coded and securely stored in two master lists (a list of those who wish to remain confidential, and a list of those who have given permission to have their name and

personal identifiers connected to the study).

F.8 State who else will have access to the **identified data**. If they are not members of the research team, they should sign a confidentiality agreement ☐ N/A

Outside of the research team, the only other person who will have access to identifying data is the interpreter/Inuit researcher. They will have signed the confidentiality agreement (attached).

F.9 Describe the procedures to be used to protect the identity of the participant and/or ensure the **security of the data**:

F.9.1 During the conduct of the research: ☐ N/A

Interview data will be collected through written notes and/or audio recordings. Audio recordings will be recorded on a password-protected Sony audio recorder, and then transferred onto the research teams' computer and erased from the recorder at the end of each day. This data, along with GPS travel and hunting data, will be stored on the research teams' encrypted, password-protect computer and hard drive. In the short term, written notes will be secured on the researcher's person and locked with their personal items (in a suitcase). In the long-term, notes will be stored in a locked file cabinet in Dr. Tristan Pearce's university office. Audio-recordings and GPS data will be stored on the PI's encrypted external hard-drive in the long-term.

F.9.2 During processing of data: ☐ N/A

Personal identifiers will be replaced with a non-identifying code (letters and numbers).

F.9.2.1 Will data be transcribed? ☐ Yes X No

If **YES**, attach copy of transcriber confidentiality agreement as an individual attachment with your application (if transcriber is not part of the research team)
☐ Attached

F.9.2.2 Will the **identified** data be transferred electronically? ☐ Yes X No

If **YES**, by what medium and how will it be protected during transit?

F.9.3 After research is complete: ☐ N/A

Unidentified and identified data will be saved on a password-protected and encrypted (following the University of Guelph encryption policy) external hard drive administered by the PI. This will include a master list of names and codes of those who wish to have their name associated with the project. The master list of those who wish to remain confidential will be destroyed at the end of the project. All other data and information will be stored on the PI's encrypted external hard-drive for up to 5 years. Unidentified (in transcript form for those who wish to remain confidential) and identified (audio recordings and identifying information) interview data will also be given to the community for storage on a hard drive at the Community Corporation office.

F.9.4 In the release of findings: ☐ N/A

Findings will be released without any direct identifiers.

F.10 Long Term Data Security

Discuss how long data will be stored, justify the duration of the storage period, discuss the security measures which will be employed, and name the individual who will be charged with stewardship of the data:

At the completion of the research, unidentified data will be saved on the PI's password-protected and encrypted external hard drive (following the university of Guelph encryption policy). All data, written, GPS and oral, will be kept for 5 years after the completion of the research project, at which time the data will be permanently deleted. Storing files for 5 years will enable continued analysis of the data. Unidentified (in transcript form for those who wish to remain confidential) and identified (audio recordings and identifying information) data will also be given to the community for storage on a hard drive at the Community Corporation office.

F.10. X Will paper records be retained, and if so, which of the following apply?

☐ Confidential shredding after .

X De-identified data will be retained in secure location

☐ Identified data will be retained in secure location

Describe secure location:

Locked in a filing cabinet in the PI's university office.

F.10.2 X Will audio/video recordings be retained, and if so, which of the following apply?

☐ Destruction of audio/video recordings after

X Will be retained in secure location

Describe secure location:

Audio files will be stored on the PI's password-protected external hard drive and stored in a locked filing cabinet in his university office.

F.10.3 X Will electronic data be retained, and if so, which of the following apply?

☐ Secure erasing of electronic data after .

X De-identified data will be retained in secure location

☐ Identified data will be retained in secure location

Describe secure location:

Electronic files will be stored on the PI's password-protected external hard drive and stored in a locked filing cabinet in his university office.

F.11 Do you intend to link the data you have gathered with any other set of data?

☐ Yes X No

Describe:

No, data from this project will not be linked with data from other projects in the community. It will be linked with key findings based on data from other projects, but not with the data itself.

Section G: Post Approval

G.1 Continuing Ethics Review

Minimum requirement for Continuing Ethics Review is the submission of a **Status Report** at least annually. The principal investigator's responsibility for the project must notify the REB using the Status Report when the project is completed, or if it is cancelled.

Indicate whether any additional monitoring or review would be appropriate for this project.

☐N/A

G.2 Adverse Events

Unanticipated consequences or results affecting participants must be reported to the Research Ethics Board and the Ethics Office as soon as possible using the <<adverse event report>>.

G.3 Additional Information

Please add any other information relevant to the project that you wish to provide to the Research Ethics Board. X N/A

SECTION H: SIGNATURES

DIRECTIONS

Create a jpeg of your signature and insert it on the signature line
OR Sign the last page of the REBApp, scan it, and submit it as a .pdf with the application.
OR Send an email to reb@uoguelph.ca from your @uoguelph.ca account stating:

> *I acknowledge that, as required by TCPS2, I am responsible for ensuring that the consent process as described in this application is followed and I am responsible for the actions of any member of the research team involved in the consent process. I have read and am responsible for the content of this application. If any changes are made in the above arrangements or procedures, or adverse events are observed, I will bring these to the attention of the ETHICS OFFICE.*
>
> In the subject line, quote the project title to which this email will be attached

REVIEW WILL NOT PROCEED UNTIL A SIGNATURE IS RECEIVED BY THE ETHICS OFFICE.

TITLE OF PROJECT: A Longitudinal Approach to Community Vulnerability and Adaptation to Climate Change

PRINCIPAL INVESTIGATOR SIGNATURE:

> I, Dr. Tristan Pearce *acknowledge that, as required by TCPS2, I am responsible for ensuring that the consent process as described in this application is followed and I am responsible for the actions of any member of the research team involved in the consent process. I have read and am responsible for the content of this application. If any changes are made in the above arrangements or procedures, or adverse events are observed, I will bring these to the attention of the ETHICS OFFICE.*

07 December 2017

Signature | Date

The Secretariat
University of Leeds
Leeds, LS2 9JT
Tel: 0113 343 4873
Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

Angus Naylor
School of Earth and Environment
University of Leeds
Leeds, LS2 9JT

Social Sciences, Environment and LUBS (AREA) Faculty Research Ethics Committee University of Leeds

17 April 2019

Dear Angus

Title of study: **A Longitudinal Approach to Community Vulnerability and Adaptation to Climate Change**

Ethics reference: **AREA 18-117**

I am pleased to inform you that the above research application has been reviewed by the Social Sciences, Environment and LUBS (AREA) Faculty Research Ethics Committee and following receipt of your response to the Committee's initial comments, I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	Version	Date
AREA 18-117 Committee Provisional_AWN_RESPONSE.doc	1	16/04/19
AREA 18-117 Consent Form_REB_Pearce_April_15_2019.doc	2	16/04/19
AREA 18-117 Tooniktoyok Final Interview Guide 15_04_19.docx	2	16/04/19
AREA 18-117 Confidentiality_Agreement_APR_2019.doc	1	16/04/19
AREA 18-117 UoL_TPearce_LVA_Ulukhaktok_rebapp_Dec 15, 2017	1	20/02/19
AREA 18-117 Ethics Certificate 20190111 Tooniktoyak Project 2019-2020	1	20/02/19
AREA 18-117 certificate_20180124	1	20/02/19

Please notify the committee if you intend to make any amendments to the information in your ethics application as submitted at date of this approval as all changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation and other documents relating to the study, including any risk assessments. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Jennifer Blaikie
Senior Research Ethics Administrator, the Secretariat
On behalf of Dr Kahryn Hughes, Chair, AREA Faculty Research Ethics Committee

CC: Student's supervisor(s)

Appendix B: Policy brief produced for CIRNAC

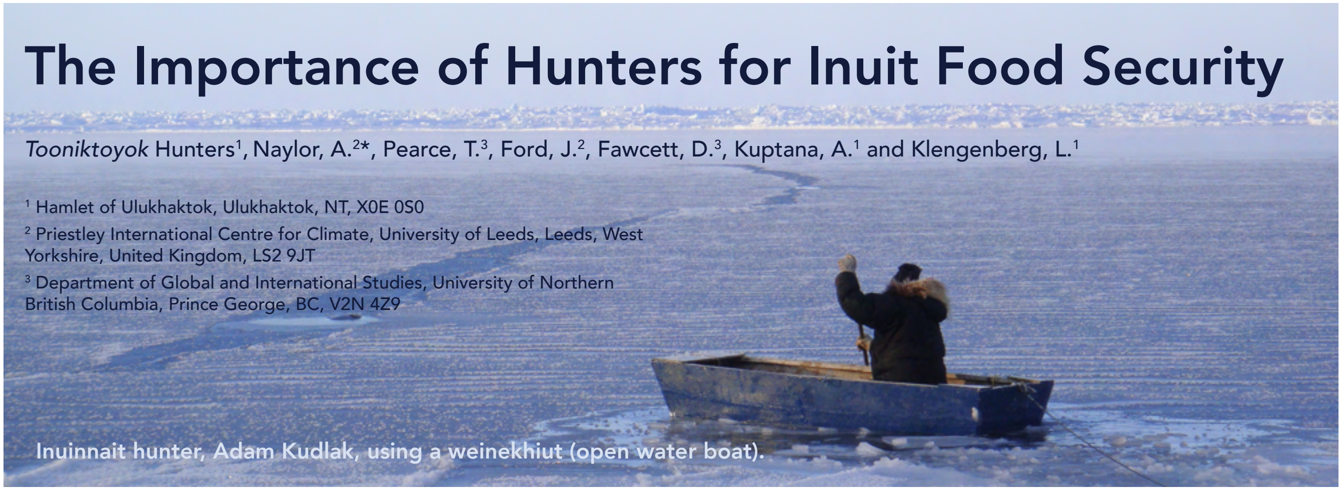
The Importance of Hunters for Inuit Food Security

Tooniktoyok Hunters[1], Naylor, A.[2]*, Pearce, T.[3], Ford, J.[2], Fawcett, D.[3], Kuptana, A.[1] and Klengenberg, L.[1]

[1] Hamlet of Ulukhaktok, Ulukhaktok, NT, X0E 0S0

[2] Priestley International Centre for Climate, University of Leeds, Leeds, West Yorkshire, United Kingdom, LS2 9JT

[3] Department of Global and International Studies, University of Northern British Columbia, Prince George, BC, V2N 4Z9



Inuinnait hunter, Adam Kudlak, using a weinekhiut (open water boat).

Executive Summary

Subsistence hunting represents a crucial and sustainable means of food production for many Inuit communities, and has significant economic, dietary, and cultural importance. The rising costs associated with hunting in the modern-day, however, are now preventing some Inuit from participating in subsistence, with implications for future food security, health, and wellbeing. This research examined the economic costs of subsistence hunting in the Arctic among Inuit hunters from Ulukhaktok, NWT. The research documented how much it costs to participate in subsistence, what quantity of foods were produced from subsistence practices, and how much it would cost to replace country foods with imported equivalents of the same edible weight at stores. Data were collected by 10-Inuit hunters over 12-months between 2018-2019 through the use of GPS tracking and bi-weekly interviews focusing on a range of topics, including costs incurred and food harvested per trip. Key findings include:

- Harvesting fish and wildlife was on average more economical than purchasing store-bought alternatives, even after accounting for the Nutrition North subsidy.
- It costs between 9.6% and 49.7% more to buy meat from the store than it does to harvest the same edible weight in meat from hunting.
- The cost of country-food per kilo was lowered the more productive a hunter was, demonstrating the importance of supporting full-time hunters.

Annual Individual Productivity	Cost of country food per-kilo (with supplies use, ammunition, capital costs, and depreciation) (CAD$)	Total annual cost of traditional food (CAD$)	Equivalent replacement store-bought food cost/ kilo (CAD$)	Total annual replacement cost of store-bought food (CAD$)	Cost of store bought food per kilo vs. country food
800kg	$15.50	$12,403.94	$16.99	$13,592.00	109.6%
1,000kg	$13.84	$13,841.94	$16.99	$16,990.00	122.7%
1,200kg	$12.73	$15,279.94	$16.99	$20,388.00	133.4%
1,400kg	$11.94	$16,717.94	$16.99	$23,786.00	142.3%
1,600kg	$11.35	$18,155.94	$16.99	$27,184.00	149.7%

Table 1: Costs associated with the harvesting of country food at different rates of annual productivity in Ulukhaktok, compared with the cost of purchasing the equivalent mass of meat in stores.

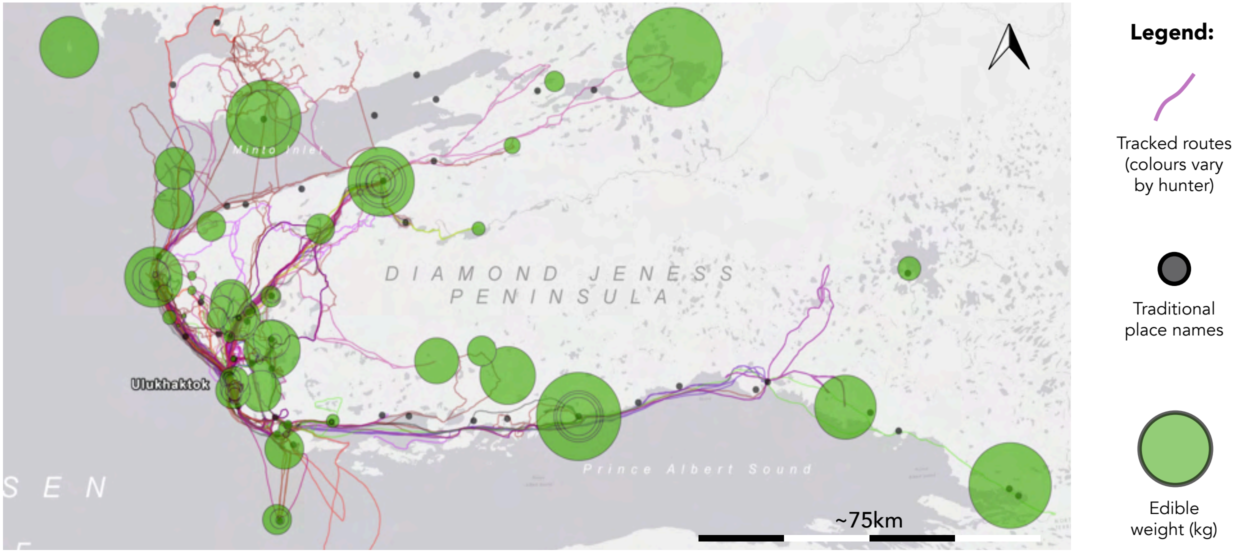


Figure 1: Tracked trails (n = 173), spanning Dec 2018 – Dec 2019, with location and edible weight of harvest (kg) illustrated by green circles. Size of circles is directly proportional to harvest mass in kilograms.

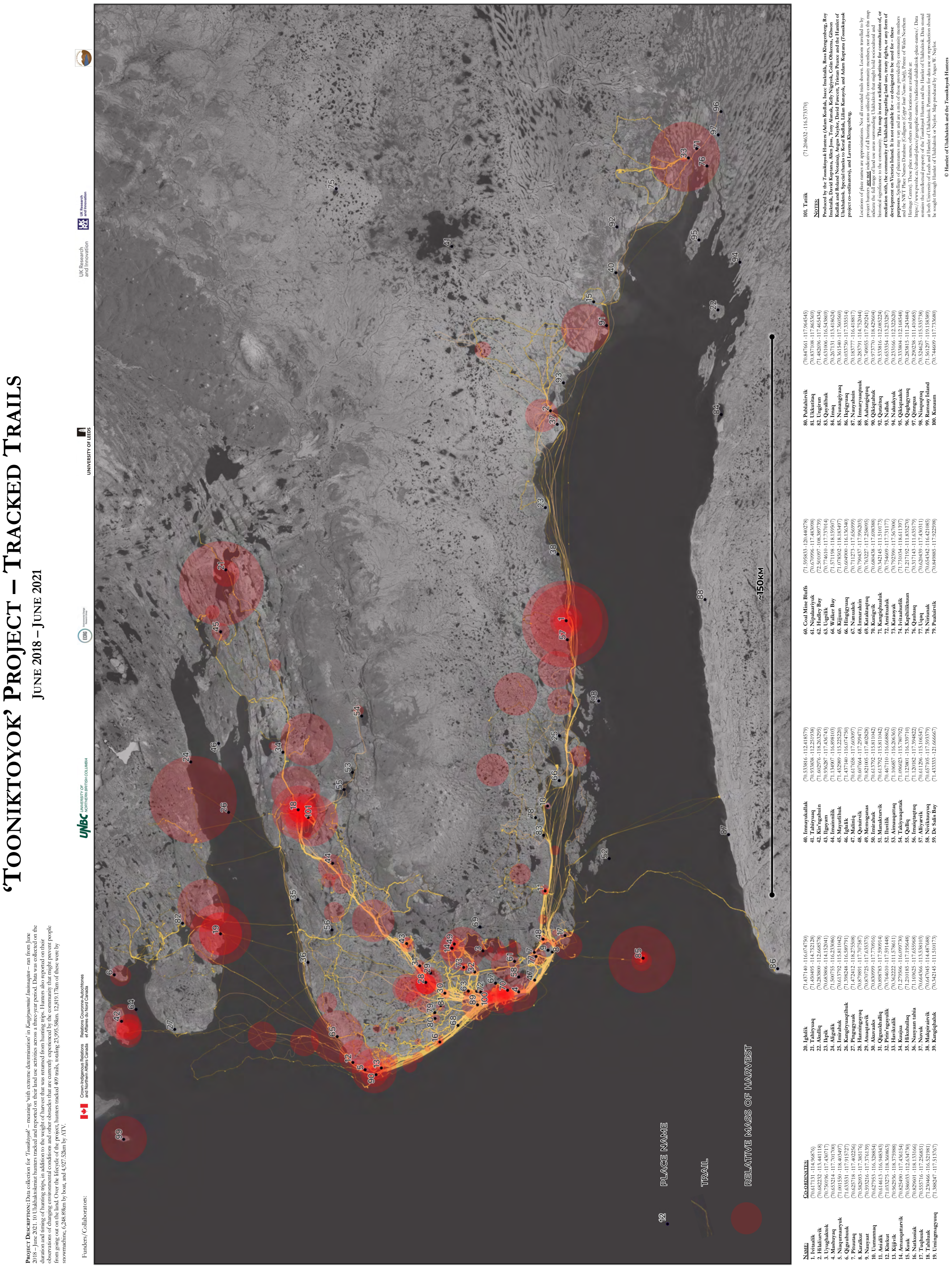
Results

- 173 hunting trails were tracked between December 2018 – December 2019 (Figure 1).
- For trips with full datasets were available (n = 33), country foods were harvested by individuals at a supplies-used cost of CAN$7.19 per kilo of edible weight.
- Cost-per-kilo was calculated based upon market prices of gasoline ($CAN8.418/gl), heating fuel (CAN$23.14/gl), and oil (CAN$9.99/l), in addition to the variable prices of other supplies (i.e. food) indicated by participants. Ammunition use was estimated retrospectively at a cost of $CAD1 per kilo of edible weight.
- An analysis of capital equipment costs conducted in 2016 calculated the financial outlay associated with hunting (covering the purchase of equipment and its years of depreciation) to be CAN$6,271.55 per hunter per annum in Ulukhaktok. Inflation adjusted, this was CAN$6,651.94 in 2019.

Conclusions

This research shows that despite Government-funded food subsidy programs like Nutrition North, it remains more economical to derive meats from the land in some areas of the Arctic than it is to purchase the same mass of meat from stores. This is especially true for those not employed within the wage-based economy, as they are not liable to lose a day's earnings whilst out hunting. It should also be noted that there is a considerable ethos of sharing associated with country foods as compared with store-bought alternatives, which may hold implications for broader community-scale food security, and country foods have been shown to often be far nutritionally superior to store-bought alternatives. Although some regional bodies provide hunting subsidies, such as the Inuvialuit Harvesters' Assistance Program and the Nunavut Harvester Support Program, it should be noted that these grants are often for small equipment items, or to values that do not meet the costs needed to actively participate in ongoing subsistence hunting. Inuit do not currently receive a federal subsidy for consumables, such as oil, gas, ammunition or heating fuel. Our findings suggest that there is a need to re-evaluate current top-down food subsidies in favour of locally-supported, culturally relevant opportunities to increase harvester's access to hunting equipment, supplies and fuels.

Appendix C: 1:250,000-scale map with traditional place names.



Appendix D: Semi-structured/conversational interview guide:

TOONIKTOYAK: INTERVIEW GUIDE

Note: If any photos are taken during this interview (e.g. of the map), please ensure that these do not show participants themselves, or any identifying materials that may identify them.

Stage ONE:

Ask these questions **with the maps and marker pens on the table** for **each** activity or hunting trip undertaken in the previous two weeks.

1. **Since we last met, did you go out travelling or hunting?**
    a. If they say NO, skip to question 12. If YES, continue with question 2.

FOR EACH TRIP ASK:

2. **Where did you go? What trail did you take?**
    a. Please show me these, **and mark them** on the map (draw a line of the route you took).
    b. How long was the trip?

3. **What machine did you take? (e.g. snowmobile, ATV, boat)**

4. **Did you go with anyone?**

5. **How was the trip?**
    a. Weather conditons?
        i. Are these normal?
        ii. Did you do anything differently because of the conditions?
        iii. Was there anywhere in particular where conditions were the worst? Please show me **and mark (and annotate) on the map**.
    b. Any problems with your equipment?
        i. Did anything break?
        ii. Please show me **and mark (and annotate) on the map** where you had problems?
        iii. Has this happened before?
        iv. What did you do about it?

6. **What did you take? How much...**

a. Oil (litres)
b. Gas (gallons)
c. Naptha (litres)
d. Food (price)

7. **Did anyone loan you any equipment/supplies? If so, who, and what did they loan?**

8. **What did you use?**
   a. Oil (litres)
   b. Gas (gallons)
   c. Naptha (litres)
   d. Food (price)

9. **What did you get?**
   a. (If they don't specify) How many of each animal? What quality?
   b. Please show me (approximately) where you got them, **and mark (and annotate) them** on the map.

10. **What did you do with what you got? (Keep/share/sell)**
    a. If sold, how much was sold and to who?

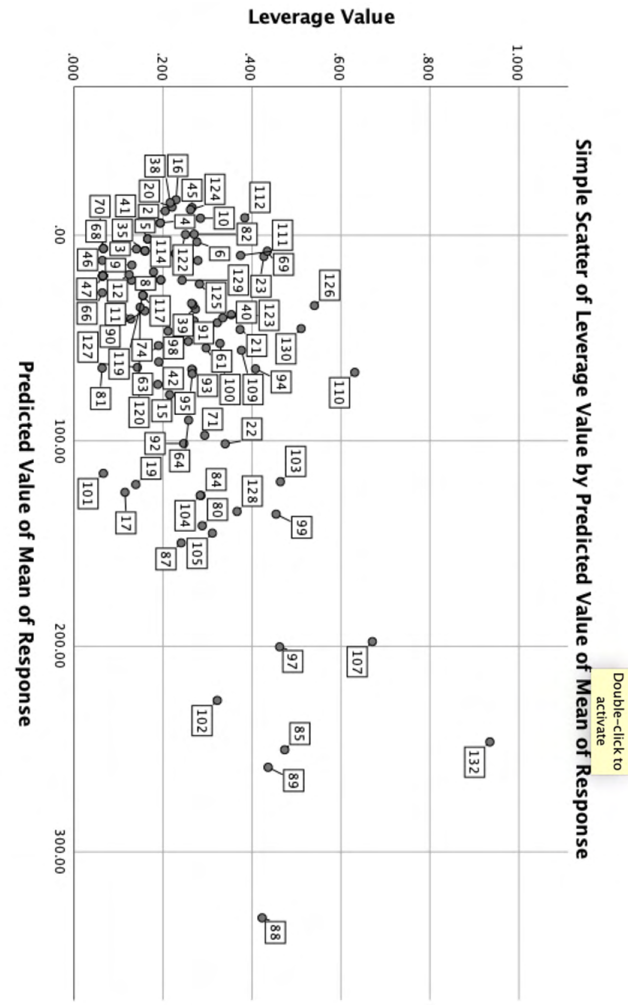
Stage TWO: (MORE GENERAL QUESTIONS TO BE ASKED PERIODICALLY)

11. **Since we last met was there anything that stopped you going out?**
    a. What was it?
    b. How did this affect you?
    c. (If possible) **Can you mark this on the map**?

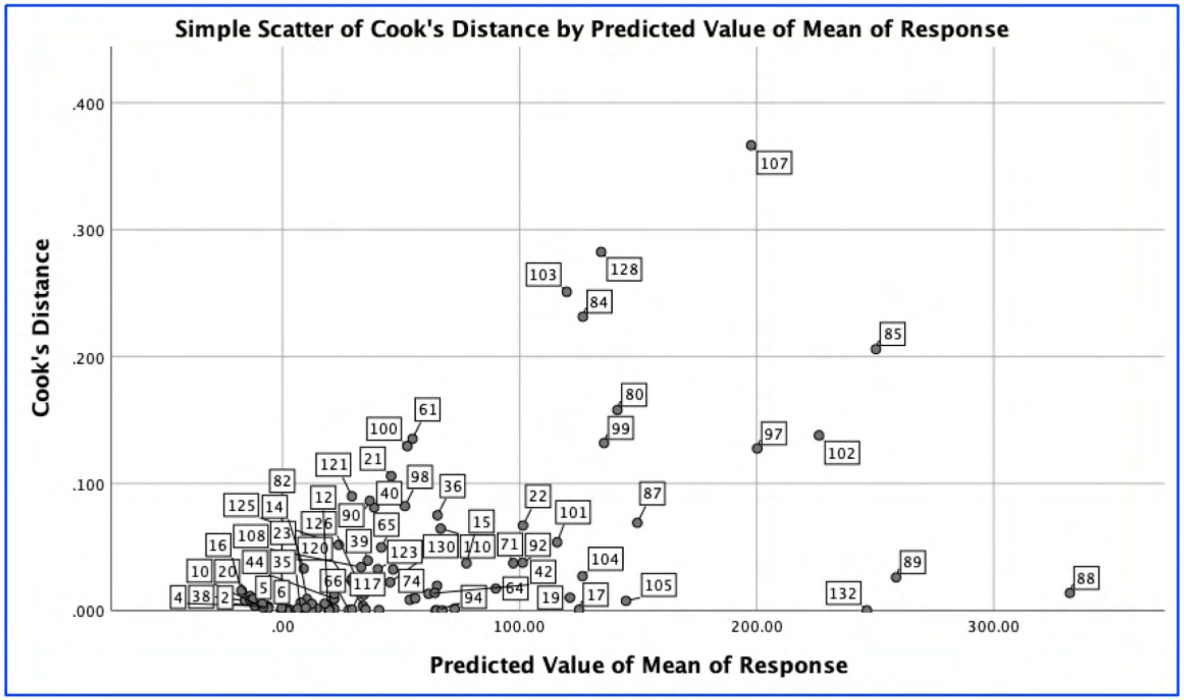
12. **Since we last spoke have there been any traditional foods that you have found particularly difficult to get?**
    a. Which traditional foods?
    b. Where have you in the past been most successful at hunting/getting these? (**please show me and mark (and annotate) an approximate area on the map**)
    c. What has made it difficult to get them (weather/land conditions/costs)?
       i. If possible, **show me why and mark (and annotate) on the map**.
    d. Have you experienced this problem before?

13. **Is there anything else that you want to add or share right now?**

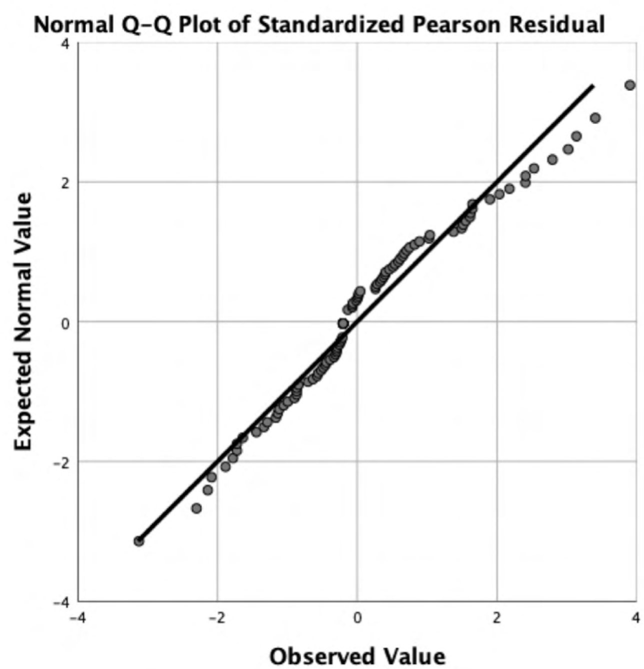
Appendix E: Leverage, cook's distance, Q-Q plots, predicted value of mean response, loess smoothing scatterplots



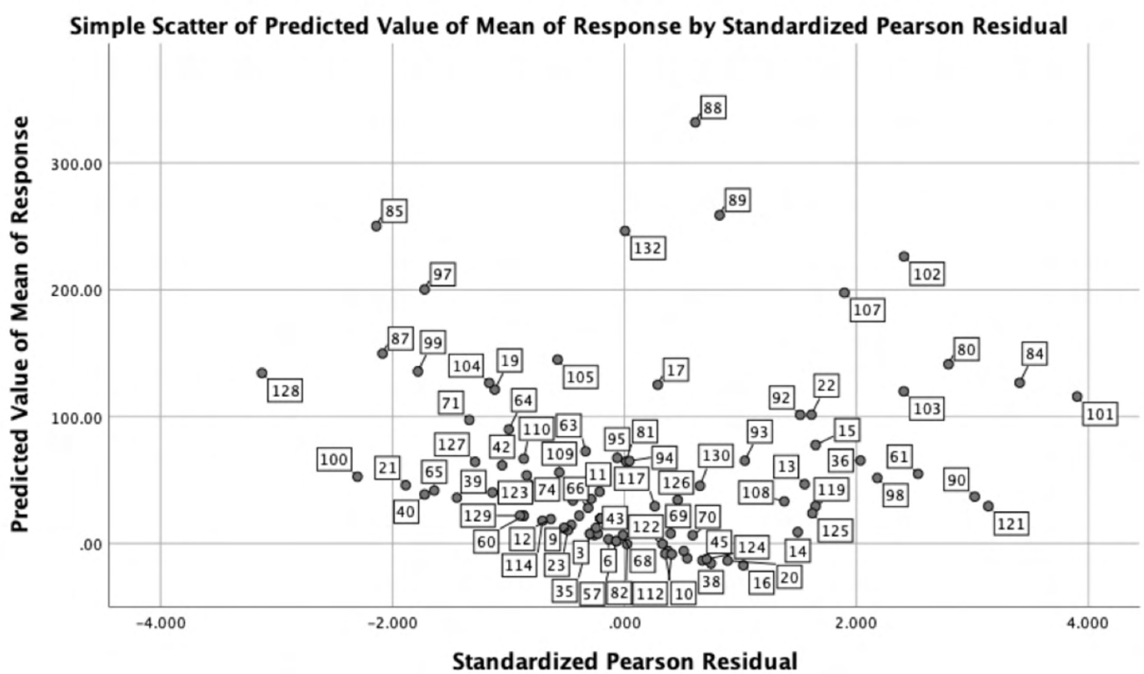
Plot assessing leverage of individual observations. MvLRM re-run while incrementally excluding values 97, 101, 107, 85, 89, 88, 132, 110 to assess their effect on the model.



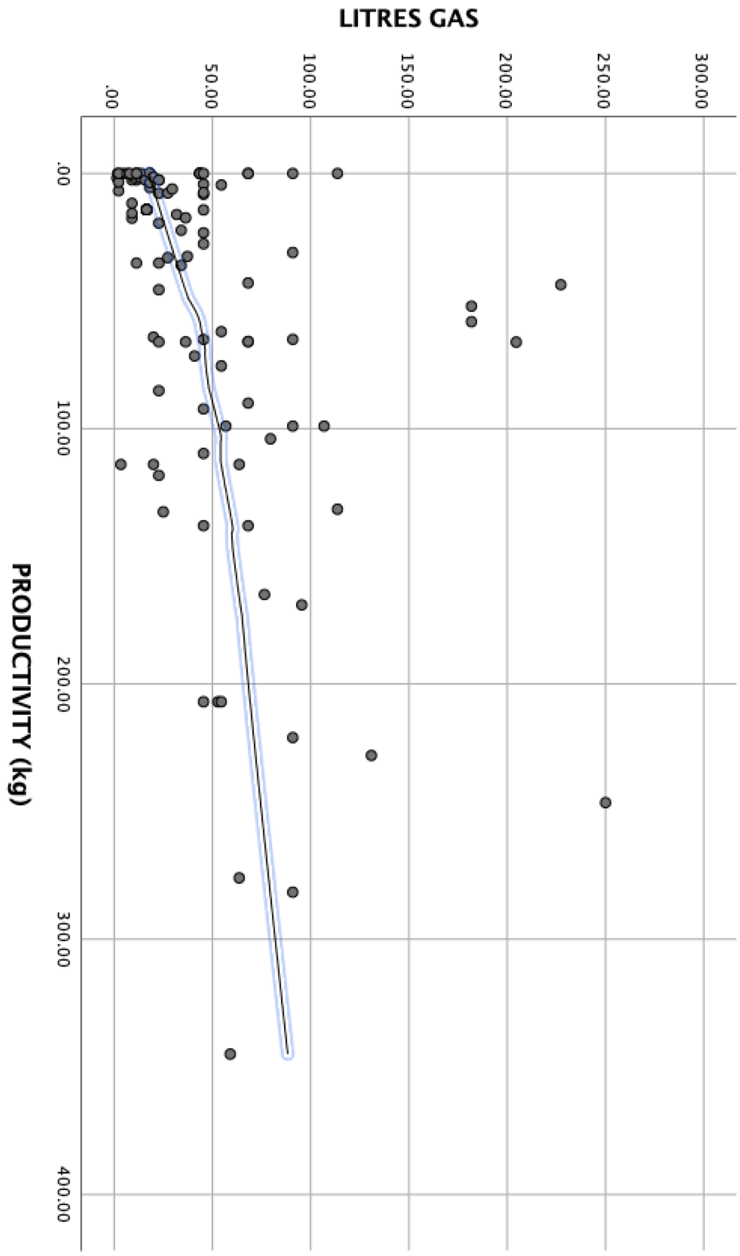
Plot assessing influence of individual observations. MvLRM re-run while incrementally excluding values 103, 128, 84, 80, 99, 97, 102, 132, 89, 88, 85, and 107 to assess their effect on the model.

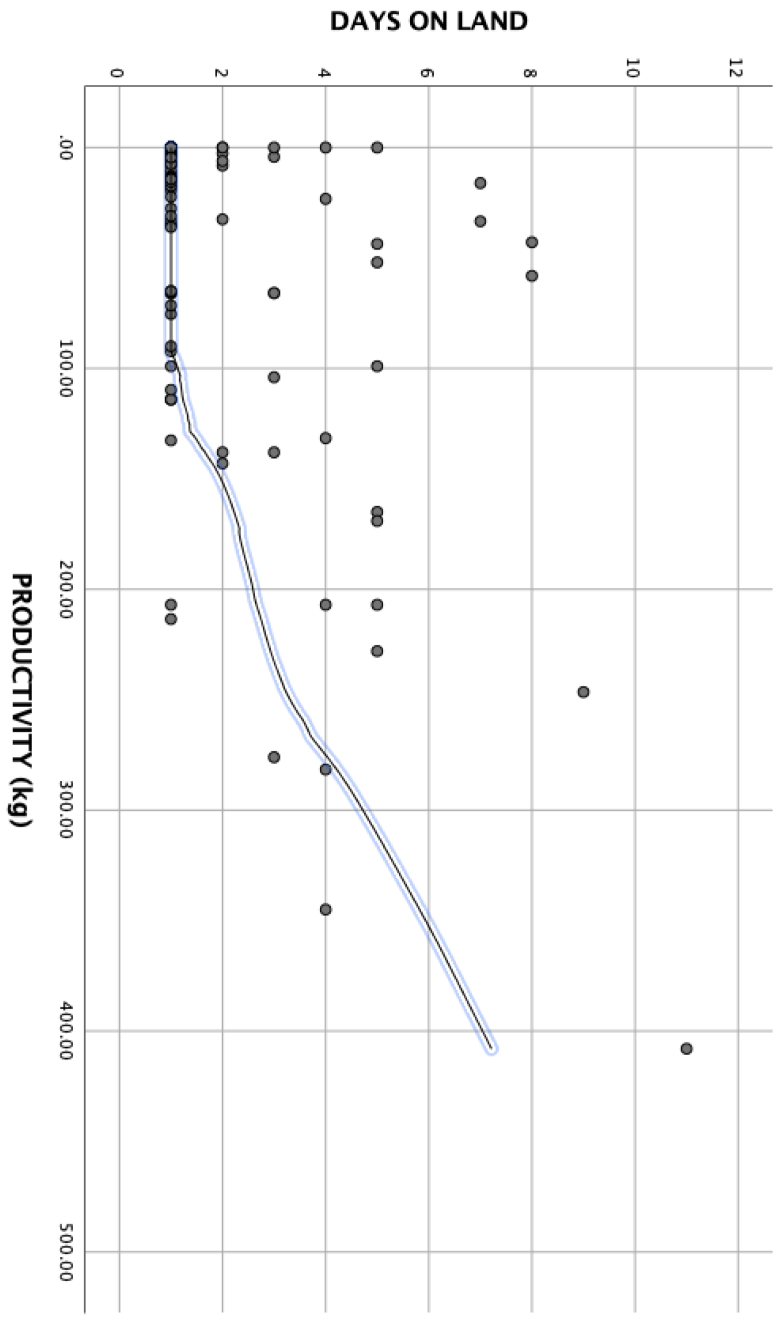


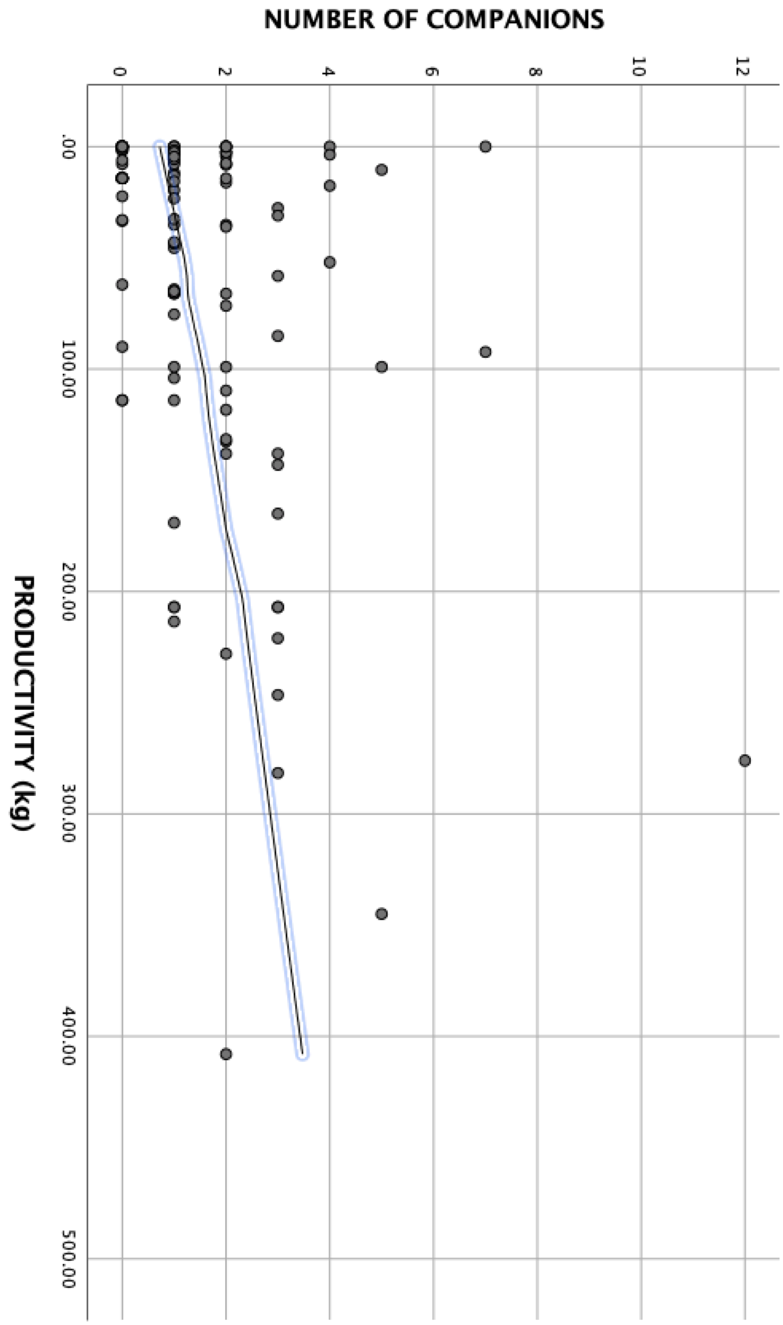
Q-Q plot used to appraise homoscedasticity within the model

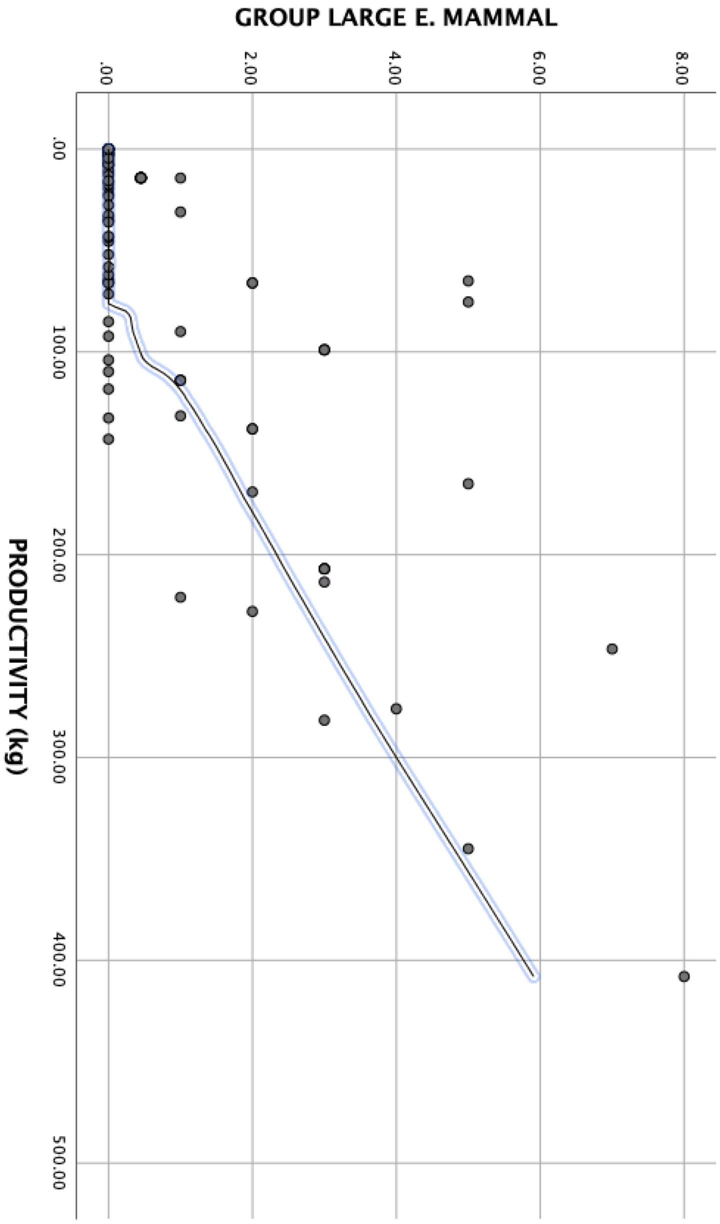


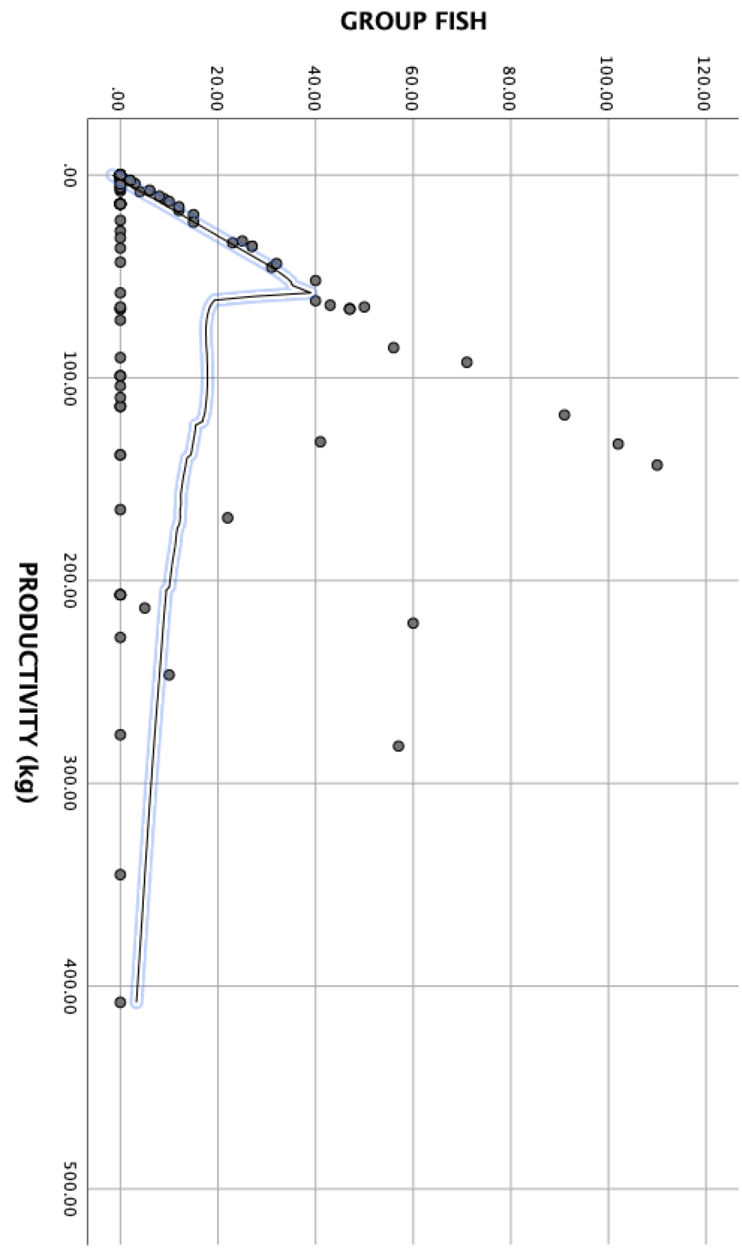
Scatter plot to assess homoscedasticity within the model


LITRES GAS
.00
50.00
100.00
150.00
200.00
250.00
300.00
.00
100.00
200.00
300.00
400.00
PRODUCTIVITY (kg)


DAYS ON LAND
PRODUCTIVITY (kg)


NUMBER OF COMPANIONS
PRODUCTIVITY (kg)
0
2
4
6
8
10
12
.00
100.00
200.00
300.00
400.00
500.00


GROUP LARGE E. MAMMAL
.00
2.00
4.00
6.00
8.00
.00
100.00
200.00
300.00
400.00
500.00
PRODUCTIVITY (kg)



GROUP FISH
.00
20.00
40.00
60.00
80.00
100.00
120.00
.00
100.00
200.00
300.00
400.00
500.00
PRODUCTIVITY (kg)

Appendix F: Raw model outputs, global significance, BIC, and descriptives

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	Hypothesis Test df	Hypothesis Test Sig.
(Intercept)	2.861	21.3387	-38.962	44.685	.018	1	.893
LITRES GAS	-.003	.1146	-.228	.222	.001	1	.979
[DAYS CAT=1.00]	10.780	14.6018	-17.839	39.399	.545	1	.460
[DAYS CAT=2.00]	39.550	11.8425	16.339	62.761	11.153	1	.001
[DAYS CAT=3.00]	0[a]	.	.	.	.	.	.
[MONTH=1]	125.471	26.3023	73.919	177.023	22.756	1	.000
[MONTH=2]	33.978	22.4622	-10.047	78.003	2.288	1	.130
[MONTH=3]	41.404	22.7033	-3.094	85.901	3.326	1	.068
[MONTH=4]	44.481	21.9810	1.399	87.563	4.095	1	.043
[MONTH=5]	10.325	19.8491	-28.578	49.229	.271	1	.603
[MONTH=6]	15.034	17.7232	-19.703	49.770	.720	1	.396
[MONTH=7]	-20.919	20.7039	-61.498	19.660	1.021	1	.312
[MONTH=8]	.103	24.8769	-48.654	48.861	.000	1	.997
[MONTH=9]	-3.415	21.9868	-46.508	39.678	.024	1	.877
[MONTH=10]	30.290	19.8619	-8.639	69.218	2.326	1	.127
[MONTH=11]	-18.539	21.6976	-61.065	23.988	.730	1	.393
[MONTH=12]	0[a]	.	.	.	.	.	.
NUMBER OF COMPANIONS	5.750	2.1264	1.582	9.917	7.311	1	.007
GROUP LARGE, E. MAMMAL	29.389	3.2558	23.008	35.770	81.480	1	.000
GROUP FISH	1.048	.2127	.632	1.465	24.293	1	.000
[TRANSPORT=1.00]	-11.202	13.3137	-37.297	14.892	.708	1	.400
[TRANSPORT=2.00]	-11.348	11.3438	-33.581	10.886	1.001	1	.317
[TRANSPORT=3.00]	0[a]	.	.	.	.	.	.
(Scale)	777.507[b]	115.2653	581.452	1039.669			

Dependent Variable: PRODUCTIVITY (kg)
Model: (Intercept), LITRES GAS, DAYS CAT, MONTH, NUMBER OF COMPANIONS, GROUP LARGE, E. MAMMAL, GROUP FISH, TRANSPORT

SPSS output for multivariable linear regression model. Including values for Beta (B), confidence interval (Wald), and p-value (Sig.).

"a" indicates a referent value category

Continuous Variable Information

		N	Minimum	Maximum	Mean	Std. Deviation
Dependent Variable	PRODUCTIVITY (kg)	91	.00	345.00	52.8784	74.35057
Covariate	LITRES GAS	91	1.45	250.03	45.9954	47.04800
	NUMBER OF COMPANIONS	91	0	12	1.42	1.758
	GROUP LARGE, E. MAMMAL	91	.00	7.00	.7137	1.38191
	GROUP FISH	91	.00	102.00	7.5495	17.74089

Tests of Model Effects

Source	Type III Wald Chi-Square	df	Sig.
(Intercept)	9.467	1	.002
LITRES GAS	.001	1	.979
DAYS CAT	11.866	2	.003
MONTH	61.048	11	.000
NUMBER OF COMPANIONS	7.311	1	.007
GROUP LARGE, E. MAMMAL	81.480	1	.000
GROUP FISH	24.293	1	.000
TRANSPORT	1.104	2	.576

Dependent Variable: PRODUCTIVITY (kg)
Model: (Intercept), LITRES GAS, DAYS CAT, MONTH, NUMBER OF COMPANIONS, GROUP LARGE, E. MAMMAL, GROUP FISH, TRANSPORT

SPSS output indicating Global Significance for days on the land (Days Cat), month, and mode of transport (Transport).

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
177.490	19	.000

Dependent Variable: PRODUCTIVITY (kg)
Model: (Intercept), LITRES GAS, DAYS CAT, MONTH, NUMBER OF COMPANIONS, GROUP LARGE, E. MAMMAL, GROUP FISH, TRANSPORT

a. Compares the fitted model against the intercept-only model.

Categorical Variable Information

			N	Percent
Factor	MONTH	JAN	3	3.3%
		FEB	5	5.5%
		MARCH	5	5.5%
		APRIL	4	4.4%
		MAY	7	7.7%
		JUNE	33	36.3%
		JULY	8	8.8%
		AUGUST	5	5.5%
		SEPT	6	6.6%
		OCT	7	7.7%
		NOV	5	5.5%
		DEC	3	3.3%
		Total	91	100.0%
	DAYS CAT	1.00	11	12.1%
		2.00	13	14.3%
		3.00	67	73.6%
		Total	91	100.0%
	TRANSPORT	ATV	17	18.7%
		SNOWMACHINE	60	65.9%
		BOAT	14	15.4%
		Total	91	100.0%

SPSS output indicating BIC value for multivariable linear regression to assess model fit.

Goodness of Fit[a]

	Value	df	Value/df
Deviance	70753.152	71	996.523
Scaled Deviance	91.000	71	
Pearson Chi-Square	70753.152	71	996.523
Scaled Pearson Chi-Square	91.000	71	
Log Likelihood[b]	-431.976		
Akaike's Information Criterion (AIC)	905.951		
Finite Sample Corrected AIC (AICC)	919.343		
Bayesian Information Criterion (BIC)	958.679		
Consistent AIC (CAIC)	979.679		

Dependent Variable: PRODUCTIVITY (kg)
Model: (Intercept), LITRES GAS, DAYS CAT, MONTH, NUMBER OF COMPANIONS, GROUP LARGE, E. MAMMAL, GROUP FISH, TRANSPORT

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

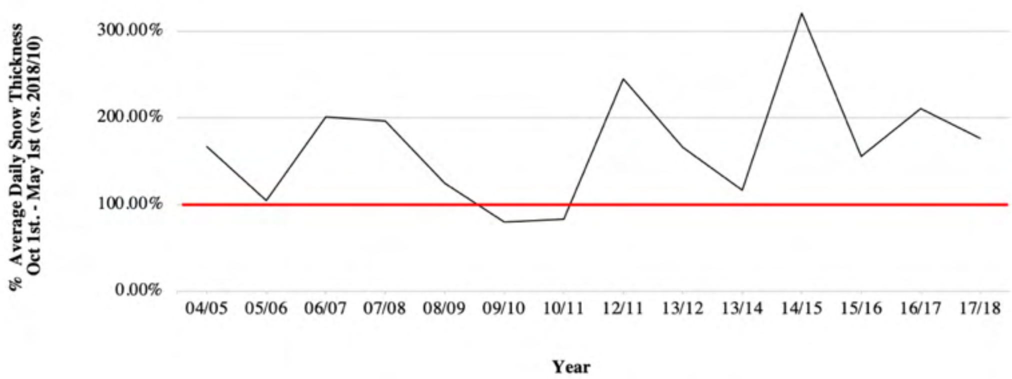
Doub

Appendix G (S1 Table): Supplementary quotes relating to current exposure-sensitivity and adaptive capacity in Ulukhaktok, 2018-2020.

Theme/s	Quote
(Climate Change) *Climatic variability affecting land access and safety*	"Yeah: rocks – sometimes we only go this far with skidoo. Go that way... get stuck... go backward get stuck, go forward get stuck... I was going really good [on my] last trip then, next thing I know, my skidoo was almost upside down." (25th October 2018; #043-09). "It's getting harder for me to predict the ice conditions now compared to back then. I can't... I don't even know if two and a half inches [of thickness] is good enough for me to travel on anymore." (15th February, 2019; #057-01). "His skidoo went through some young ice… he hit some hard-enough ice [below, rather than going into the water] and then he went back up. I don't know what he was doing at night-time going through that stuff... I guess getting the wolf was kind of important..." (7th March, 2019; #145-12). "We used to never use [maps], when I was growing up… we used east and west wind directions for our compass... from the east, the wind goes this way… we cut the snowdrifts if we want to go home. Now… everything changes - the wind could change anywhere." (31st July 2019; #509-04)
(Climate Change) *Inter-annual variations in species availability and quality, multiple exposures*	"Another muskox… this winter. It had a big ball of puss, must be about… almost the size of my fist… When we started cutting off the back for tenderloins, I thought it was a kidney problem… we took them out and in there was this big white ball of puss." (7th July 2018; #010-02). "They were just talking about cutting off commercial fishing [for char]… I told them just because everybody had a bad year this summer for fishing, it doesn't mean you've got to panic." (5th March 2019; #132-11). "Hard to tell, eh, [what is happening with the char fishing]. It went down, it slowed down for a while, but looks like it's coming back again." (23rd July 2019; #481-09). "Maybe 1 out of 100 I see some people tell me there's some worms [(fish lice) (Argulus)] in the meat [of the fish]... These last two seasons, when I work [as a guide for the Department for Fisheries and Oceans], I started to note more of these worms being caught from the lake." (18th February 2019; #100-04). "I don't know, there's still some [caribou] around for sure – they're still going to be there. I'm pretty sure they're all coming from Hadley Bay. Coming all down, following…Kuujua, down this way…. they never eat there for like 20 years.." (3rd April, 2019; #207-17). "When I was at the lake, one of the muskox was just… vile. [The wildlife epidemiologist] said that was the worst lungworm he'd ever seen. The whole thing… there were just lumps all over the place, and you'd cut open one and about 50, 60 or 100 worms would come out." (7th July 2018; #010-01). "That lungworm [we're finding in muskox] is from a parasite… it goes from a snail into the muskox. With climate change they've moved north [(the parasites)]… with the weather getting warmer and the land getting greener (7th July 2018; #010-08). My dad used to tell me "not you, not your kids, maybe not your grandkids, but one day, people are going to see trees". (23rd July 2019; #489-05). "When I was growing up, when I was Ben's age we used to hear of one or two [grizzly bears] around maybe here, or there. Nowadays it's just all over the place..." (23rd May 2019; #341-03) "The bears that him and Edward got? They [(the bears)] killed a caribou, or a muskox each, and then only ate the foot, and some of the head too." (May, 2019; #341-04).
(Economics, Social Networks, Preparedness) *Mechanical issues, vehicle design*	"Me and my aluminium dog... with steel for a heart. Right now, I just threw my machine into the shop: no more bearing... driveshaft and bearing." (7th March 2019; #161-07). "Blew a piston! Piston had a hole right through… It was too far [gone] to fix [on the land]. I was heading back… it got hot and the oil injection I guess was not flowing or something..." (11th May, 2019; #306-13). "Trying to get satellite signal on the phone [after I broke down], but couldn't... I ended up walking, going up this way to get a signal somewhere. Get on top [of a hill] then I finally got a

	hold of [someone].” (27th March, 2019; #196-05). “Just before I reach... near Mashuyaaq... my machine… a bolt must have came off. I went back to town, picked up another one... another machine, and took off again.” (RNK, 7th March; #125-01). “My parents’ machine and sled box is still at Pituutaq [(out on the land)]… mine is [also] broken down. I’ve got to change the piston ring and get a new crank case [and] crankshaft! $2500... [dollars it’ll cost]… and that’s just my parent’s one!” (March 18th 2019; #215-13). “The AR mounts broke, and the A frame broke – the one that goes to the handlebars. They were broken for a while, but they finally really broke after this rough ice!” (25th February 2019; #117-07).
(Economics, Social Networks, Preparedness) *Cost of supplies*	“Some people used to even talk about going Kugluktuk to buy gas and bringing it over here [to store down Prince Albert Sound] for summertime. It still would have been cheaper than buying gas [in Ulukhaktok], brining it over there [to Prince Albert Sound], and then going back [to Ulukhaktok]!” (23rd July 2019; #448-16). “People and elders… they’re always running out of naphtha. Naphtha is not cheap… 45 gallons of naphtha is 1,078 dollars, and a barrel of skidoo gas is under 400! See what the jump on that is? Triple. [Naphtha is] the main thing you use when you’re out, to keep the heat in [the tent/cabin].” (31st July 2019; #506-07).
(Economics, Social Networks, Preparedness) *Social relationships/borrowing, adaptation, knowledge transfer, cultural change*	“For our younger generation now, without equipment they can’t go anywhere, they can’t see the land, they can’t even get food for their family” (31st July 2019; #504-08). “Just now I need to find snowmobile parts to get my snowmobile up and running. There are lots of parts in town, it’s just that some people are too tight. And then when they come around to me, I’m not tight. You expect, you know... I scratch your back, tomorrow, or next day, or next month you scratch mine... I think that way, but then “oh, no, I’m sorry”...” (8th April 2019; #226-06). “We never did fishing on that muskox trip, but we took fishing rods in case we didn’t see muskox.” (7th July 2018; #009-12). “Denise was wanting to take out Peter. She was kind of iffy about letting him go, [but] she just let him go. They came back with five ptarmigan – cute kids. Really starting to travel.” (29th April 2019; #270-07). I was trying to let Alex shoot a muskox. But the .223 [rifle]… I put a bullet in, but it couldn’t go down. I was having trouble. I grabbed Euan’s .243, but all the young ones [(muskoxen)] were all finished, so I didn’t want to try and get a big female, and I had a passenger on my sled already… None of them [(on the trip)] gave us anything [that they’d harvested]… (15th February 2019; #067-16) “He dropped all his meat. Poor tying... poor tying... you know... the rope that goes around that sled? He tied his meat down in the front [of the sled], in a tarp. There was leftover rope that was unused... He only did two ropes, and within 300 yards all his meat was falling out… He just left it there. All his meat spread out on the trail. Told him to go back for his meat: “eh, I’m just going to leave them” [he said]. He just chose not to pick it up and *payutak* [(share)], his choice... eh...” (15th February, 2019; #068-13)
(Institutions) *Harvester’s Assistance Programs, governance*	“The Nutrition North subsidy program? We said that instead of subsidizing the store-bought food they should subsidise the hunters, because the hunters spend money to get out. Not only on gas, but on vehicles; they have to repair vehicles sometimes.” (7th July 2018; #003-11). We took students out to… Fish Lake, and then across Minto [Inlet]. Three nights, four days... and they all got muskox. There was ten students, five guys, five helpers… [we got] nineteen muskox and 41 fish! [UCC] bought the gas… and the food… I would like to see this more often: the youngest generation hunting for the community.” (29th April 2019; #262-05).

Appendix H: S1 Fig. Historic average daily ground snow thickness in Ulukhaktok as a percentage of 2018/19 values.



Winter ground snow thickness, Holman (Ulukhaktok) Airport Weather Station, 1st Oct. – 1st May			
Year	Avg. daily thickness (cm)	*n* observations (of 212)	avg. daily thickness vs. 2018/19
2018/19	**11.08**	**212 (100%)**	**-**
2017/18	19.52	210 (99.1%)	176.2%
2016/17	23.29	211 (99.5%)	210.2%
2015/16	17.20	182 (85.8%)	155.2%
2014/15	35.54	169 (79.7%)	320.8%
2013/14	12.93	200 (94.3%)	116.7%
2012/13	18.35	202 (95.2%)	165.6%
2011/12	27.17	181 (85.4%)	245.2%
2010/11	**9.18**	**181 (85.4%)**	**82.9%**
2009/10	**8.80**	**188 (88.7%)**	**79.4%**
2008/09	13.81	206 (97.2%)	124.6%
2007/08	21.72	210 (99.1%)	196%
2006/07	22.29	208 (98.1%)	201.2%
2005/06	11.58	212 (100%)	104.5%
2004/05	18.47	179 (84.4%)	166.7%
All years (prior to 2018/19)	**18.43**	**2,739 (93.2%)**	**166.3%**

Appendix I: Research approach summary

This research is a part of the broader Tooniktoyok Project. Tooniktoyok is led and administered by the Hamlet of Ulukhaktok and funded through a joint community-researcher application to Crown Indigenous and Northern Affairs Canada's (CIRNAC) Climate Change Preparedness in the North Program. In Kangiryuarmiut Inuinnaqtun, "tooniktoyok" describes an action or effort undertaken "with extreme determination"; Ulukhaktokmiut hunters express tooniktoyok when they travel and hunt for food. The project was developed between the Hamlet Council and an international research team with the explicit focus of non-Indigenous researchers holding a facilitatory—as opposed to directive—role in the stages of project development, the setting of aims and objectives, and the process of data collection, analysis, and dissemination. Inuinnait control and oversight over the project has worked to ensure that the results have informed community concerns for research in a culturally appropriate way, attenuated some inequity in power dynamics that can be symptomatic of some participatory research projects, created opportunities for bi-directional learning, maintained protections for Indigenous intellectual property, and prevented the development of an "extractive" or exploitative research model (Pearce et al., 2009; Castleden et al., 2012; David-Chavez and Gavin, 2018).

The overall aim of the Tooniktoyok is to "facilitate the generation, documentation, and two-way sharing of observations, experiences and knowledge of changing climatic conditions and the costs of hunting among hunters, researchers and decision-makers, to enhance the safety and success of Ulukhaktokmiut hunters and provide timely information for decision-making." Project construction was guided by Inuit knowledge and Inuit values, with information needs and priorities for research identified by hunters and the wider community. Research was undertaken in line with the "5 Priority Areas" of the National Inuit Strategy on Research (NISR) and according to Inuit Tapiriit Kanatami and the Nunavut Research Institute's guidance on Negotiating Research Relationships with Inuit Communities (ITK NRI, 2006; ITK, 2018). Study protocols were approved by Institutional Review Boards at the University of Guelph and University of Leeds. The research was licensed by the Aurora Research Institute (#16533), which oversees research in the Northwest Territories. The project was overseen and guided by a four-person Inuit Oversight Committee within the community.

References for this appendix are contained within ch. IV, section 10.