frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 09 July 2021
doi: 10.3389/fsufs.2021.688350

Understanding Determinants of Hunting Trip Productivity in an Arctic Community

Angus W. Naylor[1,2]*, *Tristan Pearce*[3], *James D. Ford*[1,2], *David Fawcett*[3], *Peter Collings*[4] *and Sherilee L. Harper*[5]

[1] Priestley International Centre for Climate Change, University of Leeds, Leeds, United Kingdom, [2] School of Earth and Environment, University of Leeds, Leeds, United Kingdom, [3] Department of Global and International Studies, University of Northern British Columbia, Prince George, BC, Canada, [4] Department of Anthropology, University of Florida, Gainesville, FL, United States, [5] School of Public Health, University of Alberta, Edmonton, AB, Canada

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***Correspondence:**
Angus W. Naylor
eeawn@leeds.ac.uk

Specialty section:
This article was submitted to Land, Livelihoods and Food Security, a section of the journal Frontiers in Sustainable Food Systems

Received: 30 March 2021
Accepted: 15 June 2021
Published: 09 July 2021

Citation:
Naylor AW, Pearce T, Ford JD, Fawcett D, Collings P and Harper SL (2021) Understanding Determinants of Hunting Trip Productivity in an Arctic Community. Front. Sustain. Food Syst. 5:688350. doi: 10.3389/fsufs.2021.688350

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 (MvLRM) was applied to assess whether factors such as consumables used (i.e. heating fuel, gasoline, oil, food), distances traveled, 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.

Keywords: arctic, fuel use, mixed economy, subsistence, Inuit, hunting success, country food, traditional food

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 (Ready, 2019; Wenzel, 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; Pearce et al., 2011; ICC, 2012). 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 and 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 through 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 traveling 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 1-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.

METHODS

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 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 characterized 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, incentivized by government-subsidized public housing, investment in social services, and an increasing availability of wage-based labor (Condon et al., 1995; Condon, 1996; Damas, 2002).

Despite the above changes, and further government practices in the mid-to-late twentieth century aimed at acculturation—including the 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 et al., 1998, 2016; Collings, 2011), 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).

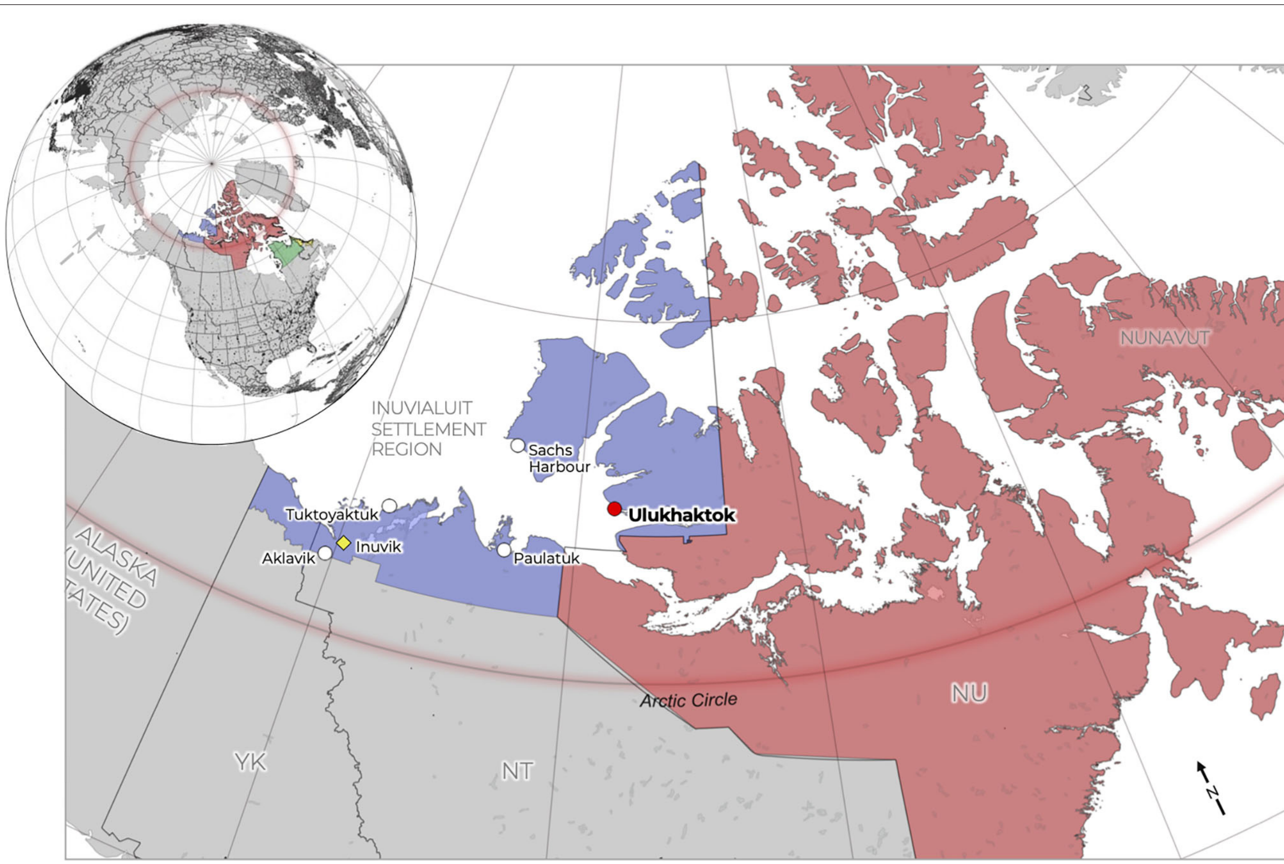

FIGURE 1 | Map of Inuit Nunangat (coloured sections), showing Ulukhaktok and the other five communities within the Inuvialuit Settlement Region. Contains information licensed under the Open Government Licence—Canada.

A diversity 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 (<5 km) 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 20 kg 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-km 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 sedentarization 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 utilizing 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 traveled 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 and 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 systematized assessment of hunting trips and on-the-land activities, nor looked at these factors from a real-time monitoring perspective.

TABLE 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
N° days on land	*123*	2.04	1.97
Borrowed machinery	*131*	N/A	N/A
Borrowed supplies	*114*	N/A	N/A
Gas taken (L)	*67*	84.64	51.36
Gas used (L)	*119*	47.12	47.02
Oil taken (L)	*68*	1.27	2.13
Oil used (L)	*114*	0.84	1.49
Naphtha taken (L)	*77*	11.84	17.16
Naphtha use (L)	*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 traveled (km)	*80*	108.37	115.18
N° of companions	*129*	1.57	1.76
Mechanical issues	*130*	N/A	N/A
Environmental issues	*130*	N/A	N/A
N° Group large edible mammals	*116*	0.78	1.54
N° Group fish	*114*	10.73	22.06
N° Group fowl	*115*	4.81	14.16
Group productivity (kg)	*123*	56.69	79.86

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

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 A**). 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 10 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 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 2 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, were 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 traveled 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 and Higgs (2005)] and were involved with 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 traveled (**Figure 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.

In total, 23 variables, previously identified within the literature as potential determinants of hunter productivity (e.g., Smith, 1985; Smith and 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 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 (2002) 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.

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 1**). Continuous independent variables were categorized if they had a non-linear relationship with the dependent variable. Spearman's ρ 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.

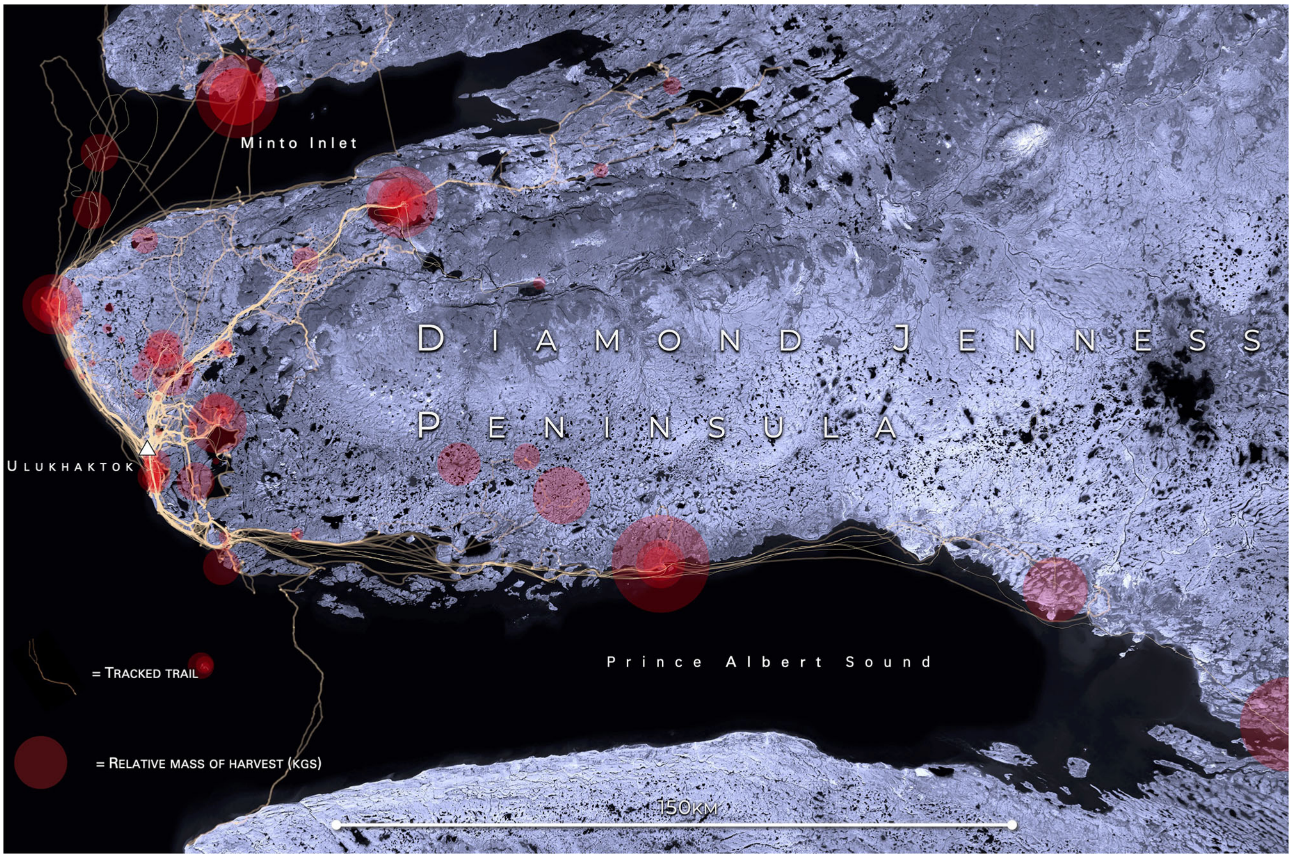

FIGURE 2 | Tracked GPS and annotated routes collected as part of the *Tooniktoyok* project, Jan–Dec 2019. Thickness of lines corresponds to frequency of trail use. Red circles indicate approximate location of harvests, with size corresponding to relative mass of standard edible weight derived. Trails 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).

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-parameterization. The model with the lowest BIC was retained as the final model.

The assumption of homoscedasticity within the model was assessed visually through standardized 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).

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).

RESULTS

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 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 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 6,972.34 kg 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 5,387.3 km of trails ($n = 80$) were tracked. Across the dataset, an average productivity of 56.7 kg/trip ($n = 123$) was calculated, with a productivity of 0.77 kg/km traveled for data available via GPS-tracked trails ($n = 73$). Two hundred and fifty-one days (i.e., 24 h periods within which at least one subsistence activity took place) were spent out on the land in total, yielding a mean productivity of 26.1 kg/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 5,607.83 L, 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$) average of 47.14 L per individual, and a productivity ratio of 1.15 kg of standard edible weight per liter ($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 traveled 67.34 km per trip ($n = 80$). **Table 2** provides a further summary of descriptive statistics derived from both the independent and dependent variables.

Productivity Association With Gasoline Use and Other Explanatory Variables

As a standalone explanatory variable, there was a significant positive association between gasoline use and hunting group productivity ($p \leq 0.001$, unadjusted); for every unit increase in an individual's gasoline use (litters) there was a 0.689 kg increase in group productivity (CI = 0.421–0.957 kg). Gasoline use, however, was no longer significant when other variables were adjusted for in the MvLRM (**Table 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 = −0.003 kg) 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 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.

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 5.750 kg 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 traveling 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 Baggio et al., 2016; Collings 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 and 2000, where large edible mammals (i.e., muskoxen, caribou, ringed seals, etc.) and fish

TABLE 2 | Summary of descriptive statistics derived from GPS tracking and interviews; DERIVED.

	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	1,688.46	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 and ATV	Total
Number of trips	23 (17.4%)	18 (13.6%)	89 (67.5%)	2 (1.5%)	132
Total SEW (kg)	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)	3,805.50 (*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 (kg)	1,734.33 (*n* = 48)	3,873.50 (*n* = 71)
Recorded distances (km)	1,614.75 (*n* = 36)	3,772.50 (*n* = 44)
Gasoline use (L)	1,734.33 (*n* = 48)	3,873.50 (*n* = 71)

	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 n° companions	2

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

(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 char with 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 40 km 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 traveling 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 a successful "expedition hunts," in addition to the general preference that community members have for meats such as

TABLE 3 | Results of the multivariable linear regression investigating association between socio-economic and biophysical variables and hunting productivity in Ulukhaktok, Jan–Dec 2019; Final MvLRM BIC = 958.679†.

Variable	β-value	95% Confidence interval		p
		Lower	Upper	
Gasoline use (L)	−0.003	−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	0.400
Snowmachine	−11.348	−33.581	10.886	0.317
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.*

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 and 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 optimizing 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 (<90 km) 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 vs. caribou (69 vs. 33 kg), 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 (Collings, 2011; Pearce et al., 2011).

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 labor 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., Beaumer and 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 characterizes 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 generalizability 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.

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).

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Guelph, Research Ethics Board Aurora Research Institute, Research Ethics Board University of Leeds, Research Ethics Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

Project construction and data collection by AN, TP, and DF. Data analysis and statistics by AN and SH. First and subsequent drafts of paper produced by AN,TP, JF, DF, PC, and SH. Editorial revisions and approval conducted and granted by all authors.

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.

ACKNOWLEDGMENTS

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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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.

APPENDIX A: RESEARCH APPROACH

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.